
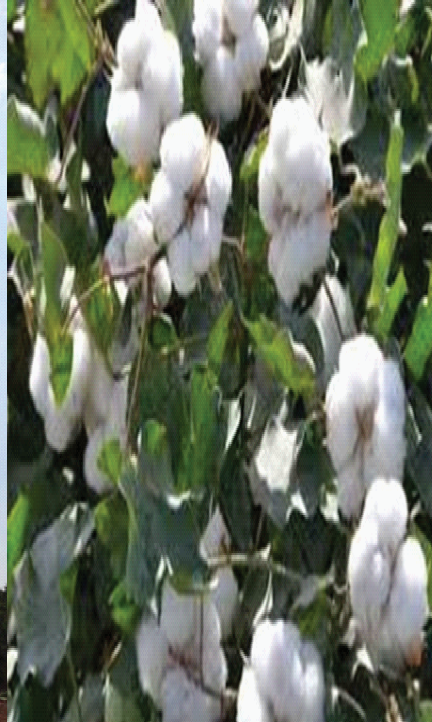


INDUSTRIAL PLANTS:

Economics, Production, Agricultural, Utilization and Other Aspects

EDITOR: Assoc Prof. Dr. Sıdıka EKREN



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INDUSTRIAL PLANTS: ECONOMICS, PRODUCTION, AGRICULTURAL, UTILIZATION AND OTHER ASPECTS

Editor

Assoc Prof. Dr. Sıdıka EKREN

Authors

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Prof. Dr. Emre İLKER
Prof. Dr. Pelin GÜNÇ ERGÖNÜL
Assoc. Prof. Dr. Ali Rıza ONGUN
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Chemical Engineering MSC Deniz DİNÇER

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TURKEY TR: +90 342 606 06 75
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PREFACE

In our country, the demand for vegetal products is increasing day by day due to both meeting the needs of the increasing population and increased level of well-being. This situation has forced to increase all types of plant-based production.

“Industrial Plants”; which are strategically important in plant production and have a high contribution to our national economy among field crops, constitutes a group that provides the raw materials needed by the industry.

Industrial plants, which have a wide range of uses because they constitute the important raw material of food, oil, sugar, textile, tobacco, pharmaceutical and many other industries, are discussed in this book from different aspects. Studies have been tried to deal with a wide range of uses of some families and plant species, from economy to production, from soil conditions to fertilization, from cultivation techniques to yield and yield parameters, from field to textile ındustry, from fatty acid composition to use in meat and dairy products, from seed to morphological, physiological and biochemical properties.

With the present book, it is aimed to contribute to science by creating a resource in the field of industrial plants, and it has been presented to the service of you, our esteemed readers.

I would like to thank our esteemed authors who contributed to the preparation of this work, Assoc. Prof. Dr. Seyithan SEYDOŞOĞLU for their help and support during the preparation of the book, and İKSAD Publishing House staff who contributed to its publication.

Assoc. Prof. Dr. Sıdıka EKREN
Editor
24th November 2022 / IZMIR

CHAPTER 1

RECENTS TRENDS IN COTTON FIBER MARKET: CURRENT AND FUTURE PROSPECTS

Assoc. Prof. Dr. Berna TURKEKUL[1]

[1] Ege University, Agriculture Faculty, Agricultural Economics Department, İzmir, Türkiye. Orchid: 0000-0003-2445-3285, e-mail: berna.turkekul@ege.edu.tr

1. INTRODUCTION

Natural fibers have been meeting human needs such as clothing and sheltering for hundreds of years. However, the demand for natural fibers has decreased due to the production of synthetic fibers and their lower prices. Today, there has been a resurgence of interest due to increasing environmental concerns and depletion of petroleum resources. This has encouraged industries to use sustainable fibers instead of traditional synthetic fibers. Numerous studies have shown the benefits of using natural fibers such as low cost, low density, high specific strength and reduced health hazards. More importantly, natural fibers are biodegradable and available in abundance. In addition, it takes less energy in production compared to synthetic fiber production. Hence, natural fibers are the obvious choice towards the use of green, sustainable materials (Siti Aiyah and Mohd Tajuddin, 2014). However, natural fibers still compete and co-exist in the twenty-first century with man-made fibers, especially as far as quality, sustainability and economy of production are concerned.

Natural fibers can be classified according to their origin: Vegetable, animal and mineral fibers. The vegetable, or cellulose-base, class includes such important fibers as cotton, flax, and jute. The animal, or protein-base, fibers include wool, mohair, and silk. An important fiber in the mineral class is asbestos. The vegetable fibers can be divided into smaller groups based on their origin within the plant. Cotton, kapok, and coir are examples of fibers originating from the seeds. Flax, hemp, jute, hibiscus and ramie are bast fibers, occurring in plant stems. Abaca, henequen, and sisal are fibers occurring as part of the leaves.

Natural fibers are used in manufacturing of textiles, ropes and nets, brushes, carpets and mats, mattresses to paper and board materials. On-going research and development over the years has greatly improved the quality of natural fibers, rendering them suitable for use as constituents in composite materials. One of the largest areas of these composites is the automotive industry. Natural plant fibers are also used in various industrial sectors such as leisure, automobile, medical, and building. The consumption of these industries have increased approximately 13% over the last decade (Rana et al, 2014).

Nowadays the position of natural fibers in the world fiber market and the level of production is stable. Based on latest figures from the Discover Natural Fibres Initiative (DNFI), world natural fiber production in 2022 is estimated at

32.6 million tons. Production reached 33.3 million tons in 2021 and 31.6 million in 2020. With these figures, natural fibers accounted for 29% of the world production of all apparel and textile fibers. Cellulosic fiber production only accounted for 6% of the total. The decline in the share of natural fibers in total fiber production in the last decade is the result of exponential growth in polyester production (DNFI, 2019).

Cotton is by far the largest fiber crop globally and is reaching almost 25 million tons production per annum, accounting for almost 81% of the natural fiber production. Jute accounted for 7%, while coir and wool each accounted for 3% (DNFI, 2019). World production of jute and allied fibers is estimated unchanged at 3.2 million tons in 2022 compared with 2021. High market prices in 2021 motivated farmers to expand planted area in both Bangladesh and India, but dry weather in jute-growing areas during June and July has undermined earlier optimistic hopes for yields. Production of coir fiber rose by an average of 18,000 tons/year during the past decade, and production was record high at 1.12 million tons in 2021. Production is expected to remain high in 2022. Flax has also been trending upward, rising by an average of 27,000 tons/year, and production in 2022 is estimated to remain above 1 million tons (Textile Technology, 2022).

An estimated 40 million households were engaged in natural fiber production during 2019, including some 29 million households producing Cotton, 6 million producing Jute, kenaf and allied fibers, about 5 million Wool producers, 1 million involved in production of Coir, and another one million involved in other natural fibers, such as Abaca, Hemp, Sisal and Silk. When family labor, hired workers and employees in associated service industries such as transportation and storage are considered, total employment in the agricultural segments of natural fiber value chains probably reaches about 200 million people per year, or between 2% and 3% of the world's population (DNFI, 2020).

Owing to the benefits and the importance of natural fibers, this chapter aims to present the achievements and future prospects in the area of natural fibers production and trade, with special emphasis on the cotton. Comparative analysis is carried out to highlight the advantages and disadvantages of each plant-based fibers in terms of production and trade.

2. MATERIALS AND METHODS

A brief presentation of the world natural fiber market (production, consumption, and trade) is obtained by using FAO and USDA statistical sources. The FAOSTAT database provides up-to-date data relating to production and trade of plant fibers by countries, specially harvested area, yield, production, exports and imports. USDA contains current and historical data on supply, use and trade of agricultural commodities for the USA and major producing and consuming countries. The data from these resources are obtained for the period 2010-2019 due to data unavailability of FAO statistics database.

The most produced natural fibers in this period were cotton (78%), jute (11%), coir (4%) and flax (2%), respectively (FAO, 2022). Since cotton (99%) take the first place in natural fiber production in Türkiye, only cotton was examined in this study.

3. WORLD NATURAL FIBER MARKET

The textile and convection industry is based on inputs called fibers. Fibers are inputs of the textile and apparel industry. In general, fibers are converted into yarns, yarn woven or woven fabrics, and materials for use on fabrics. Along the supply chain, the textile and apparel industry is divided into sub-groups such as fiber, yarn, fabric and ready-made clothing industry. A change in the supply and demand of one of the industries affects the other stages of the supply chain, depending on the degree of high or low commitment. The first stage of this integration is the fibers. Fibers are also divided into two as natural and synthetic fibers.

After the intense use of synthetic fibers in textiles, these products dominated the world fiber market. In the last 20 years, fiber production has increased from 58 million tons to 113 million tons. World production (109 million tons), which decreased with Covid 19, broke a record in 2021 and reached 113 million tonnes (Figure 1). It is estimated that total fiber production will increase 149 million tonnes by 2030. With around 68 million tonnes, synthetic fibers made up approximately 62 percent of the global fiber production in 2020. Polyester, a synthetic fiber, and cotton, natural fiber, dominate the world fiber market. Among these products, polyester has the highest share (52%). With about 25 million tonnes, cotton has a market share of approximately 22 percent of global fiber production in 2021. The demand for polyester has doubled in recent years and has replaced cotton, which has been the most used fiber for many years. By 2025, it is predicted that polyester fiber production will increase and be 3 times more than cotton production in order to meet the increasing fiber demand. Meanwhile cotton fiber production is foreseen to remain stable. Other plant-based fibers, including jute, linen, hemp, and others, had a market share of about 6 percent (Textile Exchange, 2022).

An increasingly important fiber category is manmade cellulosic fibers (MMCFs), with a market share of around 6 percent in 2020. Animal fibers had a market share of 1.57 percent in 2020 (Textile Exchange, 2022).

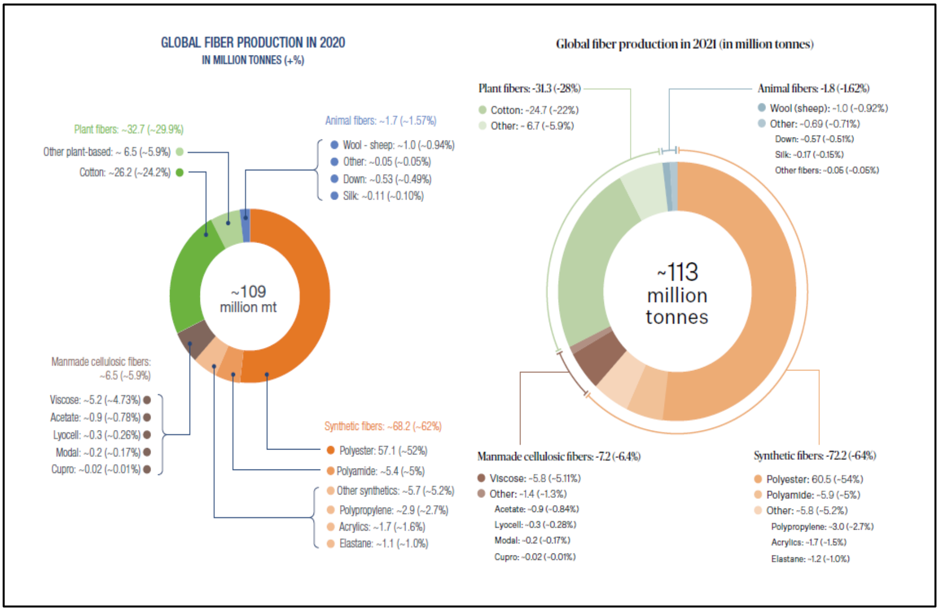

Figure 1: World Fiber Production in 2020 and 2021
Source: Textile Exchange, 2021 and 2022.

Over the years, the production of synthetic fibers has migrated to Asia. In Asia, China is the largest synthetic fiber producer. Other Asia (including Oceania) and India follow China. Together, these regions account for about 95% of the total global production, of synthetic fibers.

For natural fibers, the countries with the highest volumes of production in 2019 were India, China and the United States, together comprising 56% of global production. Brazil, Bangladesh, Pakistan, Turkey, France, Uzbekistan and Australia, which together accounted for a further 28%, followed these countries.

Synthetic fibers have the highest share in consumption as well as in production. They are accounting for about 50% of the overall fibers market. Since 2000, the consumption of synthetic fibers has grown at a sustained rate because of their low cost of production, their versatility and relatively large spectrum of applications (S&P GLOBAL, 2002). Cotton is the second-largest-volume textile fiber (Figure 2).

In consumption of natural and synthetic fibers, China ranks the first (Figure 2) because the region's extensive textile and garment manufacturing industries has been consuming increasing amounts of the products. Asia's fiber and textile industry remains export-driven, and domestic demand for textile products in the region is growing (S&P GLOBAL, 2022).

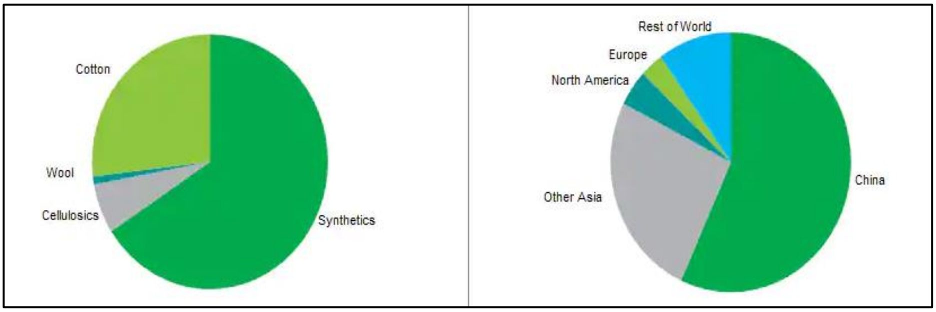

Figure 2: World Natural and Man Made Fibers Consumption in 2019
Source: S&P Global, 2022.

When we look at the trade of fibers, which have such a large market, it is seen that China is dominant in both exports and imports. Other Asian countries also have undeniable shares (Figure 3). Since these countries have significant shares in the global textile market, they have a considerable place in fibers trade, which are the raw materials of textiles (Figure 4).

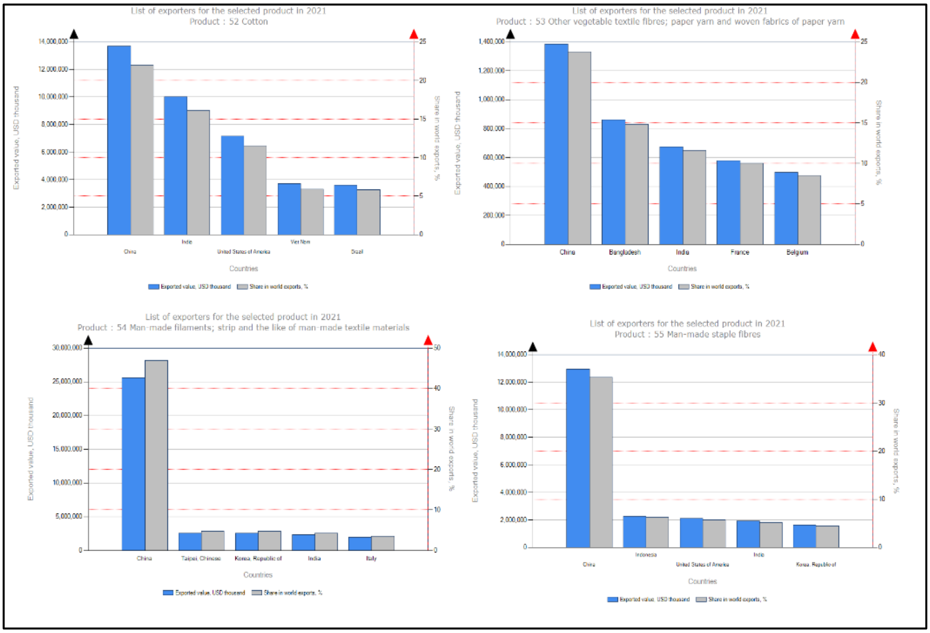

Figure 3: World Natural and Man Made Fibers Exports in 2021
Source: Trademap, 2022.

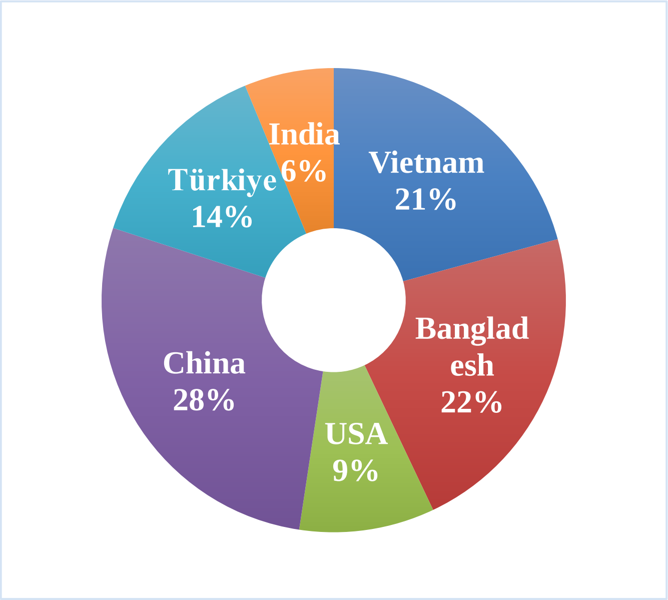

Figure 4: World Natural and Man Made Fibers Imports in 2021
Source: Trademap, 2022.

In the following section, natural fiber plants will be included. In particular, the current situation of cotton, jute, coir and flax, which are the most important fiber sources in the world, will be discussed.

4. THE COTTON MARKET DEVELOPMENTS

4.1. World Cotton Production and Consumption

Cotton, which has a long history of cultivation, is the first plant whose fiber is processed. In India, the cradle of cotton in the ancient world, it was determined in archaeological excavations that cotton cultivation was carried out at least 5000 years ago and that its use in fabric weaving coincided with 3000 BC. India, which has maintained its importance for many years, has lost its leading position today. With globalization, developed countries have moved their textile industries, especially to Asian countries. This has been an advantage for some countries. Although the general trend in the world fiber market is the increasing use of synthetic fibers, cotton is still the most important natural fiber.

Although cotton is a strategic product, it is not grown in large areas like wheat due to climate and soil demands. In fact, cotton is grown on an average of 33.3 million ha globally. The average yield is 22.168 hg/ha and cotton production is 24.9 million tons.

The cultivation areas of India has been parallel to the development in the world. Between 2010 and 2019, cotton cultivation areas increased in India, while decreased in China and the USA. In other countries, Pakistan and Brazil, the area harvested do not change. In recent years, with the increase in cotton areas in India, the ranking has changed. Although China has been the most important cotton producer in the world for many years, India has taken the first place since 2015 (Table 1).

Table 1: The cotton production developments in main producing countries (2010-2019)

	Production		Area Harvested		Yield	Consumption	
	million tonnes	Share (%)	ha	Share (%)	hg/ha	million tonnes	Share (%)
China	5.947.313	23,9	4.193.524	12,6	45.818	8.229.980	33,0
India	5.647.356	22,7	12.258.179	36,7	14.482	4.971.735	19,9
USA	3.690.435	14,8	3.920.394	11,7	25.851	733.709	2,9
Brazil	1.599.349	6,4	1.142.462	3,4	38.175	778.365	3,1
Pakistan	1.979.164	7,9	2.709.258	8,1	20.970	2.255.624	9,0
Türkiye	851.981	3,4	477.654	1,4	48.226	1.403.233	5,6
REST	5.206.049	20,9	8.669.957	26,0	--	6.581.042	26,4
World	24.921.646	100,0	33.371.426	100,0	22.168	24.743.240	100,0

Source: calculated from FAO, (2022) online database.

Among the cotton producing countries, India ranks the second after China. The U.S. ranks third with a share of 14.8%. These countries are followed by Pakistan and Brazil. Turkey is included among the world's leading cotton producers (Figure 5). Briefly, Asian countries have a predominance in world cotton production (Figure 6). The growth of world cotton production in the last decade was due to the productivity increase rather than to an increase in area harvested. Much of this increase is attributable to China (Table 1). However, the pace of technology development and adoption slowed down after 2007/08, and the world yield in 2010/19 was still nearly 22.168 hg/ha.

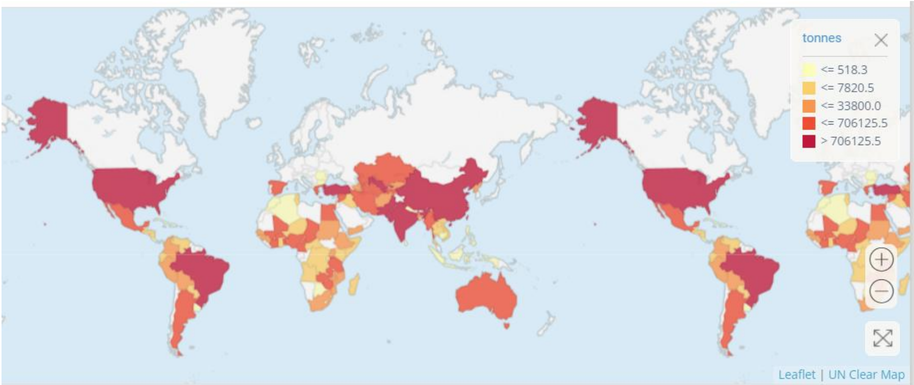

Figure 5: World Cotton Production (2010-2019)
Source: FAO, 2022.

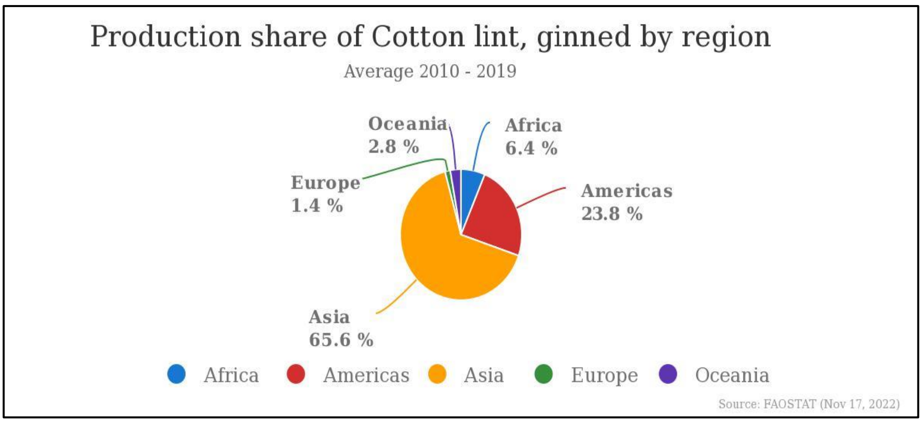

Figure 6: World Cotton Production by Region (2010-2019)
Source: FAO, 2022.

World cotton consumption is 24.7 million tons on average. Although there are fluctuations in the consumption years, the amount is increasing. In fact, cotton consumption increased by 35.7% and reached 26.8 million tons in the period under consideration. Especially in 2015, cotton production decreased due to the increase in costs and decrease in supports in China, the decrease in yield in the USA, and adverse weather conditions in Pakistan (TEPGE, 2018). Accordingly, the ratio of production to consumption decreased to 84.7%. In general, cotton production meets its consumption (Figure 7).

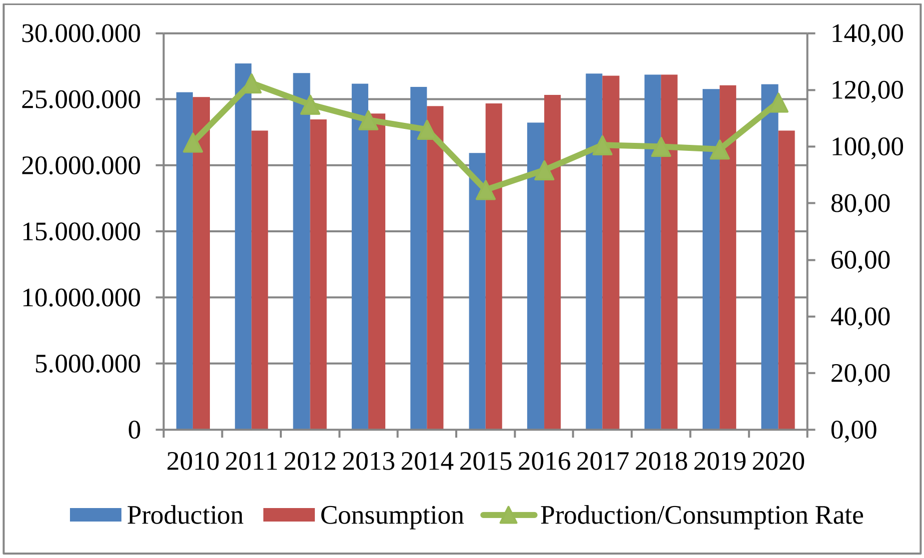

Figure 7: World Cotton Consumption (2010-2019)
Kaynak: USDA, FAS, 2022.

Although cotton production in the world meets its consumption, there have been increases in the world cotton stock since 2010 because of the contractions in international trade and marketing problems in the textile sector. Both the initial and closing stock increased between 2010 and 2019. The closing stock, which was 10.7 million tons at the beginning of the period, increased to 21.4 million tons in 2019. In 2014, cotton stock increased to 23.2 million tons (Figure 8). Due to the increasing cotton stocks, the world prices of cotton have been adversely affected. Three consecutive years of growth in cotton consumption beginning in 2016/17 finally completed a recovery from the recession and its aftermath.

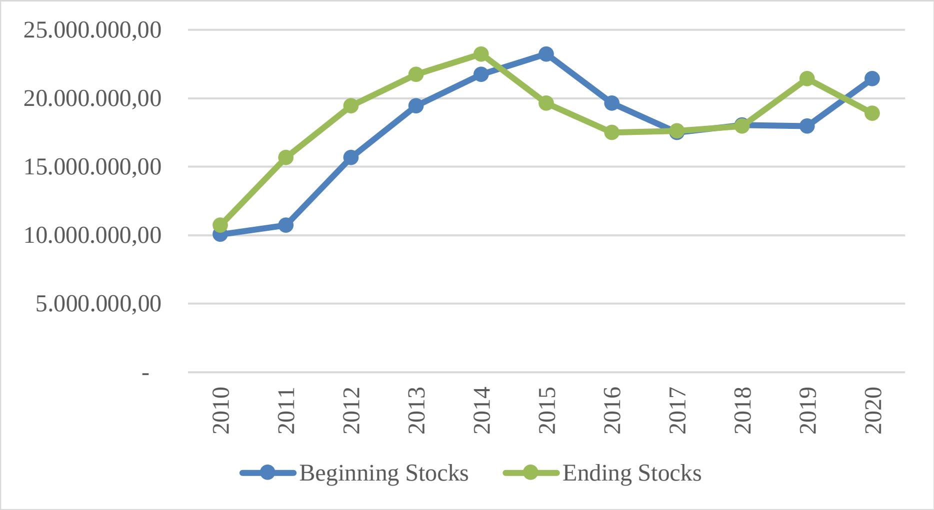

Figure 8: World Cotton Stocks
Source: USDA, FAS, 2022.

Around 64% of the world's cotton stock is in the hands of China, the most important importer and producer country. India, which ranks first in cotton production, is second with a 14% share (Figure 9). Until 2014, China, India and Brazil have increased their cotton stocks. The most important exporter country, the United States, has decreased its stocks. A decrease in cotton production in seasons 2015/16 and 2016/17 resulted in a decrease in cotton stocks (Figure 8).

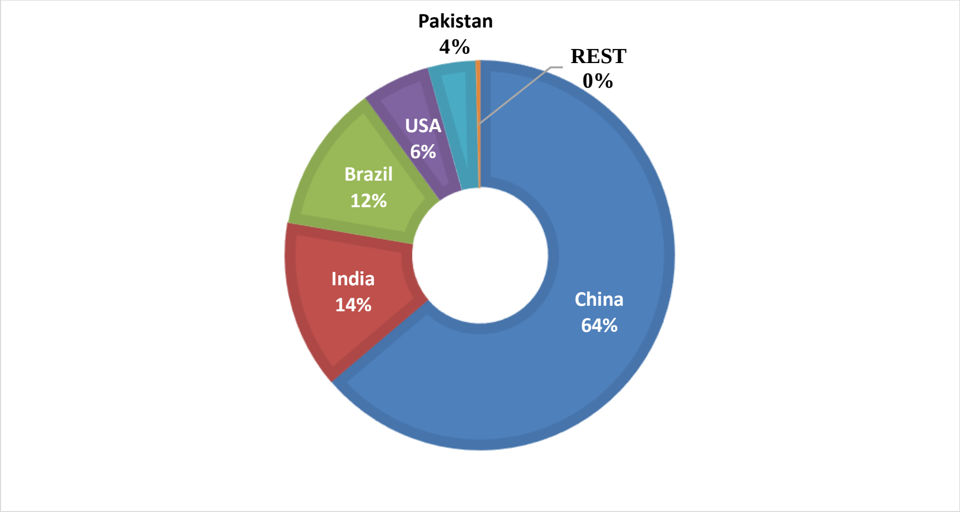

Figure 9: World Cotton Stocks by Countries
Kaynak: USDA, FAS, 2022.

Consequently, the main actors in the world cotton market are China, India and the USA, Pakistan, Brazil and Türkiye. China and India account for almost half of the world production and total consumption.

4.2. The World Cotton Trade

Cotton is one of the most widely traded agricultural products. Cotton fiber exports, which were $14.2 billion in 2010, increased to $15.1 billion in 2019. Cotton fiber exports, which rose to $20.8 billion in the period under consideration, experienced a rapid decline after 2011 and declined to $10.8 billion. Cotton fiber imports also increased until 2011. It has decreased to $10.8 billion after 2011. In general, after 2011, there was a contraction in world cotton fiber trade (Figure 10). The fall in world cotton prices was effective in this contraction (Ministry of Customs and Trade, 2016).

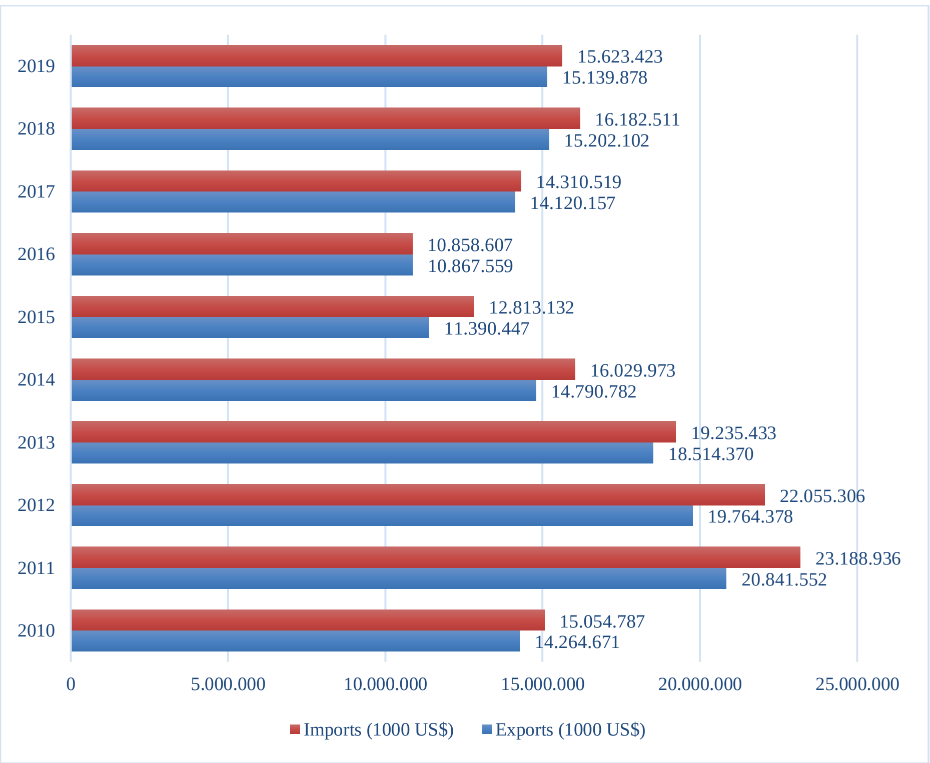

Figure 10: World Cotton Trade

Source: FAO, 2022.

The contractions in cotton exports in recent years are also seen among the most important exporting countries. Cotton exports of the USA increased until 2011, and started to decrease after 2011. Despite this, it ranks first in world cotton exports. India ranks second in world cotton exports with a share of 13.78%. In the period under consideration, India's exports increased rapidly and reached US$ 2.5 billion. Likewise, in Australia, its share increased to 10.5%. Brazil has become an important cotton exporter in the period under consideration (Figure 10).

China ranks first in world cotton imports with a share of 34.44%. Turkey, Indonesia, Bangladesh, Thailand and Vietnam follow China, respectively (Figure). Far East countries are significant in cotton imports. The increase in cotton imports in these countries is due to the demand arising from the developments in their textile and apparel sectors.

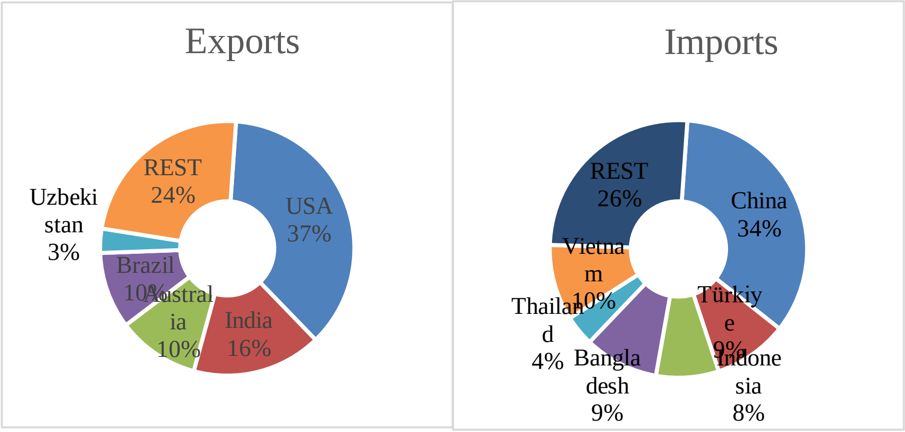

Figure 11: World Cotton Trade by Countries
Source: FAO, 2022.

4.3. The Developments in World Prices of Cotton

The Cotlook A Index represents an indicator of average world prices for cotton. The world prices fluctuated between 1.5$/kg and 3.6$/kg. The only significant upward or downward trend in nominal cotton prices was during 2010/11 and 2011/12, when cotton prices exceeded USD 2/lb due to disruptions in the cotton-textile-apparel supply chain caused by the 2008–2009 world recession (Figure 12). During the recession, all actors in the supply chain reduced their inventories for fear of an even steeper and longer reduction in demand than before. When consumer demand began to recover in early 2010, panic buying resulted in a short-lived but extraordinary spike in cotton prices (FAO, 2021). In the last decade, there has been a rapid decline in cotton prices in the world. The reasons for the rapid decline in prices are the fact that the consumption of cotton did not increase at the same pace with production due to productivity increase and this leads to increases in world stocks (Ministry of Customs and Trade, 2018). In addition, a slight increase of cotton prices is foreseen for the 2025-2030 projection years (OECD/FAO, 2021).

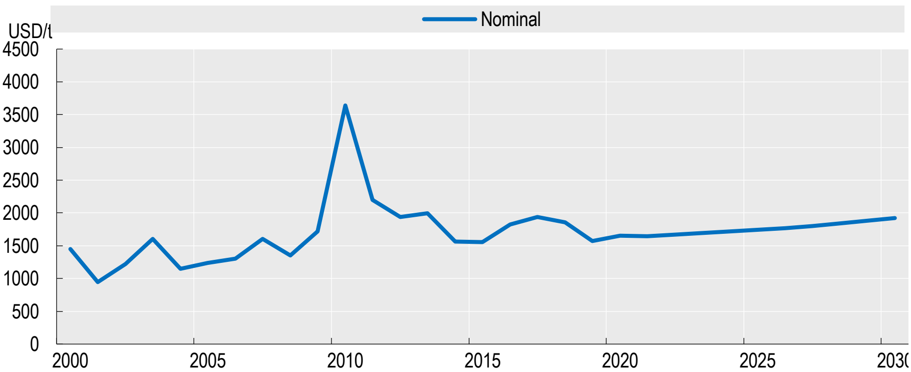

Figure 12: World Cotton Prices

Source: OECD/FAO (2021), "OECD-FAO Agricultural Outlook OECD Agriculture statistics (database)", http://dx.doi.org/10.1787/agr-outl-data-en.

5. THE DEVELOPMENTS IN TURKISH COTTON MARKET

5.1. Cotton Production and Consumption in Türkiye

Cotton has been grown in Anatolia for centuries. Because of giving a special importance with the Republican period, both cotton and cotton industries developed. In the 1980s, with the opening of the Turkish economy to the world, there was a contraction in the cultivation areas. In the 2000s, this contraction continued, with a decrease of 23.28%. As of 2017, cotton is grown in 501 thousand ha area in Turkey. This decrease was also influenced by cotton costs. The high cost of cotton production in Turkey has caused producers to turn to alternative products in regions where cotton is produced. Despite the decrease in cultivation areas, there was an increase of 8.36% in cotton production and

41.45% in yield. Despite the shrinkage of cotton cultivation areas, the increase in cotton production can be explained by the increase in yield (Table 2).

Table 2: Cotton Production and Consumption in Türkiye

Years	Area Harvested (ha)	Production (tonnes)	Yield kg/da	Consumption (tonnes)
2010	480.439	2.150.000	447	
2011	541.952	2.580.000	476	
2012	488.496	2.320.000	474	
2013	450.890	2.250.000	499	
2014	466.839	2.350.000	503	
2015	434.000	2.050.000	472	
2016	416.002	2.100.000	504	
2017	501.853	2.450.000	488	
2018	518.634	2.570.000	496	
2019	477.868	2.200.000	460	

Source: TÜİK, 2022a, Bitkisel Üretim İstatistikleri Veritabanı.

Cotton cultivation in Turkey is carried out in the Aegean Region, Southeastern Anatolia Region, Çukurova and Antalya regions. While cotton cultivation area increases in South East Anatolia Region, cotton cultivation areas decrease in Aegean Region and Çukurova Region (Table 4.9). In 2017, the share of the South East Anatolia Region in the total cotton cultivation area in terms of cultivation area was 59.36%, while the share of the Aegean Region was 21.73%, the Çukurova region was 17.74% and the Antalya region was 1.17% (Kantur, 2019).

In the period under consideration, a parallel develeopment in production by regions is observed with the developments in the cultivation areas. Accordingly, while the cotton production of the Southeastern Anatolia Region is increasing, it is seen that the production of other regions has not changed. In fact, while the share of the South East Anatolia Region in total cotton production was 56.15% in 2017, the share of the Aegean Region was 22.69%, the share of the Çukurova region was 7.74%, and the share of the Antalya region was 1.12% (Kantur, 2019). In the period under consideration, the Southeastern Anatolia

Project had an impact on the increase of both cultivation areas and production in the Southeastern Anatolia Region.

When the development of raw cotton production and consumption for the last decade is examined, it is seen that cotton consumption exceeded the production until 2002. The amount of cotton production reached the highest level of production in the period of 2002/03 and cotton production generally decreased after this period. Especially with the negative impact of the global economic crisis on cotton prices in 2008 and 2009, there has been a sharp decline in the country's production. After the crisis period, production reached the pre-crisis level in the 2011/12 season, but followed a decreasing pace until the 2016/17 season. In the 2017/2018 production period, cotton production increased with the effect of the increase in cotton prices and support policies. As a result of these developments, the ratio of production to consumption increased compared to 2000 and became able to meet domestic consumption (Figure 13). Despite the serious decline in cotton cultivation areas in Turkey, especially in Aegean and Çukurova, since the end of the 1990s, the fact that the production did not decrease at the same rate can be explained by the great increase in yield in Turkish cotton agriculture. From this point of view, if the current yield level in cotton agriculture can be combined with the cultivation level between 1995-2000 (average 730 thousand hectares), the country's fiber cotton production can reach up to 1.5 million tons and imports can be reduced by meeting the majority of consumption from domestic sources (T.R. Customs. and Ministry of Commerce, 2019).

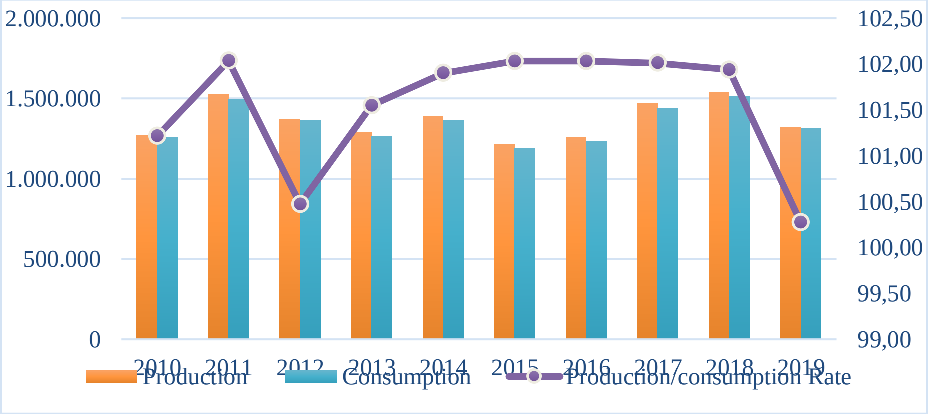

Figure 13: Cotton Consumption in Türkiye (2010-2019)
Source: TÜİK, 2022b, Bitkisel Ürün Denge Tabloları.

Although there are positive developments in the rate of production to consumption in Turkey, there has been an increase in the cotton stock in the period under consideration. Both initial and closing stocks increased between 2010 and 2019. The closing stocks, which was 2.8 thousand tonnes at the beginning of the period, increased to 1777 thousand bales in 2017. Cotton stock increased to 6.0 thousand tones in 2019 (Figure 14).

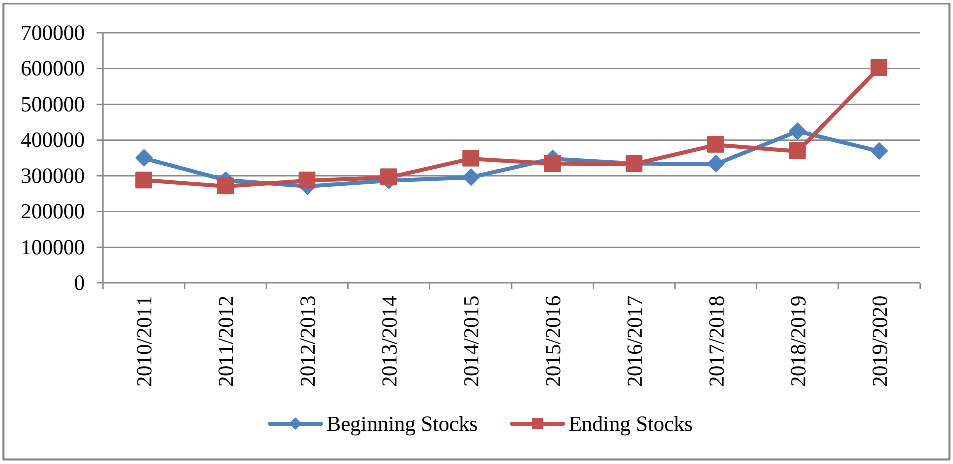

Figure 14: Cotton Stocks in Türkiye
Kaynak: USDA, FAS, 2022.

5.2. Cotton Trade in Türkiye

In parallel with the decrease in cotton production and the development in the textile sector in Turkey, the increase in cotton use cannot be met by domestic production. Therefore, cotton imports have increased and Turkey, which is a net cotton exporter, has become a net cotton importer country. As of the period under consideration, cotton imports have gradually increased. On the other hand, there was no significant development in cotton exports. As a result of these developments, Turkey maintained its position as a net importer (Figure 15)

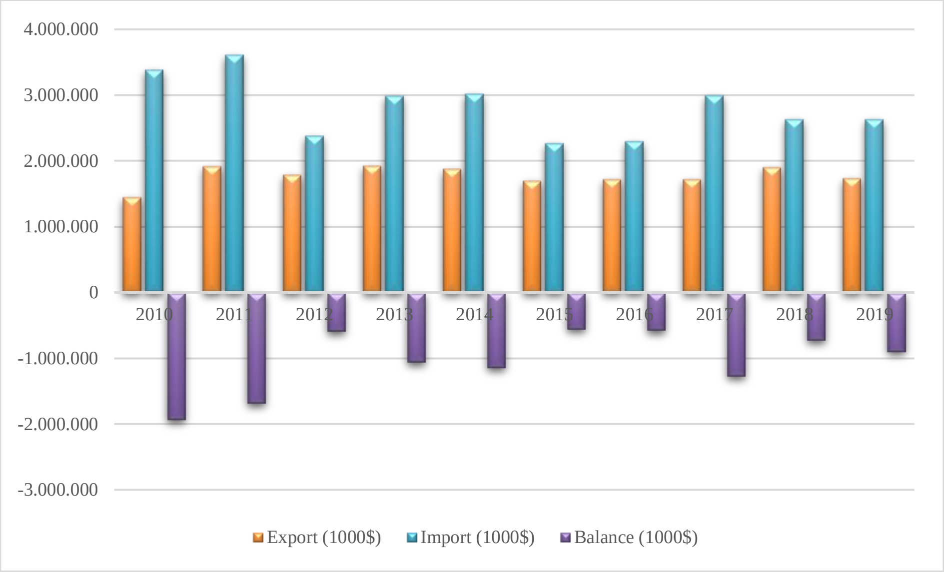

Figure 15: Cotton Trade in Türkiye
Source: TÜİK, 2022c, Dış Ticaret Veritabanı.

In the 2013-2017 period, 14.69% of Turkey's cotton exports of 1.78 billion dollars were realized to Italy. This country was followed by Germany and Tunisia respectively. While the majority of cotton exports were made to European countries in the years considered, it is noteworthy that in recent years North African countries have taken the first place. The USA takes the first place in Turkey's cotton imports of approximately 2.64 billion dollars with a share of 25.62%. As it has been for many years, the country profile in imports has not changed, 52.88% of imports are made from the USA, Turkmenistan, Greece and Pakistan. These countries are followed by China, Brazil, India, Egypt, Uzbekistan and Vietnam. GSM credits are very effective in cotton imports from the USA (Kantur, 2019).

5.3. Cotton Prices in Türkiye

Cotton trade in Turkey has been operating strictly according to the free trade market since the 1990s. There are no taxes or restrictions on export and import. For this reason, cotton prices are formed according to the supply-demand balance in national and international markets, and there is no government intervention on prices (T.R. Ministry of Customs and Trade, 2019).

Only within the scope of deficiency payments support, deficiency payment is given per decare for cotton.

As in other countries, cotton prices in Turkey follow a parallel pattern with the Cootlook A Index (Figure 16). Depending on the exchange rate increase, there may be a significant increase in cotton stock market prices. However, these increases are not reflected in the prices received by cotton producers at the same rate. While the price formed in the stock market was 1.66 times the producer price in 2009, it was 3.45 times in 2017. Another negative development against the producer is that producer prices remained below cotton costs (Table 3). In addition to the increase in cotton input/product price parity, the "average domestic market price" is insufficient to cover the cost due to the effect of subsidized imports. In this case, it negatively affects Turkey's competitiveness in international markets.

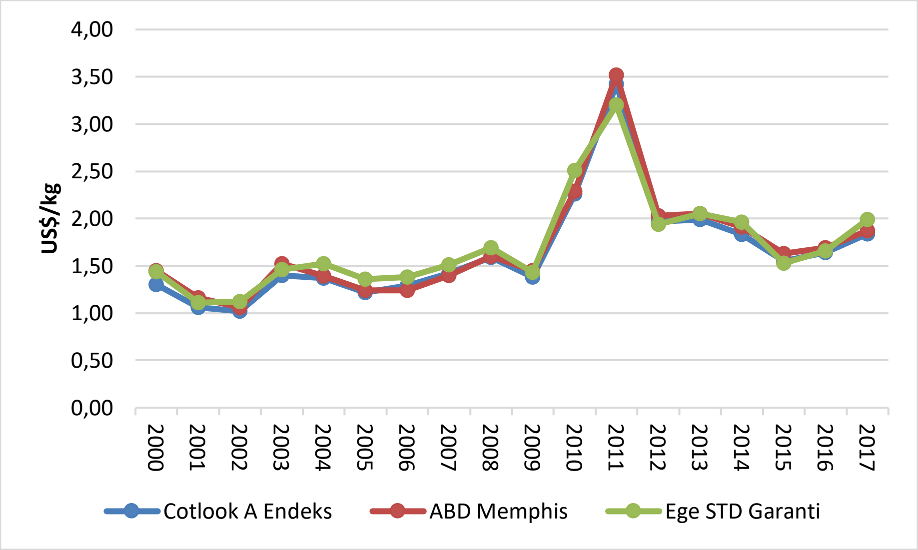

Figure 16: Cotton Prices in Türkiye (US$/kg)
Source: İTB, Pamuk Bültenleri, Çeşitli Yıllar

Table 3: Cotton Prices and Cost in Türkiye

	Üretici Fiyatı (TL/kg)	Borsa Fiyatı (TL/kg)	Maliyet (TL/kg)
2009/2010	1,34	2,23	0,88
2010/2011	1,91	3,76	1,09
2011/2012	1,87	5,27	1,25
2012/2013	1,24	3,49	1,71
2013/2014	1,35	3,91	1,71
2014/2015	1,32	4,29	1,96
2015/2016	1,46	4,39	2,10
2016/2017	1,68	5,03	2,34
2017/2018	2,10	7,26	3,57

Source: TÜİK, 2022d ve T.C. Gümrük ve Ticaret Bakanlığı, 2019.

6. CONCLUSION

Most of the production growth in the coming decade is expected to come from Asian countries, with India accounting for more than 40% of the global increase. At the global level, the cotton area is projected to expand by 1% while yields are projected to increase by 10% (OECD/FAO, 2021). In the last decade, world average yield was stagnant. For some major producers (United States, Pakistan, India) yields were stagnant or decreasing. cotton area in China (where yields are well above average) was declining. Cotton area in India (where yields are well below average) was expanding. These factors are expected to continue to affect global yield trends in the coming decade, despite growth in both yields and cotton area in Brazil.

Production in India is projected to grow by around 1.5% p.a. over 2025-2030, mainly because of higher yields rather than area expansion, since cotton already competes for acreage with other crops (OECD/FAO, 2021). Raw cotton productivity has remained stagnant and the lowest globally in recent years, as producers struggle with adverse weather, insect pests, and diseases. However, growing demand from the domestic apparel industry continues to spur investments in the sector. OECD/FAO assumes a growth in yields that reflects increased use of smart mechanization, varietal development, and pest management practices. Nonetheless, climate change, with most cotton grown under rain-fed conditions, may undermine the yield growth potential.

The prospects for global cotton use depend on developments in developing and emerging economies. International Cotton Advisory Committee (ICAC) suggests that global per capita demand for cotton products decreased between 2007 and 2012, but that it has since stabilized. The effects of income growth should lead to a higher demand for cotton products. However, strong population growth in regions where per capita demand for cotton products is below average dampens this effect. Demand from developing regions with lower absolute levels of consumption but higher income responsiveness will put an upward trend on global demand as the incomes and population of these countries are projected to increase (OECD/FAO, 2021). Therefore OECD/FAO expects that global consumption of cotton products will grow at a slightly higher pace than global population in the coming decade. Correspondingly, global mill use is projected to grow by around 1.5% p.a. over 2025-2030 (OECD/FAO, 2021).

Trade tensions may also play a role in affecting the development of the raw cotton markets. In recent years, the cotton market has been affected by the US-China trade dispute. This issue is increasingly an important concern for consumers, industry, and policy makers in many countries and, depending on whether these concerns will increase or decrease in the future.

On the other hand, natural fibers are threatened by the growth of man-made fiber alternatives. For natural fiber industries to remain competitive, the technological progression that started with directed breeding, and continued with mechanization, synthetic fertilizers, plant protection chemicals and the tools of genetic engineering must continue.

The main raw material source for synthetic polymers is petroleum. Energy and chemicals based on non-renewable resources are also needed in the production of renewable natural fibers such as cotton. It is very difficult to say which fiber type is more environmentally friendly, because each fiber has its own environmental burden. Some fibers cause high consumption of natural resources during the fiber production phase, while others during the textile production processes. Although some fibers are obtained from renewable sources, they cannot be recycled, while some fibers are produced from non-renewable sources and can be easily recycled into high quality products.

It is seen that both natural and synthetic fibers obtained by conventional production methods lag far behind in the sustainability ranking, and fibers produced by recycled or organic production methods are the most environmentally friendly fibers.

The use of sustainable materials and production methods is important for the solution of this increasing problem in the textile and ready-made clothing industry, which is one of the most polluting industries in the world. For this, cyclical material flow should be adopted instead of conventional linear material flow and the use of recycled fibers should be reassured.

Sustainability considerations will continue to influence future demand and supply of cotton. The share of cotton lint produced under special sustainability or organic standards has increased steadily since 2010. In 2018, it reached a share of 25%. Among the existing standards, the Better Cotton Initiative dominates globally, accounting for more than 45% of sustainable cotton supply in 2018, followed by the Responsible Brazilian Cotton initiative with 35%. Brazil, where about 80% of cotton production is certified under these two initiatives, takes a leading role in global sustainable cotton production. It is most likely that the sustainable and organic segment will continue to grow in the future with the implication that this will lead to an increased need for transparency and traceability along the supply chain (OECD/FAO, 2021).

Recycling by the textile industry is creating a competitive secondary market that provides raw material to producers of lower-quality textiles and non-textile products. This trend could further reduce the demand for cotton and other fibers. However, in high-income countries there appears to be an increasing consumer preference for natural fibers that could favor cotton over polyester.

REFERENCES

DNFI, (2019). Natural Fibres and the World Economy July 2019, Posted On 8th August 2019 By Terry Townsend, https://dnfi.org/natural-fibres-and-the-world-economy-july-2019. (Access on 15.09.2022).

DNFI, (2020). 40 Million Households Produce Natural Fibres, Posted on 20th April 2020 by Terry Townsend, https://dnfi.org/40-million-households-produce-natural-fibres. (Access on 15.09.2022).

FAO, 2021, Recent trends and prospects in the world cotton market and policy developments, https://www.fao.org/3/cb4589en/cb4589en.pdf.

FAO, 2022, FAOSTAT Statistical Database, http://www.fao.org/faostat/en/#home, (Access on: 10 Eylül 2022).

İTB, Pamuk Bültenleri. Çeşitli Yıllar.

Kantur, Ç., 2019, Türkiye'nin Dünya Pazarında Pamuk ve Pamuklu Dokuma Sektörü Açısından Rekabet Gücünün Analizi, Ege Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi.

OECD/FAO, 2021, "OECD-FAO Agricultural Outlook 2021-2030, OECD Agriculture statistics (database)", http://dx.doi.org/10.1787/agr-outl-data-en.

Rana, S., Pichandi, S., Parveen, S., Fangueiro, R., 2014. Natural Plant Fibers: Production, Processing, Properties and Their Sustainability Parameters in S. S. Muthu (ed.), Roadmap to Sustainable Textiles and Clothing, Textile Science and Clothing Technology, DOI: 10.1007/978-981-287-065-0_1, Springer Science+Business Media Singapore.

S&P GLOBAL, 2022, Natural and Man-Made Fibers Overview in Chemical Economics Handbook, https://www.spglobal.com/commodityinsights/en/ci/products/fibers-chemical-economics-handbook.html. (Access on 15.10.2022).

Siti Aiyah, G., Mohd, Tajuddin, R. (2014). Trends In Natural Fibre Production And Its Future. *5th Brunei International Conference on Engineering and Technology* (BICET 2014). 1-3 November, Brunei Darussalam, DOI: 10.1049/cp.2014.1080

T.C. Gümrük ve Ticaret Bakanlığı, Kooperatifçilik Genel Müdürlüğü, 2016, 2015 Yılı Pamuk Raporu, 35s.

T.C. Tarım ve Orman Bakanlığı, Tarımsal Ekonomi ve Politika Geliştirme Enstitüsü Müdürlüğü, 2017, Durum ve Tahmin Pamuk 2017/2018, TEPGE Yayın No: 285 ISBN: 978-605-9175-89-0, 37s.

T.C. Ticaret Bakanlığı, 2019, Ticaret Bakanlığı Devlet Yardımları Rehberi, Ankara, 144s.

Textile Exchange, 2021. Preferred Fibers and Materials Market Report, https://textileexchange.org/knowledge-center/reports/preferred-fiber-materials-market-report-2021/. (Access on 15.09.2022).

Textile Exchange, 2022. Preferred Fibers and Materials Market Report, https://textileexchange.org/knowledge-center/reports/preferred-fiber-and-materials/. (Access on 15.09.2022).

Textile Technology, 2022. Stable world natural fiber production in 2022. August 12, 2022. https://www.textiletechnology.net/fibers/news/dnfi-stable-world-natural-fiber-production-in-2022-32691. (Access on 15.09.2022).

Trademap, 2022. Trade statistics for international business development, https://www.trademap.org/, (Access on:15.10.2022)

TÜİK, 2022a, Bitkisel Üretim İstatistikleri Veritabanı, https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr.

TÜİK, 2022b, Bitkisel Ürün Denge Tabloları Veritabanı, https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr.

TÜİK, 2022c, Dış Ticaret İstatistikleri Veritabanı, https://biruni.tuik.gov.tr/disticaretapp/menu.zul.

TÜİK, 2022d, Tarım Ürünleri Üretici Fiyat Endeksi (Tarım ÜFE), http://www.tuik.gov.tr/PreTablo.do?alt_id=1101.

USDA, FAS, PSD, 2022, Production, Supply and Distribution Online, https://apps.fas.usda.gov/PSDOnline/app/index.html#/app/advQuery.

CHAPTER 2

BLACK GOLD (BIOCHAR) FOR WHITE GOLD (COTTON): IMPLICATIONS AND PROSPECTS

Assoc. Prof. Dr. Ilkay YAVAS[1],
Assoc. Prof. Dr. Saddam HUSSAIN[2]

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[1] Aydin Adnan Menderes University, Kocarli Vocational School, Department of Crop and Animal Production, Aydin, TURKEY, (ORCID. 0000-0002-6863-9631), iyavas@adu.edu.tr

[2] Department of Agronomy, University of Agriculture, 38040, Faisalabad, PAKISTAN, (ORCID. 0000-0002-0895-1287), saddamhussainuaf@gmail.com

1. INTRODUCTION

Stubble burning is widely practiced to many parts of world; however, it is being discourged to harmful effects on health and environment. Conversion of plant residues into biochar and its application with inorganic fertilizers offers an attractive alternative for protection of soil health and biota. Waste management has become an important economical and environmental challange globally. Biochar is a viable waste management option and has attracted attention in recent past due to its beneficial effects for agriculture and environment (Younis et al., 2015).

Decrease in soil fertility and soil health is an important problem in our soils due to monoculture agricultural practices, unnecessary and intensive use of synthetic fertilizers, soil erosion and nutrient losses due to poor irrigation management. The use of biochar for soil remediation not only increases soil fertility but also helps to protect the soil for plant cultivation on sustainable basis. Biochar and biofertilizer effectively increased the stability of heavy metals in the soil by mitigating the inhibitory effect of cadmium on photosynthesis and chlorophyll production (Choi et al., 2009; Kamran et al., 2020).

The application of biochar to the soil improves the physical and chemical properties of the soil, reduces greenhouse gas emissions, and increases microbial activity of the soil and therefore the plant yield (Hui, 2021).

Instead of burning various plant residues such as cotton and corn, preparing biochar will also help reduce the problem of global warming. Due to the increasing population and the gradual decrease of agricultural lands, a sustainable crop production practice becomes mandatory. Biochar is recommended to improve contaminated agricultural soils, reduce acidity, increase soil fertility and nutrient content. Therefore, the addition of biochar to the soil will be one of the best practices in any stress condition to overcome the stress and increase plant yield. The positive effects of biochar on the soil-plant-water interactions help to increase the photosynthesis capacity, nitrogen and water use efficiency of the plant. Therefore, from this comprehensive review, it can be concluded that biochar has the potential to improve soil properties, microbial activity, biological nitrogen fixation and plant growth. In the long term, it can be recommended to use biochar as a soil conditioner. It is observed that the addition of biochar will improve root physiology and morphology, as well as cotton yield and quality characteristics, and this will be related to the rate of biochar used. In addition, with the use of biochar, pollution and waste of resources will be prevented.

Biochar Properties

Biochar is a fine-grained and porous substance, a kind of charcoal, formed after the anaerobic pyrolysis of organic wastes at 450-650°C. The use of biochar in soil improvement dates back to 2500 years ago in the Amazon Basin (Younis et al., 2015).

Biochar causes an increase in the rate of photosynthesis and uptake of nutrients (such as N, K, P, and Ca) thereby positively affecting physiological processes in plants (Xu et al., 2015). It is also known to increase soil fertility and reduce the effects of climate change (Atkinson et al., 2010; Al-Wabel et al., 2013). Biochar absorbs moisture, retains nutrients in the soil, thus reducing the required amount of mineral fertilizer and protecting plants from the effects of drought stress (Laghari et al., 2016).However, the properties of the biochar material produced by the pyrolysis process vary depending on the biomass used and the temperature during preparation. Biochar applied to the soil improves the physical, chemical and biological properties of the soil (Singh et al., 2012). It was observed that the corn grain yield was 150% and 98% higher in biochar applications of 15 $t.ha^{-1}$ and 20 $t.ha^{-1}$, respectively, compared to the control conditions. The increase in plant yield after application is due to the increase in the amount of nutrients and the concentration of basic cations (Uzoma et al., 2011).

In acidic soils, the liming effect of biochar increases the cation exchange capacity and improves soil microbial diversity and function along with plant water content (Anderson et al., 2011). The application of biochar to sandy soils increases the water holding capacity. With its porous and large surface area, biochar provides higher moisture retention in the soil (Fang et al., 2014).

Biochar produced at temperatures above 300 °C provides a significant increase in the available phosphorus content, but does not cause any change in the total phosphorus level of the soil (DeLuca et al., 2009). The increased availability of phosphorus is attributed to the oxidation and combination of Al and Fe in soils. The addition of biochar to the soil also significantly reduces the leaching of nitrogen (N), calcium (Ca) and magnesium (Mg) (Jha et al., 2010). The application of biochar to soils contaminated with chromium increases the organic carbon and total nitrogen content in the soil (Nigussie et al., 2012).

When biochar is applied with fertilizer, it prevents the leaching of nutrients and thus reduces the need for fertilizer (Gaskin et al., 2008; Peng et al., 2012). In fact, the application of 5 tons/ha biochar reduced the need for fertilizer by 7 percent (Gaskin et al., 2008). Compared to other organic materials, biochar is more stable in the soil and can remain for many years. In addition, biochar application has been reported to be more effective in degraded, nutrient-poor, sandy and acidic soils (Gaskin et al., 2008; He et al., 2011).

Biochar increases the nutrient holding capacity of the soil, and prevents environmental damage associated with fertilizers, including nitrogen oxide emissions, phosphorus runoff to surface waters, and nitrogen leakage into groundwater (Laghari et al., 2016).

The improvement in the nitrogen use efficiency of plants as a result of biochar reduces not only planting costs, but also the use of chemical fertilizers and energy consumption (Dickinson et al., 2015), which will help mitigate the effects of global climate change. The combined application of biochar and chemical nitrogen fertilizer slows down nitrogen release, regulates microbial diversity, prevents denitrification, and increases plant yield and nitrogen use efficiency by stimulating nitrification, compared to the application of chemical fertilizers as the sole nitrogen source (Feng et al., 2021).

Effect of Bıochar on C3 AND C4 Plants

When the effect of biochar application in terms of C3 and C4 plants was evaluated, it was observed that photosynthesis rate, chlorophyll content, total biomass, water use efficiency, plant height, transpiration rate, root biomass, shoot biomass and stomatal conductivity increased, while carbon content decreased in C3 plants. In C4 plants, while stomatal conductivity, transpiration rate, water use efficiency and chlorophyll content increased less with biochar application, no significant effect was observed on root biomass, shoot biomass and total biomass. Therefore, it has been determined that it would be more appropriate to use biochar, which has high pH and low carbon content in systems that are dense in terms of C3 plants, instead of C4 plants, in order to achieve high biomass increase (He et al., 2020). The application of biochar obtained from the stem of the Redgram plant at a dose of 5 t ha^{-1} (Pandian et al., 2016), and the application of *Lantana camara* biochar as 12 t ha^{-1} in peanuts increased the plant height (Berihun et al. (2017). Similarly, plant heights of beans, fenugreek and mint increased by 55%, 62% and 35%, respectively, after the application of biochar to the soil (Kalyani, 2016). In another study, it was observed that biochar application increased the yield of soybean plant (Suppadit et al., 2012).

The combined application of organic amendments and biochar resulted in an increase in leaf chlorophyll content, thus resulting in higher biomass and grain yield (Agegnehu et al., 2017). It is due to the different responses of C3 and C4 plants to biochar application in terms of stomatal conductivity, the effects of plants on productivity in biochar applications and their different responses in photosynthesis. Moreover, in C4 species, the photosynthetic pathway is catalyzed by a series of carbonic anhydrases and PEPc. Therefore, C4 plants have a higher affinity for CO_2 and a higher maximum velocity which fixes CO_2 from the carboxylation point via RuBisCO. However, a more efficient photosynthetic carboxylation enzyme system in C4 plants leads to higher nitrogen utilization efficiency than in C3 plants. It is also possible that increases in plant nitrogen uptake and reductions in soil nitrogen leaching following biochar application promote the rate and efficiency of photosynthesis for C3 plants compared to C4 plants (He et al., 2020) (Figure 1).

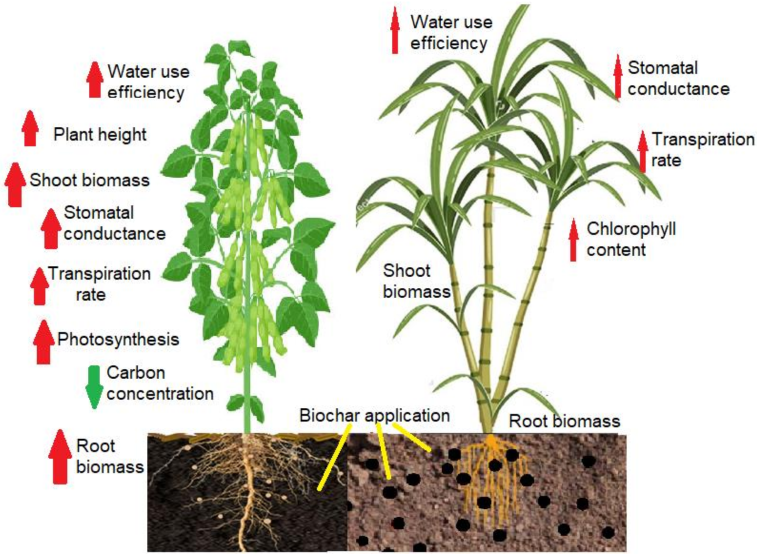


Figure 1: The effect of biochar application on C3 (left) and C4 (right) plants. Bold marks indicate greater effect of biochar (Modified from He et al., 2020).

Biochar Applications to White Gold Cotton

Cotton Growth And Productivity

Known as the king of fibers, cotton is one of the most important fiber crops grown in the world due to its high economic value (Karthik et al., 2020). In China, application of biochar to cotton increased the number of boll and cotton yield at the end of the second year (Xu et al., 2016). The application of 1% biochar to the soil at different potassium levels significantly increased the number of bolls and branches and dry biomass weight in cotton. In particular, cotton plants treated with 150 mg.kg^{-1} K_2O and 1% biochar appeared to have the highest growth parameters, while 75 mg.kg^{-1} K_2O application provided the highest yield in cotton with 1% biochar (Wu et al., 2019). Composted biosolids applied to greenhouse-grown cotton plants increased shoot length, shoot and root biomass in the plant after paddy bark biochar and cotton biochar application (Mowrer et al., 2021). Similarly, the *Miscanthus* x *giganteus* biochar also significantly increased its biomass in cotton (Li et al., 2018). Shen et al. (2018) reported that biochar application increased the seed yield due to the increase in plant nutrients. In addition, it was determined that the organic carbon, total nitrogen, and available potassium contents and fiber yield increased significantly with the application of biochar. The highest cotton yield was obtained from 20 t ha^{-1} biochar application (Tian et al., 2018). Prosopis biochar increased germination and root length of cotton seeds compared with control (Rajalakshmi et al., 2015). In addition, the application of farm manure and 10 t ha^{-1} biochar along with the recommended fertilizer dose to the cotton caused an increase in plant height (Elangovan 2014). It was observed that the application of biochar significantly increased the microbial diversity when applied to cotton fields for many years (Qian et al., 2017; Zeng et al., 2019) (Figure 2). Application of biochar and biofertilizer to cotton grown in cadmium-contaminated soils increased dry weight, chlorophyll content, photosynthesis, stomatal conductivity, transpiration, intercellular CO_2 concentration, malondialdehyde content, boll cadmium accumulation, superoxide dismutase and catalase activity in leaves and roots, decreased electrolyte leakage rate and malondialdehyde (Zhu et al., 2020).

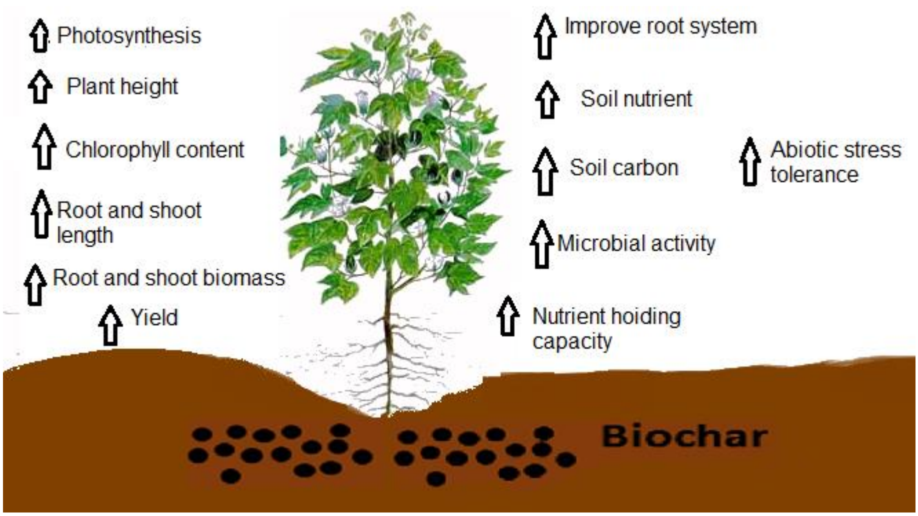


Figure 2: The effect of biochar application on cotton morphology, physiology, yield and soil properties (Modified from Jabborova et al., 2021).

Fiber Quality

The application of biochar in cotton has also significantly increased fiber length and durability. It was observed that the highest effect on cotton yield and fiber quality varied greatly with biochar application dose and time (Tian et al., 2018). As biochar doses increased, cotton lint index, fiber finenes, span length, uniformity increased, and the maximum value was obtained at 10 t ha^{-1}. Biochar application also increased ginning out performance in cotton. However, bundle strength and elongation percentage were little affected by biochar application (Elangovan and Sekaran, 2014). In another study, it was observed that the effect of different doses of biochar applications on cotton fiber yield was insignificant (Sorensen and Lamb, 2016).

Soil Properties

The application of prosopis and cotton biochar to the cotton at a dose of 4.0 t.ha^{-1} significantly improved soil organic carbon content, cation exchange capacity, porosity and reduction of bulk density (Karthik et al., 2019). Application of wheat straw biochar and phosphorus fertilizer to cotton increased phosphorus availability in soil, nitrogen and phosphorus uptake and cotton yield. The addition of high amount of biochar had a more limited effect on cotton yield compared to the addition of low amount of biochar. Therefore, it is necessary to add an appropriate amount of biochar to increase soil phosphorus content and cotton yield (Kong et al., 2021).

Nitrogen utilization in cotton and the effect of biochar application on nitrogen assimilation efficiency are strongly associated with hormone activation (Feng et al., 2021). In addition, long-term biochar application in cotton fields positively affected the diversity of soil bacteria (Han et al., 2017).

Biochar application helped to increase the cotton yield as well as improving the moisture content and nutrients of the soil (Silber et al., 2010; Karhu et al., 2011). The addition of cotton stalk biochar to the soil increased total nitrogen, organic matter, available phosphorus content and alkaline hydrolysed nitrogen in the cotton field (Dong et al., 2022).

2. CONCLUSIONS

Biochar is a type of charcoal used in soil improvement and is produced by the pyrolysis of biomass. Biochar application, due to carbon sequerestion, reduces the effects of climate change, soil acidity and diseases, improves the physical, chemical and biological properties of the soil, increases the pH of acidic soils, and thus has the potential to improve plant yield. In addition, due to its increased water holding capacity, it also alleviates the effects of drought that will occur with the effect of climate change. Biochars can stay in the soil for a long time because the amount of nitrogen it contains is not very high and it is difficult to decompose by microorganisms. In addition, due to its large surface area, it adsorbs more water and nutrients, improving both soil structure and plant growth.

Biochar reduces the lime requirement of acidic soils and prevents acidification caused by nitrogen fertilizers due to its alkaline feature. In conclusion the addition of biochar into soil is very promising in improving nutrient uptake, increasing soil fertility and cotton productivity, especially under abiotic stress conditions. In order to protect soil health and continue cotton production against future climate change scenarios, large-scale studies should be conducted. Besides, biochar increases cotton growth, improves soil properties, eliminates negative effects especially in acidic soils and indirectly increases cotton yield. However, it is very important to determine the plant and dose to be used as biochar. There are very few studies on the effect of biochar application on fiber yield and quality in cotton. It is necessary to increase the studies to be carried out on this subject and to pay attention to these issues while working

REFERENCES

Agegnehu, G., Bass, A.M., Nelson, P.N., Bird, M.I. (2016). Benefits of biochar, compost and biochar compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil. *Science of the Total Environment* 543:295-306.

Al-Wabel, M.I., Al-Omran, A., El-Naggar, A.H., Nadeem, M., Usman, A.R. (2013). Pyrolysis temperature induced changes in characteristics and chemical composition of biochar produced from conocarpus wastes. *Bioresource technology* 131:374-379

Anderson, C.R., Condron, L.M., Clough, T.J., Fiers, M., Stewart, A., Hill, R.A., Sherlock, R.R. (2011). Biochar induced soil microbial community change: implications for biogeochemical cycling of carbon, nitrogen and phosphorus. *Pedobiologia* 54(5, 6):309-320

Atkinson, C.J., Fitzgerald, J.D., Hipps. N.A. (2010). Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. *Plant and soil* 337(1, 2):1-18.

Berihun, T., Tolosa, S., Tadele, M., Kebede, F. (2017). Effect of biochar application on growth of garden pea (*Pisum sativum* L.) in acidic soils of Bule Woreda Gedeo Zone southern Ethiopia. *International Journal of Agronomy.* https://doi.org/10.1155/2017/6827323

Choi, A., Wang, S., Lee, M. (2009). Biosorption of cadmium, copper, and lead ions from aqueous solutions byralstoniasp. and bacillus sp. isolated from diesel and heavy metal contaminated soil. *Geosciences Journal* 13: 331-341

DeLuca, T., MacKenzie, M., Gundale, M. (2009). Biochar effects on soil nutrient transformations. *Science and technology* 1:251-270.

Dickinson, D., Balduccio, L., Buysse, J., Ronsse, F., Van Huylenbroeck, G., Prins, W. (2015). Cost-benefit analysis of using biochar to improve cereals agriculture. *Gcb Bioenergy* 7(4): 850-864.

Dong, X., Zhang, Z., Wang, S., Shen, Z., Cheng, X., Lv, X., Pu, X. (2022). Soil properties, root morphology and physiological responses to cotton stalk biochar addition in two continuous cropping cotton field soils from Xinjiang, China. *PeerJ 10*. e12928.

Elangovan, R. (2014). Effect of biochar on soil properties, yield and quality of cotton-maize-cowpea cropping sequence (Doctoral dissertation). Department of Soil Science and Agricultural Chemistry Agricultural College. Department of Soil Science and Agricultural Chemistry, Agricultural College and Research Institute, Tamil Nadu Agricultural University Coimbatore-641-003.

Elangovan, R., Sekaran, N.C. (2014). Effect of biochar application on soil properties and quality parameters in cotton. *Asian Journal of Soil Science* 9(1): 1-10.

Fang, Y., Singh, B., Singh, B., Krull, E. (2014). Biochar carbon stability in four contrasting soils. *European Journal of Soil Science* 65(1):60-71.

Feng, L., Xu, W., Tang, G., Gu, M., Geng, Z. (2021). Biochar induced improvement in root system architecture enhances nutrient assimilation by cotton plant seedlings. *BMC plant biology* 21(1): 1-14.

Gaskin, J.W., Steiner, C., Harris, K., Das, K., Bibens, B. (2008). Effect of low-temperature pyrolysis conditions on biochar for agricultural use. *Transactions of the ASABE* 51(6):2061-2069.

Han, G., Lan, J., Chen, Q., Yu, C., Bie, S. (2017). Response of soil microbial community to application of biochar in cotton soils with different continuous cropping years. *Scientific reports* 7(1):1-11.

He, X., Geng, Z., She, D., Zhang, B., Gao, H. (2011). Implications of production and agricultural utilization of biochar and its international dynamic. *Transactions of the Chinese Society of Agricultural Engineering* 27(2):1-7.

He, Y., Yao, Y., Ji, Y., Deng, J., Zhou, G., Liu, R., Shao, J., Zhou, L., Li, Na., Zhou, X., Bai, S.H. (2020). Biochar amendment boosts photosynthesis and biomass in C3 but not C4 plants: A global synthesis. *GCB Bioenergy* 12(8): 605-617.

Hui, D. (2021). Effects of biochar application on soil properties, plant biomass production, and soil greenhouse gas emissions: a mini-review. *Agricultural Sciences* 12:(03).

Jabborova, D., Annapurna, K., Paul, S., Kumar, S., Saad, H. A., Desouky, S., Mohamed Ibrahim, M.F., El kelish, A. (2021). Beneficial features of biochar and arbuscular mycorrhiza for improving spinach plant growth, root morphological traits, physiological properties, and soil enzymatic activities. *Journal of Fungi 7*(7): 571.

Jha, P., Biswas, A., Lakaria, B., Rao, A.S. (2010). Biochar in agriculture–prospects and related implications. *Current Science* 99(9):1218-1225.

Kalyani, K. (2016). Residual and Cumulative effect of Organics and Inorganic P on Soybean (*Glycine max* L.)-Onion (*Allium cepa* L.) Production System in a High P Alfisol. *International Journal of Agriculture Sciences* 8(62):3515-3518.

Kamran, M., Malik, Z., Parveen, A., Huang, L., Riaz, M., Bashir, S., Mustafa, A., Abbasi, G.H., Xue, B., Ali, U. (2020). Ameliorative effects of biochar on rapeseed (*Brassica napus* L.) growth and heavy metal immobilization in soil irrigated with untreated wastewater. *Journal of Plant Growth Regulation* 39(1): 266-281.

Karhu, K., Mattila, T., Bergström, I., Regina, K. (2011) Biochar application to agricultural soil increased CH_4 uptake and water holding capacity- results from a short-term pilot field study. *Agric. Ecosyst. Environ* 140: 309-313.

Karthik, A., Duraisamy, V.K., Prakash, A.H. (2019). Influence of different sources of biochar on soil physical and chemical properties in cotton (*Gossypium hirsutum* L.). *Journal of Pharmacognosy and Phytochemistry* 8:2051-2055.

Karthik, A., Hussainy, S.A.H., Rajasekar, M. (2020). Effect of biochar on the growth and yield of cotton and maize: a review. *International Journal of Chemical Studies* 8(3): 572-578.

Kong, F., Ling, X., Iqbal, B., Zhou, Z., Meng, Y. (2021). Soil phosphorus availability and cotton growth affected by biochar addition under two phosphorus fertilizer levels. *Archives of Agronomy and Soil Science*, 1-14.

Laghari, M., Hu, Z., Mirjat, M.S., Xiao, B., Tagar, A.A., Hu, M. (2016). Fast pyrolysis biochar from sawdust improves the quality of desert soils and enhances plant growth. *Journal of the Science of Food and Agriculture* 96(1):199-206.

Li, Z., Delvaux, B., Yans, J., Dufour, N., Houben, D., Cornelis, J.T. (2018). Phytolith-rich biochar increases cotton biomass and silicon-mineralomass in a highly weathered soil. *Journal of Plant Nutrition and Soil Science* 181(4): 537-546.

Mowrer, J., Dembele, G., Strzelec, A., Thapa, B. (2021). Amending Soil With Biochar From Available Agricultural Wastes to Improve Sustainability of Cotton Production in Mali. 1-19. https://doi.org/10.21203/rs.3.rs-945517/v1

Nigussie, A., Kissi, E., Misganaw, M., Ambaw, G. (2012). Effect of biochar application on soil properties and nutrient uptake of lettuces (*Lactuca sativa*) grown in chromium polluted soils. *American-Eurasian Journal of Agriculture and Environmental Science* 12 (3):369-376.

Pandian, K., Subramaniayan, P., Gnasekaran, P., Chitraputhirapillai, S. (2016). Effect of biochar amendment on soil physical, chemical and biological properties and groundnut yield in rainfed Alfisol of semi-arid tropics. *Archives of Agronomy and Soil Science*. 62(9):1293-1310.

Peng, F., He, P.W., Luo, Y., Lu, X., Liang, Y., Fu, J. (2012). Adsorption of phosphate by biomass char deriving from fast pyrolysis of biomass waste. *Clean- Soil, Air and Water* 40(5):493-498

Qian, L., Zhang, W., Yan, J., Han, L., Chen, Y., Ouyang, D., Chen, M. (2017). Nanoscale zero-valent iron supported by biochars produced at different temperatures: Synthesis mechanism and effect on Cr (VI) removal. *Environmental Pollution* 223:153-160.

Rajalakshmi, A., Kumar, S.K., Bharathi, C.D., Karthika, R., Divya Visalakshi, K., Meera, R. (2015). Effect of Biochar in Seed Germination-*in-vitro* Study. *International Journal of Biosciences and Nanosciences* 2:132-136.

Shen, Z., Tian, D., Zhang, X., Tang, L., Su, M., Zhang, L. Li, Z., Hu, S., Hou, D. (2018). Mechanisms of biochar assisted immobilization of Pb^{2+} by bioapatite in aqueous solution. *Chemosphere* 190:260-266.

Silber, A., Levkovitch, I., Graber, E. (2010). pH-dependent mineral release and surface properties of corn straw biochar: agronomic implications. Environ. Sci. Technol 44: 9318-9323. https://doi.org/10.1021/ es101283d PMID: 21090742

Singh, B.P., Cowie, A.L., Smernik, R.J. (2012). Biochar carbon stability in a clayey soil as a function of feedstock and pyrolysis temperature. *Environmental science & technology* 46 (21):11770-11778.

Sorensen, R.B., Lamb, M.C. (2016). Crop yield response to increasing biochar rates. *Journal of Crop Improvement* 30(6): 703-712.

Suppadit, T., Phumkokrak, N., Poungsuk, P. (2012). The effect of using quail litter biochar on soybean (*Glycine max* [L.] Merr.) production. *Chilean Journal of Agricultural Research* 72(2):244.

Tian, X., Li, C., Zhang, M., Wan, Y., Xie, Z., Chen, B., Li, W. (2018). Biochar derived from corn straw affected availability and distribution of soil nutrients and cotton yield. *PloS One* 13(1): e0189924

Uzoma, K., Inoue, M., Andry, H., Fujimaki, H., Zahoor, A., Nishihara, E. (2011). Effect of cow manure biochar on maize productivity under sandy soil condition. Soil use and management. 27(2):205-212

Wu, X., Wang, D., Riaz, M., Zhang, L., Jiang, C. (2019). Investigating the effect of biochar on the potential of increasing cotton yield, potassium efficiency and soil environment. *Ecotoxicology and environmental safety* 182: 109451.

Xu, C.Y., Hosseini-Bai, S., Hao, Y., Rachaputi, R.C., Wang, H., Xu, Z., Wallace, H. (2015). Effect of biochar amendment on yield and photosynthesis of peanut on two types of soils. *Environmental Science and Pollution Research* 22: 6112-6125.

Xu, P., Sun, C.X., Ye, X.Z., Xiao, W.D., Zhang, Q., Wang, Q. (2016). The effect of biochar and crop straws on heavy metal bioavailability and plant accumulation in a Cd and Pb polluted soil. *Ecotoxicology and environmental safety* 132:94-100.

Younis, U., Athar, M., Malik, S.A., Bokhari, T.Z., Shah, M. (2015). Biochemical characterization of cotton stalks biochar suggests its role in soil as amendment and decontamination. *Advances in environmental research* 6(2): 127-137.

Zeng, Z., Ye, S., Wu, H., Xiao, R., Zeng, G., Liang, J., Zhang, C., Yu, J., Fang, Y., Song, B. (2019). Research on the sustainable efficacy of g-MoS2 decorated biochar nanocomposites for removing tetracycline hydrochloride from antibiotic-polluted aqueous solution. *Science of the Total Environment* 648:206-217.

Zhu, Y., Wang, H., Lv, X., Zhang, Y., & Wang, W. (2020). Effects of biochar and biofertilizer on cadmium-contaminated cotton growth and the antioxidative defense system. *Scientific Reports* 10(1):1-12.

CHAPTER 3

OILSEED PRODUCTION AND FOREIGN TRADE IN TURKIYE AND THE WORLD

Dr. Özlem YILDIZ[1]

[1] Ege University Faculty of Agriculture Department of Agricultural Economics, C Blok 35100 Bornova, Izmir, Türkiye. ORCID NO:0000-0002-5581-0102, e-mail: ozlem.yildiz@ege.edu.tr

1. INTRODUCTION

Fats are one of the three basic nutrients, necessary for people to have an adequate and healthy diet, within the framework of ending hunger which is one of the United Nations Sustainable Development Goals. Most of the fats used in human nutrition are obtained from vegetable oils. And indeed, more than 90% of the world's crude oil production comes from vegetable sources (Kıllı ve Beycioğlu, 2019).

Oilseed plants have multiple uses. Oilseeds, which have an important place in nutrition due to the oil, protein, carbohydrate, mineral substances, and vitamins they contain, are also an important raw material source in bio-diesel production and industry. The meal, which remains after the oil content is removed in oilseeds, has very high values in terms of crude protein ratio, and is used in animal nutrition. In addition, since oilseed crops such as soybean and groundnuts belong to the legume family, they contribute to the increase and sustainability of soil fertility by fixing the free nitrogen on the air to the soil (Arıoğlu, 2016; Arıoğlu ve ark. 2010; Karakuş 2014).

For these reasons, the production and foreign trade of oilseeds, just like the production and trade of agricultural products, has become a sector of increasing strategic importance in the world. In addition, the oilseed market has its own characteristics, such as interchangeability of products, complex composition, and dependence on other agricultural and food products.

There are more than 25 oilseeds and fats subject to the world oilseeds foreign trade. Seven basic types of them (soybeans, rapeseed, cotton, sunflower, sunflower, peanut, palm oil and copra) account for a significant share of world market production (Vinnichek et al., 2019).

2. OILSEED PRODUCTION IN THE WORLD

World oilseed cultivation areas have increased in the last decade. Oilseed cultivation areas, which were 283,637,000 hectares in 2011, reached almost 332 million hectares in 2020 with an increase of 17%. Soybean is the oilseed crop with the largest cultivation area, almost 127 million hectares. Soybean is followed by rapeseed with nearly 35.5 million hectares and cottonseed with 31.8 million hectares, respectively. These three crops constitute 58.5% of the world's oilseed cultivation areas. In recent years, there has been a decline in the cottonseed cultivation areas (Table 1).

Table 1: World Oilseed Harvested Area (1000 ha)

	Cottonseed	Oil palm fruit	Sunflower seed	Rape or colza seed	Soybean	Safflower seed	World
2011	34,491	20,384	25,655	33,770	103,860	804	283,637
2012	34,692	21,257	24,844	34,718	105,461	969	288,166
2013	32,220	22,177	25,352	36,564	111,109	897	297,213
2014	34,613	21,978	24,350	36,460	117,733	893	306,490
2015	31,623	22,739	24,528	34,490	120,902	1,054	304,359
2016	30,156	23,476	26,343	32,868	122,036	1,170	307,539
2017	34,666	27,067	26,850	35,762	125,863	861	322,817
2018	32,742	27,736	26,809	37,002	124,052	654	324,658
2019	36,717	28,402	27,332	34,290	121,533	648	324,960
2020	31,840	28,736	27,874	35,497	126,952	817	331,911

Source: FAOSTAT, 2022.

It is obvious that total production has been on an increasing trend over the years in world oilseed production. Although there has been 17% increase in oilseed cultivation areas, the increase in production has been 29.4% in the last decade. According to 2020 data, palm (36.8%) ranks the first in world oilseed production, soybean (31.1%) the second, and cottonseed (7.3%) the third. These three crops account for 75.3% of world oilseed production. Total oilseed production reached from 877 million tons in 2011, to more than 1.1 trillion tons in the last production period (Table 2). Palm production, which is the most produced oilseed in the world, reached almost 418.5 million tons. Soybean production more than 353 million tons, cottonseed production 83 million tons, rape seed nearly 72 million tons, sunflower seed 56 million tons, safflower seed 586 thousand tons.

Table 2: World Oilseed Production (1000 tons)

	Cottonseed	Oil palm fruit	Sunflower seed	Rape or colza seed	Soybeans	Safflower seed	World total
2011	79,537	296,436	40,143	62,769	261,602	678	877,678
2012	79,147	308,999	36,315	62,651	241,337	844	866,867
2013	72,851	325,518	43,459	73,170	277,673	722	939,461
2014	76,222	327,324	40,613	74,509	306,301	731	964,976
2015	66,033	335,876	42,300	70,278	323,308	825	980,451
2016	67,478	333,892	47,477	68,242	335,945	948	995,137
2017	73,842	406,687	48,609	76,574	359,511	735	1,109,122
2018	72,049	409,265	51,914	75,184	344,732	608	1,110,269
2019	83,859	415,898	56,021	71,839	336,329	586	1,115,390
2020	83,113	418,439	50,230	72,376	353,464	653	1,135,622

Source: FAOSTAT, 2022.

3. OILSEED PRODUCTION IN TÜRKIYE

Türkiye has the necessary potential conditions for oilseed production due to its geographical structure, climate, and cultivation areas (Altıntop ve Gıdık, 2019; Kadakoğlu ve Karlı, 2019). Soybean, groundnut, sunflower, sesame, safflower, rapeseed, cottonseed, and poppy are among the oilseeds produced in Türkiye. In addition, a small amount of linseed and hemp seed have been produced in recent years. Palm and coconut are not produced in Türkiye. In addition, cottonseed is not produced as oilseed, it is obtained as a by-product in cotton production (Küçük ve ark., 2020; Kıllı ve Beycioğlu, 2019; Altıntop ve Gıdık, 2019).

Cultivation areas of oilseed has reached 10,806,728 hectares with an increase of 39.5% from 7,742,481 hectares in 2011 in Türkiye, although it has fluctuated over the years on the product base.

Sunflower, which comes after important oil crops such as soybean, rapeseed, cottonseed, safflower, groundnut, and sesame, is the oilseed plant with the largest cultivation area in Türkiye. In the last production period, more than 9 million hectares of sunflowers were planted. The second oilseed, with the largest cultivation area, is the cottonseed (4,322,790). It is followed by groundnut (579,192), soybean (438,917), rapeseed (376,017), sesame (2,548,62) and safflower (145,882) (Table 3, Figure 1).

Groundnut, soybean, rapeseed, sunflower and safflower acreages have increased significantly in the last years. However, there have been some decreases in sesame and cottonseed cultivation areas.

Table 3: Türkiye Oilseed Harvested Area (ha)

	Cottonseed*	Sunflower Seed	Rape or Colza Seed	Soybean	Safflower Seed	Groundnut	Sesame	TOTAL
2011	5,420,000	6,557,000	268,298	264,209	131,668	254,711	266,455	7,742,481
2012	4,884,963	6,046,160	295,421	315,990	155,918	373,881	292,063	7,479,677
2013	4,508,900	6,097,839	311,272	432,600	292,920	359,428	248,070	7,742,136
2014	4,681,429	6,574,576	321,330	343,178	443,050	333,289	263,496	8,278,929
2015	4,340,134	6,853,174	350,817	367,323	431,071	377,729	280,887	8,661,011
2016	4,160,098	7,201,081	354,530	381,804	395,710	422,444	289,332	9,044,926
2017	5,018,534	7,796,217	165,195	316,695	273,762	419,495	280,316	9,251,704
2018	5,186,342	7,344,651	378,456	328,483	246,932	443,342	259,858	9,001,781
2019	4,778,681	7,526,318	525,146	352,947	158,601	424,211	248,604	9,236,363
2020	3,592,200	7,288,528	349,891	351,343	151,150	547,747	256,663	8,949,574
2021	4,322,790	9,011,531	376,017	438,917	145,882	579,192	254,862	10,806,728

*Area sown is the same with cotton (raw) and not included in the total oilseed cultivated area.

Source: TÜİK, 2022a.

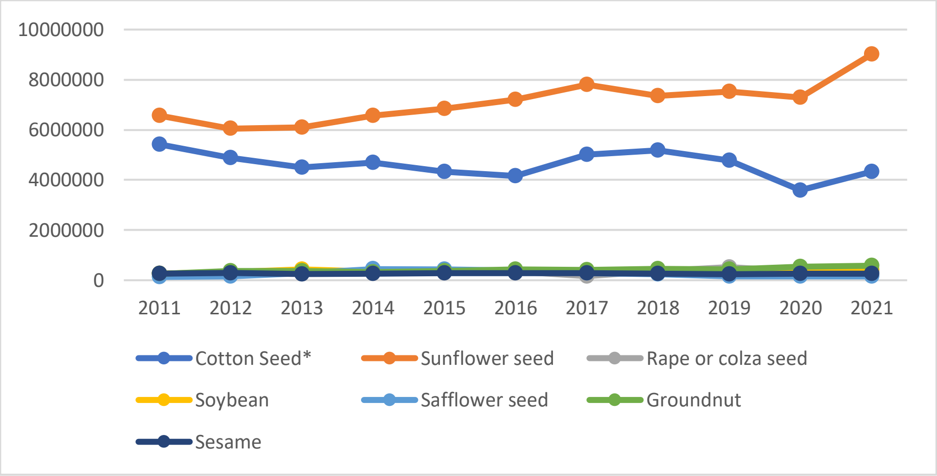


Figure 1: Türkiye Oilseed Harvested Area

Oilseed production in Türkiye has increased by 35.5% in the last years and reached four million three hundred thousand tons. When evaluated on a product base, production amounts show fluctuations due to changes in cultivation areas over the years. While the production amounts of sunflower, rapeseed, soybean, and peanut increased in the last decade, the production amount of sesame remained almost the same, while the production amounts of cottonseed and safflower decreased by approximately 11% (Table 4, Figure 2).

Table 4: Türkiye Oilseed Production (tons)

	Cottonseed*	Sunflower seed	Rape or colza seed	Soybean	Safflower seed	Groundnut	Sesame	TOTAL
2011	1,527,360	1,170,000	91,239	102,260	18,228	90,416	18,000	3,227,588
2012	1,373,440	1,200,000	110,000	122,114	19,945	122,780	16,221	3,138,361
2013	1,287,000	1,380,000	102,000	180,000	45,000	128,265	15,457	3,299,967
2014	1,391,200	1,480,000	110,000	150,000	62,000	123,600	17,716	3,508,640
2015	1,213,600	1,500,000	120,000	161,000	70,000	147,537	18,530	3,442,098
2016	1,260,000	1,500,000	125,000	165,000	58,000	164,186	19,521	3,480,629
2017	1,470,000	1,800,000	60,000	140,000	50,000	165,330	18,410	3,883,370
2018	1,542,000	1,800,000	125,000	140,000	35,000	173,835	17,437	4,009,495
2019	1,320,000	1,950,000	180,000	150,000	21,883	169,328	16,893	3,985,412
2020	1,064,189	1,900,000	121,542	155,225	21,325	215,927	18,648	3,684,675
2021	1,350,000	2,215,000	140,000	182,000	16,200	234,167	17,657	4,376,082

Source: TÜİK, 2022a.

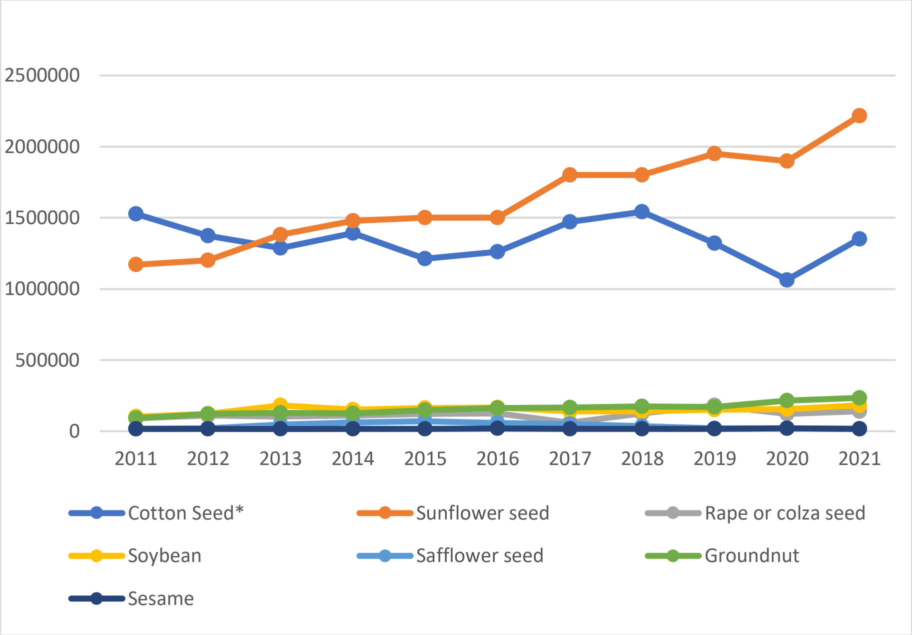


Figure 2: Türkiye Oilseed Production (tons)

4. WORLD OILSEEDS FOREIGN TRADE

Foreign trade in oilseeds and its strategic importance in trade of agricultural products has been increasing over the years. In the last production period (2021), the export value of oilseeds is 130,566,931,000 dollars. The largest exporting country is Brazil with a 30% share in world oilseed exports. Brazil is followed by the USA (25.3%), Canada (6.6%), the Netherlands (3.7%), Argentina (2.8%), Paraguay (2.4%), Australia (2.4%), China (2.3%), France (2.1%) and Ukraine (1.6%). These ten countries account for 79.2% of the world oilseed export value (Figure 3, Figure 4). Brazil, the largest oilseed exporter, mostly exports soybeans (ITC, 2022).

The country with the largest export value increase in the last five years is the Russian Federation. Spain, Argentina, Australia, the USA; the Netherlands, Brazil, Paraguay, and France followed, respectively. The export value of Ukrainian oilseeds has not increased in the last five years (Figure 3). Linseed is the most exported oilseed by the Russian Federation. Argentina also ranks first in groundnut exports (ITC, 2022).

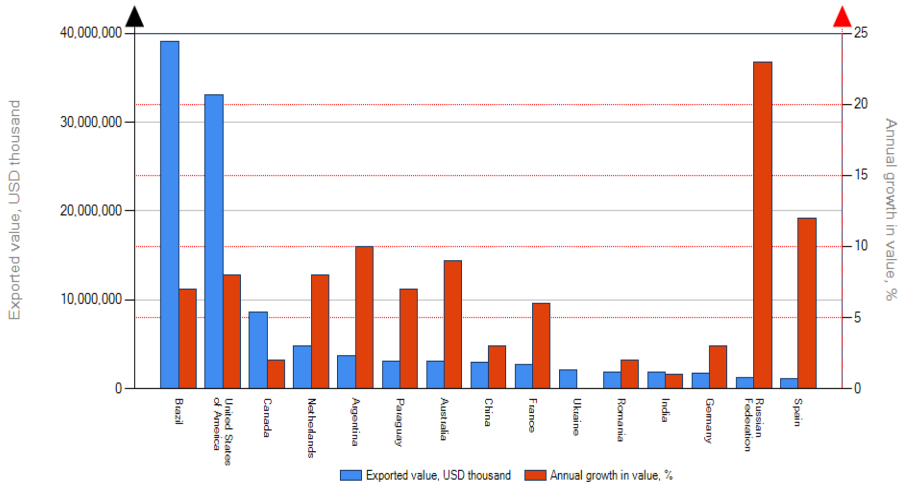


Figure 3: Exporters of Oilseeds in 2021 and Annual Growth Value between 2017-2021 (%)
Source: ITC, 2022.

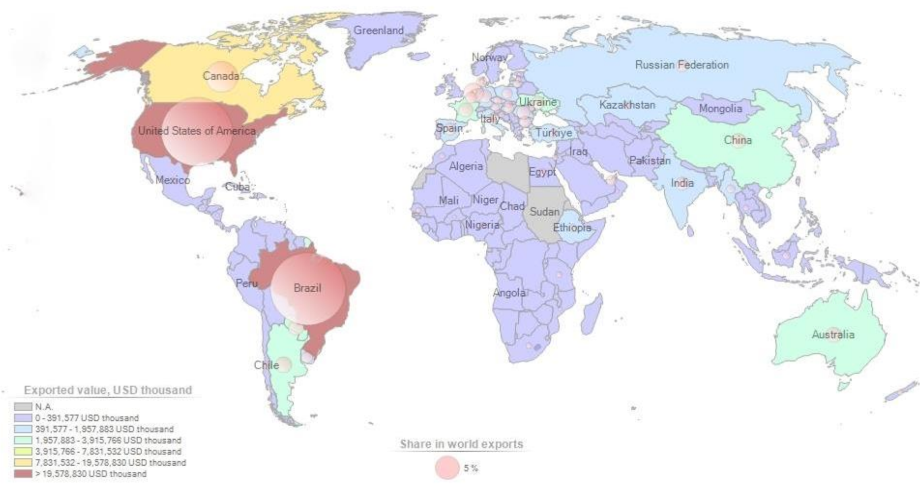


Figure 4: World Oilseed Exporters (2021)
Source: ITC, 2022

The world oilseeds import value is 146,176,109,000 dollars according to 2021 data. China is by far the largest importer, ranking first with a 41.2% share in total oilseeds import value. Germany ranked second with a 5% share. They were followed by the Netherlands, Japan, Mexico, Spain, the USA, Argentina, Türkiye, France, Belgium, Thailand, Egypt, Italy, and the Russian Federation (Figure 5). Soybeans are the most imported product of China.

According to the last five-year averages, the country with the highest increase in oilseed imports was Argentina (25%). Argentina was followed by Egypt (17%), Thailand (15%), Italy (13%), Mexico (10%), Türkiye (9%), France (9%), the Netherlands (8%), Spain (7%) and China (7%). Germany, Belgium, the Russian Federation, Japan, and the United States have lower import growth than other countries (Figure 5). Argentina, Egypt and Thailand, whose imports have increased the most in the last five years, import soybeans intensively (ITC, 2022).

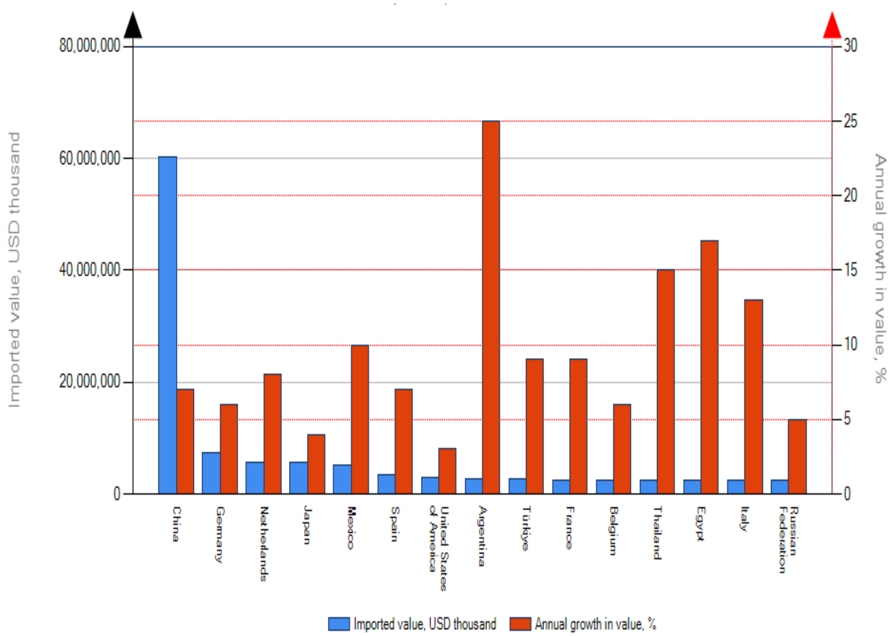


Figure 5: Importers of Oilseeds in 2021 and Annual Growth Value of Import between 2017-2021 (%)
Source: ITC, 2022

According to FAO estimates, vegetable oil consumption will reach 249 million tons and oilseeds 137 million tons (55% of the vegetable oil) by 2031. Food use is expected to account for 66% of total consumption due to population growth as well as increasing per capita vegetable oil use in low- and middle-income countries (OECD, FAO, 2022)

5. TÜRKIYE OILSEEDS FOREIGN TRADE

According to 2021 data, Türkiye ranked 25th in the world oilseed exports worth nearly 131 trillion dollars, with an export value of 579,105,000 dollars. The USA is the leading country where oilseeds are exported. The USA accounts for 13.5% of total oilseed exports. The USA was followed by Romania with 7.8%, Germany with 7.6%, Russian Federation with 6.3% and Iraq with 6%. Syrian Arab Republic (4.7%), Ukraine (4.1%), Italy (3.8%), Azerbaijan (3.6%) and Greece (3.5%) were among the top ten oilseed exporting countries. According to the export value averages for the last five years, the value of products exported to Greece (79%), Syrian Arab Republic (66%) and Iraq (40%) showed significant increases (Figure 6, Figure 7).

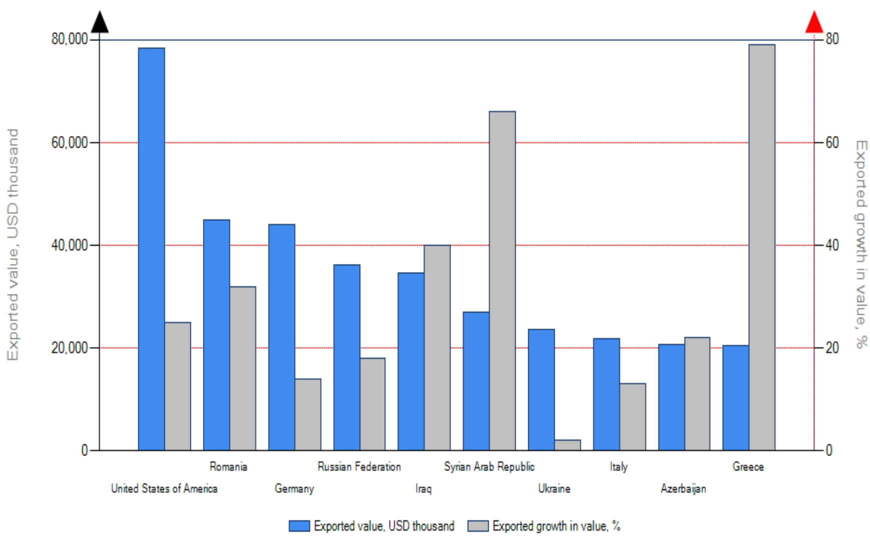


Figure 6: Türkiye's Exporters of Oilseeds in 2021 and Annual Growth Value between 2017-2021 (%)
Source: ITC, 2022

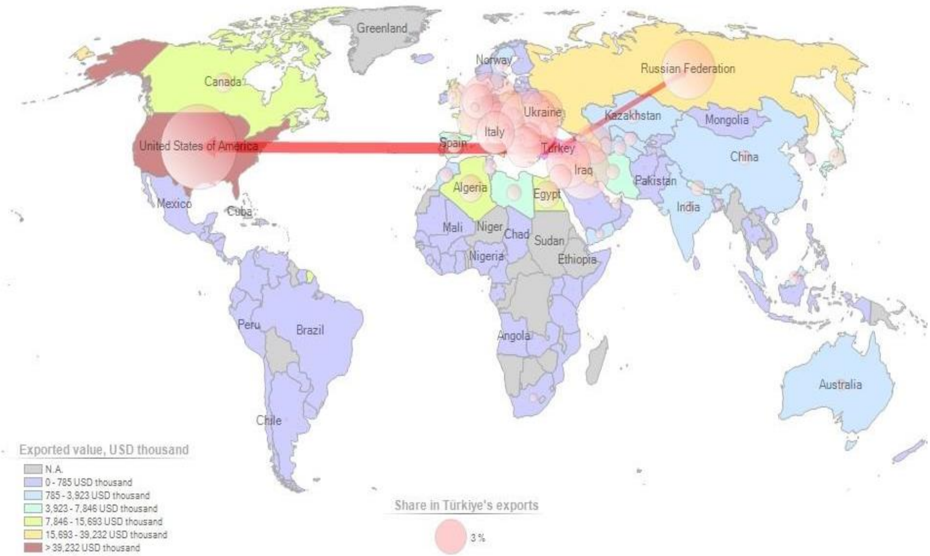


Figure 7: Türkiye's Oilseeds Exporters in 2021
Source: ITC, 2022

As in the rest of the world, the demand for vegetable oil is increasing in Türkiye with increasing population and income. Although Türkiye's oilseed production areas and production quantities have increased significantly in the last decade (Table 3, Table 4), there still are supply deficits. This oilseeds supply deficit is compensated by imports (Küçük ve ark., 2021; Arıoğlu, 2016). As a matter of fact, Türkiye ranked 9th in the world oilseed imports with a value of 2,599,002,000 dollars.

In order to reduce the supply deficit and meet the increasing domestic demand, different support policies have been implemented from past to present to increase oilseed production in Türkiye. The support policies for oilseed crops have been implemented in the form of premium payments, support purchases, input support (fertilizer and diesel fuel), direct income support, certified seed use support and alternative crop support, although they vary from time to time (Kadakoğlu ve Yılmaz, 2022; Onurlubaş ve Kızılaslan, 2007).

Considering that Türkiye's self-sufficiency rate in sunflower production is 62.5%, 5.4% in soybean, 111.2% in rapeseed and 103.7% in cottonseed (TÜİK, 2022), it is inevitable that the resulting deficit will be met through imports. Due to low self-sufficiency especially in soybean and sunflower, imports are concentrated in these products. According to 2021 data, the import value of these two products accounts for 77.2% of total oilseeds imports.

Brazil is Türkiye's largest exporter of oilseeds. Of total oilseed imports, 41.6% is from Brazil, 8.7% from Ukraine, 5.6% from USA, 5.1% from Bulgaria, 4.7% from Moldova, 4.2% from Chad, 4.7% from Romania, 3.2% from China, 2.2% from Russian Federation, 2.2% from Sudan. Türkiye imports soybeans mostly from Brazil, Ukraine, and USA. Soybeans account for 73% of the oilseeds imported from Brazil.

According to the average of the last five years, oilseed imports from Brazil increased by 58%, from Chad by 51%, from China by 19%, from Bulgaria by 17%, from Romania by 16% and from Sudan by 8%. In the last five years, oilseed imports with the USA decreased by 22%, with Ukraine by 6%, with Moldova by 4% and with the Russian Federation by 2% (Figure 8, Figure 9).

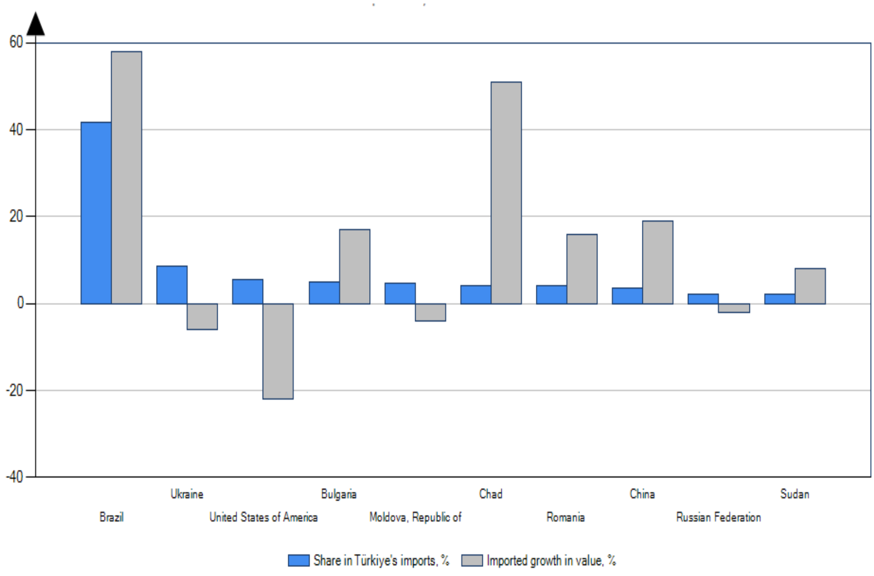


Figure 8: Türkiye's Importers of Oilseeds (2021) and Annual Growth Value of Import between 2017-2021 (%)

Source: ITC, 2022

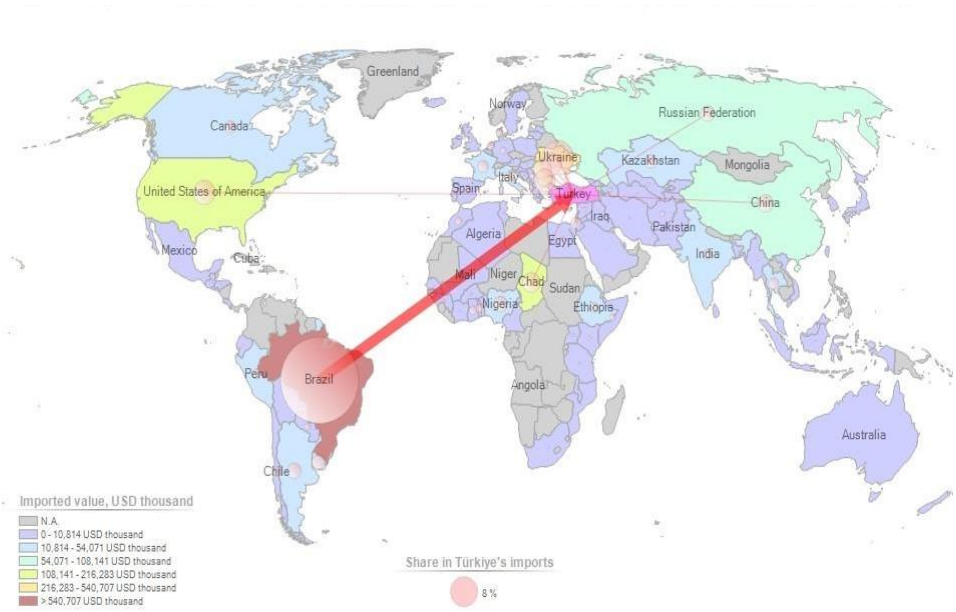


Figure 9: Türkiye’s Oilseeds Importers in 2021

Source: ITC, 2022

In the last production period, the country with the largest deficit in Türkiye’s oilseeds foreign trade balance was Ukraine. It is followed by the USA, Romania, and the Russian Federation. The countries with positive foreign trade balance are Germany, Iraq, Syria, Azerbaijan, Greece, and Italy (Figure 10).

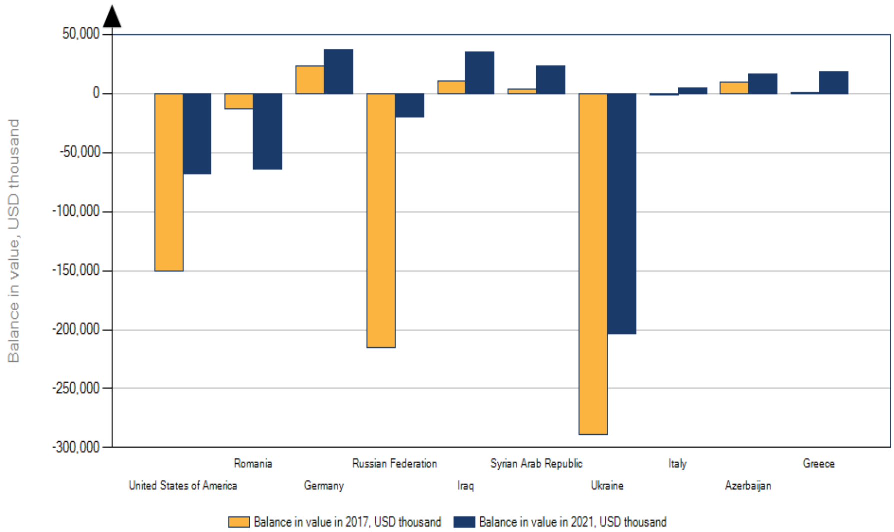


Figure 10: Türkiye Oilseeds Trade Balance
Source: ITC, 2022

Sunflower, Türkiye's most exported oilseed, has a 226,586,000 dollars export value. According to 2021 data, the top export destinations of sunflowers are Romania, the Russian Federation, Ukraine, Germany, and Austria. These five countries represent 55.2% of total sunflower exports (ITC, 2022) (Figure 11).

The import value of soybeans, the most imported oilseed in Türkiye, is 1,464,087,000 dollars. The top soybean importing countries are Brazil, Ukraine, USA, Uruguay, and Canada. These five countries account for 90.1% of total soybean imports (ITC, 2022) (Figure 12).

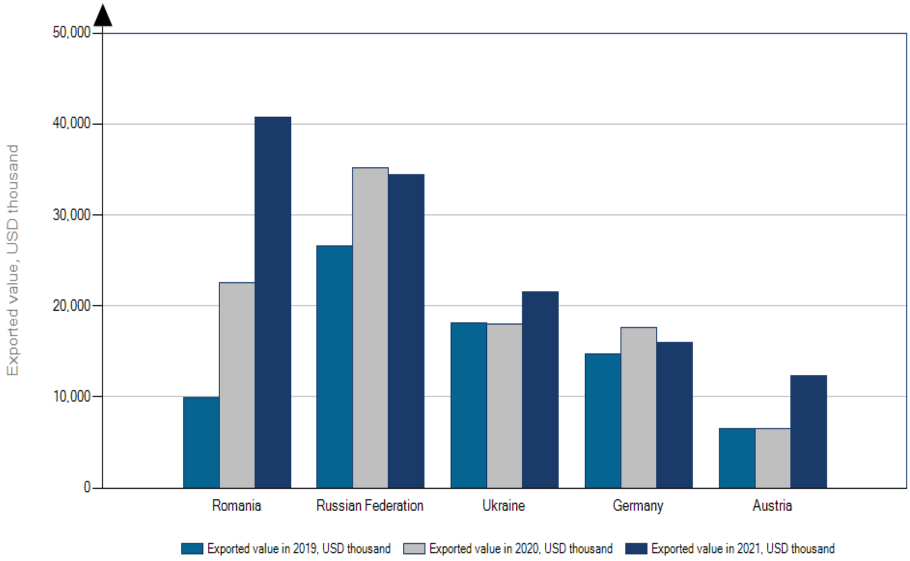


Figure 11: Sunflower Seed Export Markets of Türkiye

Source: ITC, 2022

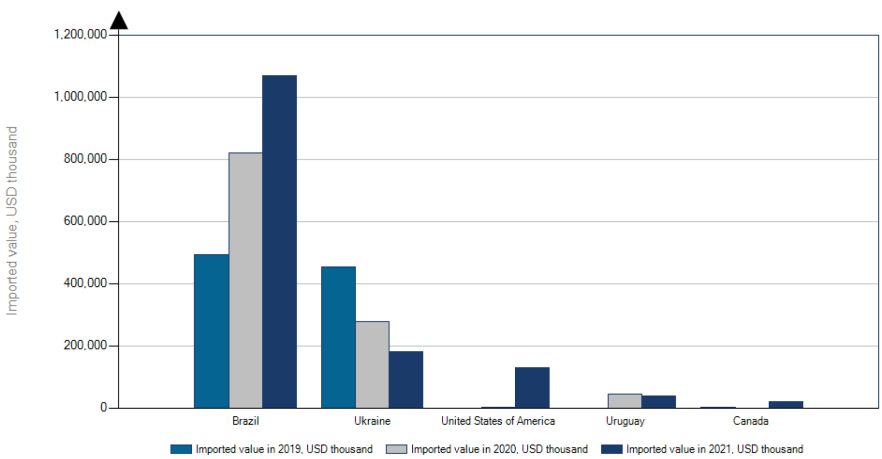


Figure 12: Soybeans Import Markets of Türkiye

Source: ITC, 2022

6. CONCLUSION

Oilseed foreign trade is one of the important trade items in the world, same as other agricultural products trade and its importance is increasing over the years. World oilseed cultivation areas have increased by 17% in the last ten years, and the amount of production has increased by 29.4%. Improvements in production technologies and the use of more productive varieties have led to these production increases. World oilseed export value is nearly 131 billion dollars and import value is 147 billion dollars. According to FAO projections, world oilseed production is expected to increase.

In recent years, Türkiye's oilseed acreage has increased by 39.5% and production by 11%. Türkiye's oilseed export value is 579 million dollars and import value is 2.5 billion dollars. Oilseeds foreign trade balance showed a deficit of 2 billion dollars in the last production period. Sunflower exports constitute a significant share of Türkiye's total oilseed exports, while soybean is the most imported oilseed. Even though Türkiye has agricultural areas suitable for oilseed production, a significant amount of oilseeds are imported every year because the amount of oil needed cannot be met. Although exporting oilseeds, Türkiye is one of the major importer countries of oilseeds. Even though various supports were provided to increase the production of oilseed crops, the desired development could not be seen.

As a result, it is expected that the world oilseeds trade will remain important in the near future, while Türkiye will continue to be a net importer of oilseeds.

REFERENCES

Altıntop, M., ve Gıdık, B. (2019). Türkiye'de ayçiçeği, soya, kolza ve aspir üretimindeki gelişmeler. *Bayburt Üniversitesi Fen Bilimleri Dergisi*, 2(2), 307-315.

Arıoğlu, H., (2016). Türkiye'de yağlı tohum ve ham yağ üretimi, sorunlar ve çözüm önerileri. *Ç.Ü. Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi*, 25 (Özel Sayı-2), 357-368. https://dergipark.org.tr/en/pub/tarbitderg/issue/26737/284325.

Arıoğlu H. H., Kolsarıcı, Ö., Göksu, A. T., Güllüoğlu, L., Arslan, M., Çalışkan, M., Söğüt, T., Kurt, C., Arslanoğlu, F., (2010). Yağ Bitkileri Üretiminin Artırılması Olanakları. *Ziraat Mühendisliği VII. Teknik Kongresi Bildiriler Kitabı-1,* s. 361-376, Ankara.

FAOSTAT, (2022). Crops and Livestock Products, https://www.fao.org/faostat/en/#data/QCL, Accessed:04.11.2022

ITC, (2022). Trade Map Trade statistics for international business development, https://www.intracen.org/, Accessed: 04.11.2022.

Kadakoğlu, B. ve Karlı, B. (2019). Türkiye'de yağlı tohum üretimi ve dış ticareti. *Akademik Sosyal Araştırmalar Dergisi*, 7(96), 324-341.

Kadakoğlu, B. ve Yılmaz, H. (2022). Türkiye'de Uygulanan Tarımsal Destekleme Politikalarının Ayçiçeği Üretimine Etkisinin Analizi. *Tarım Ekonomisi Dergisi*, 28(1), 89-98.

Karakuş, M.Ü., (2014). 12. Uluslararası Yem Kongresi Açılış Konuşması. *Türkiye Yem Sanayicileri Birliği Dergisi*. Sayı.70:29-40s, Ankara.

Kıllı, F. ve Beycioğlu, T. (2019). Türkiye'de ve Dünyada Yağlı Tohum ve Ham Yağ Üretim Durumu Türkiye Yağlı Tohum Üretimine İlişkin Önemli Sorunlar. *Uluslararası Anadolu Ziraat Mühendisliği Bilimleri Dergisi*, 1(5), 17-33.

Küçük, N., Aydoğdu, M. H., Şahin, Z. (2021). Yağlı Tohum Piyasalarındaki Gelişmeler ve Türkiye Kolza Piyasası Trend Analizi. *Fırat Üniversitesi Sosyal Bilimler Dergisi*, 32(1), 215-227.

OECD, FAO. (2022). OECD-FAO Agricultural Outlook 2022-2031. https://www.fao.org/3/cc0308en/cc0308en.pdf, Acessed:10.11.2022.

Onurlubaş, H.E. ve Kızılaslan, H. (2007). Türkiye'de Bitkisel Yağ Sanayindeki Gelişmeler ve Geleceğe Yönelik Beklentiler. Tarımsal Ekonomi Araştırma Enstitüsü Yayınları Yayın No:157, 59 s.

TÜİK, (2022). Bitkisel Ürün Denge Tabloları 2020. https://biruni.tuik.gov.tr/medas/?kn=104&locale=tr, Accessed: 08.11.2022.

TÜİK, (2022a). Tahıllar ve Diğer Bitkisel Ürünler, Yağlı Tohumlar 1988-2021, https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111&dil=1 , Erişim: 22.10.2022

Vinnichek, L., Pogorelova, E., Dergunov, A. (2019). Oilseed market: Global trends. In *IOP conference series: Earth and environmental science*, Vol. 274, No. 1, p. 012-030. IOP Publishing.

CHAPTER 4

THE EFFECTS OF NITROGEN DOSES ON YIELD AND YIELD COMPONENTS OF LINSEED (*Linum usitatissimum* L.) IN SEMI-ARID ECOLOGICAL CONDITIONS.

Assoc. Prof. Dr. Ismail DEMIR[1]

[1] Kırşehir Ahi Evran University Faculty of Agriculture, Department of Field Crops, Kırşehir, Turkey. Orcid ID:0000-0002-8950-5253
E-mail:ismail.demir@ahievran.edu.tr

1. INTRODUCTION

It is an important cultivated plant from the Linaceae family, which benefits from both its fiber and oil. Linum usitatissimum is the only cultivated species of about 200 flax species distributed in the world. There are two main types of this species: oil flax (linseed) and fiber flax (flax). Among these two groups, there are alternative flax varieties suitable for both seed and fiber production (Baydar and Erbaş 2014). Flaxseed (*Linum usitatissimum* L.) is an important fiber and oilseed crop and is mainly grown for its oil, which is used for both edible and industrial purposes (Meenakshi et al. 2017). Fiber flax is mainly grown in parts of Northern Europe, Russia, and China, while oilseed flax is widely grown in the cool temperate regions of Argentina, India, China, Russia, the United States, and Canada. However, since flax is harvested mostly for oil, it is an economically important oilseed crop (Oomah 2001). Although the production of flax seeds decreased compared to 1990, the cultivation area decreased to 1.98 million hectares and production to 1.65 million tons in 2007. With the increase again, flaxseed has reached 3.4 million tons of production in 2020 with a yield of approximately 950 kg/ha on 3.5 million hectares of land in the world. The most important producer in the world is Kazakhstan, which produces approximately 31.4% of the world's flaxseed with a production of 1.0 million tons. Russia supplies 27.4% of world flaxseed production with 788 thousand tons and Canada supplies 10.5% with 578 thousand tons (FAO, 2022).

The industrial quality of flax can be attributed to the oil concentration of its seeds, which can vary between 30% and 48%. It also contains high levels of dietary fiber and protein. Flaxseed oil has a very healthy fatty acid profile with low levels of saturated (9%), moderate levels (18%) of monounsaturated fatty acids, and high concentrations (73%). Polyunsaturated fatty acids consist of approximately 16% linoleic fatty acids and 57% linolenic fatty acids (Gallardo et al. 2014).

According to Singh and Verma (1998), flax seed yield can be increased by more than 100% in dry farming conditions with appropriate fertilization, weed control and plant protection measures, and it has been reported that fertilizer is more effective than common management practices. In addition, Singh and Verma (1998) attribute the reasons for low flaxseed yield to poor soil fertility, inadequate fertilizer use and traditional crop management practices. In this respect, it is known that fertilization, which is one of the most important plant management techniques, affects seed yield (Dordas 2010). Intercultural processes such as fertilizer use status (NPKS), sowing time, soil moisture, seed amount, hoeing and maintenance are the main factors determining crop yield and quality (Singh et al. 2007).

One of the origin centers of linen is Anatolia. Linen culture has been traditionally practiced for thousands of years in Anatolia. The linseed oil obtained from the seeds of the flax plant called 'Zeyrek' or 'Zeğrek', which is widely planted for its seed in Central Anatolia, was also used in cooking (Ertuğ 1998). Linseed oil, which is mostly known for its industrial use, has been used in Anatolia as oil lamp for lighting, as feed and therapeutic oil in livestock, and as cooking oil in kitchens until recently. Flax seeds have been used in folk medicine as a pain reliever, wound healer and cough suppressant (Baytop 1984; Ertuğ 1998). However, flax cultivation area and production are decreasing every year.

There are both annual and perennial varieties of flax. However, only annual Linum usitatissimum is cultivated. Annual cultivars with herbaceous structure complete growing stages and harvested within 3-4 months after planting. In the flax plant, the main stem and branches end with a flower. The flowers, borne on stems growing from the branch tips, have five petals, usually blue in colour but sometimes white or pink. The fruits are small dry capsules composed of five lobes and 4 to 10 seeds in a capsule. 1000 seed weight varies between 4-15 g. Seed color is usually brown. There are 5-20 capsules per plant and a maximum of 10 seeds per capsule (Baydar and Erbaş 2014; Zuk et al. 2015).

In this study, it was aimed to determine the effect of nitrogen doses on yield and yield parameters of linseed (Karakız cultivar), which were cultivated in the past in our region and whose agricultural land is almost non-existent today.

2. MATERIAL AND METHOD

This study, which aims to determine the effects of different nitrogen doses on yield and yield components of linseed cultivars, was carried out in Kırşehir Ahi Evran University Faculty of Agriculture Research and Application Area in 2019 and 2020. The trial area is located at an altitude of 1015 meters above sea level, at 39.13° North latitude and 34.12° East longitude.

Experimental land soil is classified as clayey-loamy textured, alkaline, calcareous, unsalted, with a certain amount of usable phosphorus concentration, rich in potassium, poor in nitrogen and organic matter (Table 1) (Kacar 1994).

Table 1. Soil characteristics of the trial site

Soil parameters	*0-30 cm*
Saturation (Isba%)	56%
pH	7.53
EC (mmhos/cm)	0.59
Salt (%)	0.021
Retrievable P2O5	(%) 0.19
Lime CaCO3 (%)	23.2
Receivable K2O K (ppm)	64.12
Organic Matter (%)	1.31

It is seen that the total precipitation of research years are less than long term total precipitation (Table 2). Research years for linseed cultivars were drier than long term with comparing the vegetative period of linseed.

Table 2. Climate data of research area

Months	**Total Precipitation (mm)**			**Temperature (°C)**			**Humidity (%)**		
	2019	2020	1980-2021	2019	2020	1980-2021	2020	2021	1980-2021
March	10.2	15.4	36.7	6.3	8.0	5.6	56.4	61.6	67.2
April	29.0	25.3	42.4	9.7	10.8	10.9	64	55.2	63.3
May	17.1	42.1	45.6	17.5	15.9	15.4	52.7	56.6	61.3
June	84.7	38.3	36.4	21.8	20.6	19.7	56.1	49.3	55.5
July	8.7	9.7	8.9	22.4	25.6	23.3	47.5	41.1	48.9
Total/ Average	149.7	130.8	178.8	15.5	16.2	15.0	55.3	52.8	59.2

The average monthly air temperature is warmer then long term average mean temperature (Table 2). It is seen that lower humidity was occurred both 2019 and 2020 compared long term of linseed growth period (Table 2).

In the study, Karakız cultivar was obtained from Trakya Agricultural Research Institute. The experiment was set-up in a randomized complete block design with three replications and five treatments of different N fertilization rates (0, 20, 40, 60 and 80 kg N/ha). All plots were given 60 kg/ha P_2O_5 by using triple super phosphate (TSP) fertilizer as a phosphorus source at planting time. In the research, different nitrogen doses were determined as 0, 20, 40, 60 and 80 kgN/ha, and the first half was given from urea (46%N) fertilizer at planting and the other half was applied from ammonium nitrate (33%) fertilizer before branching.

During sowing, 40 kg/ha of linseed was used. As maintenance operations, hoeing was done when the plants were 3-4 true leaves and before flowering and weed control was provided. Harvesting was done by hand after full maturity. Plant height (cm), number of branches (branch/plant), number of capsules (capsule/plant), capsule diameter (cm), thousand-grain weight (g), seed yield (kg/ha) and crude oil ratio (%) were recorded on the basis of ten randomly selected plants and plots. The obtained data were subjected to the analysis of variance using MSTAT-C software according to the split-plot design in the randomized blocks. The differences among the treatments were grouped by DUNCAN multiple comparison test.

3. RESULTS AND DISCUSSION

Plant height

The plant height of the linseed showed a significant difference between years and this difference was statistically significant at the $P<0.01$ level. In the first year of the research (2019), the plant height was higher in all treatments and the average plant height was 4 cm higher than 2020. Especially in dry farming conditions in semi-arid region, climate factors (precipitation and temperature) effect plant height significantly. Nitrogen doses considerably affected plant height, as statistically ($P<0.01$) significant differences were detected amongst all treatments. Even though the plant height was significantly increased in all the treatments compared control, the most notable height increment was observed after 60kg/ha nitrogen doses in 2019. On the other hand, the notable increase in plant height was detected at 40 kg/ha nitrogen dose and plant height differences among the higher fertilization (between 60kg/ha and 80 kg/ha) were insignificant. Plant height in linseed is a genetic feature controlled by many genes, but it is also under the influence of environmental factors. Plant height varied between 30 cm and 75 cm in similar studies on linseed, depending on the variety, sowing time, sowing frequency and growing conditions. The similar findings were also reported by Kurt (2002), Yılmaz et al. (2007), Tunçtürk (2007), Endes (2010) and Demir (2021). In other studies ((Karaaslan and Toncer (2001), Bozkurt and Kurt (2007), Tanman (2009), Yıldırım and Arslan (2013)) carried out under irrigated conditions, plant height is considerably higher than our results (47.6 - 72.3 cm).

Number of lateral branches

The number of lateral branches of the linseed showed a significant difference between years and this difference was statistically significant at the P<0.01 level. The number of lateral branches in 2019 was 6.74 and this values higher than 2020 in all treatments and the average plant height was 4 cm higher than 2020. While the average number of lateral branches was determined as 6.74 pieces in 2019 and 4.87 pieces in 2020 (Table 3). The effect of nitrogen doses on the number of lateral branches was found to be statistically significant at the P<0.01 significance level. Nitrogen doses increase significantly increased the number of side branches compared to the control.

Table 3. The effect of nitrogen fertilizing on agronomic characters of linseed

	Plant height	***Number of lateral branches***	***Number of Capsules***
		2019	
$MS_{Nitrogen}$	32.37**	4.76**	3.39**
CV (%)	3.92	5.55	3.57%
0 kg/ha	35.44c	5.10c	12.24c
20 kg/ha	37.39bc	6.00bc	13.92ab
40 kg/ha	38.53bc	6.63b	13.4bc
60 kg/ha	41.05ab	7.90a	14.64ab
80 kg/ha	43.88a	8.07a	14.90a
LSD	4.22	1.026	1.35
Mean	39.26A	6.74A	13.82A

2020			
***MS**Nitrogen*	29.73**	2.57**	4.30*
CV (%)	3.89	6.0The number of	10.24
0 kg/ha	31.47c	3.70c	7.37b
20 kg/ha	33.27bc	4.17c	8.60ab
40 kg/ha	36.93ab	4.97b	9.20ab
60 kg/ha	38.20a	5.67ab	9.30ab
80 kg/ha	38.53a	5.83a	10.67a
LSD	3.80	0.7995	2.532
Mean	35.68B	4.87B	9.03B

MS: mean squares, CV: Coefficient of variation, LSD: Least Significant Difference, means within a column followed by the different letters are significantly different p = 0.01. ("ns": not statistically significant; * and **: statistically significant for a significance level of P<0.05 and P < 0.001 respectively).

The values of the number of lateral branches ranged from 5.10 to 8.07 pieces during the first year (2019), and from 3.70 to 5.83 pieces during the second year(2020). The highest number of lateral branches value was recorded in the 80 kg/ha nitrogen doses with 8.07 pieces in 2019 and with 5.83 pieces in 2020.

Number of Capsules

The number of capsules per plant differed by years and this difference was found to be statistically significant at the P<0.01 level. It is thought that the number of capsules per plant was higher in 2019 (13.82 pieces) and the significant decrease in the number of capsules in 2020 (9.03 pieces) is due to climatic conditions, especially precipitation and temperature. Effect of various rates of Nitrogen on number of capsules per plant of linseed is given in Table 3. The number of capsules per plant of linseed was affected significantly (P<0.01) with different rates of Nitrogen application in semi-arid climate condition. The number of capsules per plant of linseed varied from 12.24 to 14.90 pieces in 2019 and from 7.37 to 9.30 pieces in 2020. The treatment 80 kg/ha nitrogen dose performed the best with the value of 14.90 (2019) and 9.30 pieces (2020) capsules per plant and remained superior when compared other treatments. The control dose with value of 12.24 (2019) and 7.37 pieces capsules per plant (2020) remained the inferior most statistically (Table 3).

Capsule diameter

Linseed mean capsule diameter values did not differ between years and capsule diameter was 7.45 mm in 2019 and 7.10 mm in 2020. While the nitrogen dose treatments did not show any significant difference in capsule diameter values in 2019 and capsule diameter values changed from 7.00 to 8.07 mm (Table 4). However, nitrogen dose applications caused significant changes in capsule diameter values in 2020.

Table 4. The effect of nitrogen fertilizing on agronomic characters of linseed

	Capsule diameter	***Number of seed in capsule***	***Thousand seed weight***
		2019	
$MS_{Nitrogen}$	0.609ns	0.695ns	1.24**
CV (%)	7.61	7.60	3.82
0 kg/ha	7.00	7.49	5.99b
20 kg/ha	7.07	7.56	6.22b
40 kg/ha	7.73	8.27	6.93a
60 kg/ha	8.07	8.63	7.33a
80 kg/ha	7.40	7.92	7.40a
LSD			0.709
Mean	7.45	7.98A	6.77A
		2020	
$MS_{Nitrogen}$	0.518**	4.88**	0.317öd
CV (%)	3.77	5.83	5.62
0 kg/ha	6.47b	5.03d	5.66
20 kg/ha	6.93ab	6.03cd	6.28
40 kg/ha	7.21a	6.83bc	6.54
60 kg/ha	7.50a	7.67ab	6.25
80 kg/ha	7.40a	8.23a3	6.24
LSD	0.734	1.079	
Mean	7.10	6.76B	6.19B

MS: mean squares, CV: Coefficient of variation, LSD: Least Significant Difference, means within a column followed by the different letters are significantly different p = 0.01. ("ns": not statistically significant; * and **: statistically significant for a significance level of P<0.05 and P < 0.001 respectively).

Capsule diameter values varied between 6.47 mm and 7.50 mm. While the lowest capsule diameter was observed from the control dose, the highest capsule diameter was obtained from the 60 kg/ha nitrogen dose. There was no significant difference between the nitrogen doses of 60 and 80 kg/ha, both were in the highest group (Table 4).

Number of seed in capsule

The difference between the years in the number of seeds in the capsule was statistically significant at the $P<0.01$ significance level. While the average number of seeds in the capsule was 7.98 pieces in 2019, it was 6.76 pieces in 2020. The effect of nitrogen dose application on the number of seeds in the capsule was not statistically significant in 2019. The number of seeds in the capsule varied from 7.49 to 8.63 in 2019. Although there was a slight increase in the number of seed in the capsule compared to the control, this was not statistically significant in 2019. The effect of nitrogen dose application on the number of seeds in the capsule in 2020 was statistically significant at the $P<0.01$ significance level (Table 4). The number of seeds in the capsule varied from 5.03 to 8.23 pieces in 2020. It was determined that increase of nitrogen dose level resulted increase in number of seed in capsule and all nitrogen doses higher than control dose in terms of number of seed in capsule. The highest number of seeds in the capsule was 8.23 spices at 80 kg/ha nitrogen dose treatment.

Thousand seed weight

The difference of thousand seed weight between years is statistically significant at the $P<0.01$ significance level. While the thousand seed weight was 6.77 g in 2019, it was 6.24 g in 2020 (Table 4). It was determined that thousand seed weight changed with the nitrogen dose level increase and this change was statistically significant at the $P<0.01$ level. The increase in nitrogen dose caused an increase in thousand seed weight. In the statistical grouping, the control and 20 kg/ha nitrogen dose were in the same low group. Although the highest thousand seed weight was observed at the nitrogen dose of 80 kg/ha, it was in the same statistical group with the nitrogen dose of 40 and 60 kg/ha. The change of thousand seed weight with nitrogen dose applications is not statistically significant in 2020. Thousand seed weights varied between 5.66 g and 6.54 g in 2020. Although nitrogen dose applications provide a higher thousand seed weight than the control, this is not statistically significant. The highest thousand seed weight was observed from the application of 40 kg/ha nitrogen dose (Table 4).

Seed yield

Seed yield differed between years and this difference was statistically significant at the $P<0.05$ significance level. While the seed yield was 1089.73 kg/ha in 2019, it was 949.60 kg/ha in 2020. With the increase of nitrogen dose, an increase in seed yield was observed and this increase was statistically significant at the $P<0.01$ significance level. Control dose and 20 kg/ha nitrogen dose were not statistically different in 2019. The highest seed yield was obtained from 1320.30 kg/ha and 80 kg/ha nitrogen dose application. In addition, seed yields obtained from 40 and 60 kg/ha nitrogen doses in 2019 were in the same statistical group. There is a significant difference at $P<0.01$ significance level between nitrogen dose and seed yield in 2020. The highest seed yield was obtained from 1149.00 kg/ha and 80 kg/ha nitrogen dose in 2020.

Table 5. The effect of nitrogen fertilizing on agronomic characters of linseed

	Seed yield	***Crude oil rate***	***Crude oil yield***
		2019	
$MS_{Nitrogen}$	98172.5**	4.03**	10518.8**
CV (%)	4.72	2.8	5.50
0 kg/ha	866.60c	40.78a	353.09c
20 kg/ha	951.60c	39.41ab	375.36bc
40 kg/ha	1167.83b	38.73ab	452.62a
60 kg/ha	1142.33b	38.30ab	437.62ab
80 kg/ha	1320.30a	37.79b	499.02a
LSD	140.80	2.99	63.87
Mean	1089.73A	39.00	423.54
		2020	
$MS_{Nitrogen}$	96066.9**	4.318**	10754.6*
CV (%)	10.18	2.02	11.21

0 kg/ha	730.3b	41.13a	300.53b
20 kg/ha	851.3b	40.70ab	346.80ab
40 kg/ha	900.00ab	40.00abc	360.08ab
60 kg/ha	1117.33a	38.50c	430.59a
80 kg/ha	1149.00a	38.60bc	443.52a
LSD	264.95	2.20	115.61
Mean	949.60B	39.79	376.30

MS: mean squares, CV: Coefficient of variation, LSD: Least Significant Difference, means within a column followed by the different letters are significantly different p = 0.01. ("ns": not statistically significant; * and **: statistically significant for a significance level of P<0.05 and P < 0.001 respectively).

Since there was no significant difference between the control dose and 20 kg/ha nitrogen dose in seed yield, they were in the same low group. When the increase in nitrogen dose was evaluated, there was 9.8% seed yield increase observed at 20 kg/ha nitrogen dose compared to the control. The 80 kg/ha nitrogen dose increased seed yield15.58 and 52.35% compared to the 60 kg/ha nitrogen and control dose, respectively in 2019. A similar situation occurred in 2020 and the increase in nitrogen dose caused a significant increase in yield. The 80 kg/ha nitrogen dose provided approximately 57.33% higher seed yield compared to the control dose. The results are in conformity with findings of Endes (2010) (653-1241 kg/ha), Yıldırım (1998) (400-1630 kg/ha), Tunçtürk (2007) (997-1490 kg/ha), Karaaslan and Toncer (2001) (628.3-1193 kg/ha).

Crude oil rate

The change in crude oil rate between years is statistically insignificant. While the crude oil rate was 39.00% in 2019, it was 39.79% in 2020. The effect of the nitrogen dose change on the crude oil rate was significant at the P<0.01 significance level in 2019. A decrease in crude oil rate was observed with the increase of nitrogen dose. While the lowest crude oil rate was obtained from the nitrogen dose of 80 kg/ha with 37.79%, the highest crude oil rate was obtained from the control dose with 40.78%. It was determined that there was no statistical difference between 20, 40 and 60 kg/ha nitrogen doses in terms of crude oil rate in 2019. A similar situation was observed in 2020 and the effect of nitrogen dose change on crude oil ratio was significant at P<0.01 significance level. A decrease in crude oil ratio was observed with the increase of nitrogen dose. The lowest crude oil rate was obtained from the nitrogen dose of 38.50% with 60 kg/ha, while the highest crude oil rate was obtained from the control dose with 41.13%.

Crude oil yield

Crude oil yield differed between years and this difference was statistically significant at the P<0.05 significance level. While the crude oil yield was 423.54 kg/ha in 2019, it was 376.30 kg/ha in 2020. With the increase of nitrogen dose, an increase in crude oil yield was detected and this increase was statistically significant at the P<0.01 significance level in 2019. The highest crude oil yield was obtained from 80 kg/ha nitrogen dose with 499.02 kg/ha, and the lowest crude oil yield was obtained from the control dose with 353.09 kg/ha in 2019. Compared to the control dose, 20 kg/da nitrogen dose increased the crude oil rate by 6.31%. The highest increase in crude oil yield was observed at 80 kg/ha nitrogen dose and the rate of increase was 41.33% compared to the control. The increase in nitrogen dose affected the crude oil yield and this interaction was significant at the P<0.05 significance level in 2020. Similarly, the increase in nitrogen dose provided an increase in crude oil yield in 2020. The lowest crude oil yield was obtained from the control dose with 300.53 kg/ha. The highest crude oil yield was obtained from 80 kg/ha nitrogen dose with 443,52kg/ha. Since the difference between 60 and 80 kg/ha nitrogen doses in terms of crude oil yield was not statistically significant, both doses were in the same highest group. Crude oil ratio increased with nitrogen dose. 20 kg/ha nitrogen dose provided 15.39% higher crude oil yield than the control. Compared to the control dose, the highest rate of increase in crude oil yield was 47.57% from the 80 kg/ha nitrogen dose.

4. CONCLUSION

In this study, which was carried out to ensure flaxseed production and oil production in the Anatolian region, where flax farming was common in the past, registered variety Karakız and 5 different nitrogen (0, 20, 40, 60 and 80 kg/ha) doses were used. Since the research was carried out in dry farming conditions, climatic factors in the research year significantly affect plant growth and yield. The fact that the linseed was grown (March-July) period in 2019 and 2020, was hotter and drier than the long term, had a negative effect on the growth and yield parameters of the linseed. The difference between the years in the yield and yield elements of the linseed is due to the difference in the amount of precipitation. Nitrogen dose caused a significant change in yield and yield parameters of linseed. It had a positive effect on growth and yield parameters except crude oil rate and this effect is statistically significant. The crude oil ratio showed a decreasing trend with the increase of nitrogen dose and the highest crude oil ratio was obtained from the control dose. Considering both years of the study, 60 and 80 kg/ha nitrogen doses gave the best results in terms of seed, crude oil yield and other yield parameters.

5. REFERENCE

Baydar H, Erbaş S (2014) Yağ bitkileri bilimi ve teknolojisi. Süleyman Demirel Üniversitesi Ziraat Fakültesi Yayın 97:313

Baytop T (1984) Türkiye'de Bitkiler ile Tedavi, İstanbul Üniv. Eczacılık Fak Yayınları

Bozkurt, D. ve Kurt, O., 2007, Keten (*Linum usitatissimum* L.)'in verim ve verim unsurlarına ekim zamanı ve toprak sıcaklığının etkisi, *Anadolu Tarim Bilimleri Dergisi,* 22 (1), 20-25.

Demir, İ., 2021, The effect of different nitrogen doses on yield and yield components of Linseed (Linum usitatissimum L.) cultivars in Kırşehir ecological conditions., *1. International Hasankeyf Scientific Research and Innovation Congress,* Batman, Iksad Publications ISBN: 978-625-8007-59-6, 339-347.

Dordas CA (2010) Variation of physiological determinants of yield in linseed in response to nitrogen fertilization. *Industrial Crops and Products* 31:455-465

Endes, Z., 2010. Konya şartlarında bazı yağlık keten *(Linum usitatissimum L.)* çeşit ve populasyonlarında farklı ekim zamanlarının verim ve kalite üzerine etkisinin belirlenmesi. Doktora Tezi. Selçuk Üniversitesi Fen Bilimleri Enstitüsü, Tarla Bitkileri Anabilim Dalı, Konya.

Ertuğ F (1998) Anadolu'nun Önemli Yağ Bitkilerinden Keten/Linum ve Izgın/Eruca Orta Anadolu'da Beziryağı Üretimi ve Bezirhaneler. *TÜBA-AR Türkiye Bilimler Akademisi Arkeoloji Dergisi*:113-127

FAO, 2022, Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/faostat/en/ #home,[Acces date 20 September 2022].

Gallardo MA, Milisich HJ, Drago SR, González RJ (2014) Effect of cultivars and planting date on yield, oil content, and fatty acid profile of flax varieties (Linum usitatissimum L.). *International Journal of Agronomy* 2014

Kacar B (1994) Bitki ve toprağın kimyasal analizleri. Ankara Üniversitesi Ziraat Fakültesi Eğitim, Araştırma ve Geliştirme Vakfı

Karaaslan, D. ve Tonçer, Ö. 2001. Diyarbakır koşullarında bazı keten çeşitlerinin adaptasyon üzerine bir araştırma. *Türkiye 4. Tarla Bitkileri Kongresi.* Bildiri Kitabı Cilt II, 295- 298, 17-21 Eylül, Tekirdağ.

Kurt, O., 2002. Tarla bitkileri yetiştirme tekniği, Ondokuz Mayıs Üniversitesi Ziraat Fakültesi Ders Kitabı, No: 44, Samsun

Meenakshi G, Sarabdeep K, Vikas G, Rajeev B, Charu S (2017) Effect of different doses of fertilizers on yield and NPK uptake of linseed (*Linum usitatissimum* L.). *Bangladesh Journal of Botany* 46:575-581

Oomah BD (2001) Flaxseed as a functional food source. *Journal of the Science of Food and Agriculture* 81:889-894

Singh N, Verma K (1998) Productivity of late-sown linseed (*Linum usitatissimum* L.) grown under variable resource constraints in rainfed areas of eastern Uttar Pradesh. *Indian Journal of Agronomy* 43:158-161

Singh T, Singh V, Singh Y, Singh M (2007) Effect of sowing dates, seed rates and sulfur levels on growth, yield, quality and moisture use of rainfed linseed. Environment and *Ecology* 25:978

Tanman, D., 2009. Tekirdağ Koşullarında Kışlık Ekim Zamanlarının Bazı Keten *(Linum usitatissimum* L.*)* Çeşitlerinin Verim ve Verim Özelliklerine Etkisinin Araştırılması. Yüksek Lisans Tezi. Namık Kemal Üniversitesi, Fen Bilimleri Enstitüsü, Tekirdağ.

Tunçtürk, M., 2007. Van koşullarında bazı keten (*Linum usitatissimum* L.) çeşitlerinin verim ve bazı verim ögelerinin belirlenmesi, *Tarım Bilimleri Dergisi*, 13 (4), 365-371.

Yıldırım, M., 1998. Yabancı Kökenli Keten *(Linum usitatissimum L.)* Çeşit ve Populasyonlarının Bazı Bitkisel Özellikleri. Yüksek Lisans Tezi. Atatürk Üniversitesi, Fen Bilimleri Enstitüsü, Ankara.

Yıldırım, M. ve Arslan, N., 2013, Seçilmiş keten (*Linum usitatissimum* L.) hatlarının bazı bitkisel özelliklerinin karşılaştırılması, *Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi*, 22 (2), 59-68.

Yılmaz, G., Telci, İ., Kandemir, N. ve Özdamar, M. 2007. Bazı keten çeşitlerinin Tokat koşullarındaki performansları. 1. Ulusal Yağlı Tohumlu Bitkiler ve Biyodizel Sempozyumu Bildiri Kitabı, 28-31 Mayıs, Samsun. s: 126-132.

Zuk M, Richter D, Matuła J, Szopa J (2015) Linseed, the multipurpose plant. *Industrial Crops and Products* 75:165-177

CHAPTER 5

CURRENT STATUS of POTATOES and SUGAR BEET PRODUCTION and TRADE

Assist. Prof. Dr. Buket KARATURHAN[1]

[1] Ege University Faculty of Agriculture Department of Agricultural Economics, C Blok 35100 Bornova, Izmir, Türkiye. ORCID NO: 0000-0002-7002-6615 email: karaturhanbuket@gmail.com

1. INTRODUCTION

Starch and sugar, both carbohydrates, are produced from many different plants today. However, starch-rich crops such as potato (Solanum tuberosum L.), sweetpotato (Ipomoea batatas (L.) Lam.), cassava (Manihot esculenta Crantz.), yams (Helianthus annuus L.), taro (Colocasia esculanta), yam (Dioscorea alata) and sugar-rich plants such as sugar beet (Beta vulgaris) and sugar cane (Saccharum officinarum L.) are classified under the starch and sugar crops group in Turkey. Among in this group, potatoes and sugar beet have a very important place in the Turkish agriculture (Çalışkan et al., 2020).

Starch and sugar industries are among the most important branches of the agriculture-based industry in Turkey as in the rest of the world. Both starch and sugar industries are also the raw material producers of the food industry. Therefore, the production of plants used in starch and sugar production is of great importance for the Turkish economy (Günel et al., 2005)

The widespread use of potatoes as a basic food product and the increase in the world population, rapidly increase the demand and consumption of potatoes. In this respect, potato ranks fifth, after sugar cane, corn, rice, and wheat in the list of the most produced crops in the world. According to 2020 FAO data, approximately 360 million tons of potatoes were produced on 16.49 million hectares (FAO, 2022b).

Even though potatoes are used in very limited quantities for starch production in Turkey, potatoes are a staple food consumed by all income groups from the poorest to the wealthiest. Annual fluctuations in potato prices negatively affect both producers and consumers, despite the fact that Turkey is one of the world's major potato producing countries with an annual production of 4-5 million tons. The most important problems of the potato sector of Turkey are still foreign dependency in seed, high input (seed, fertilizer, pesticide) and labor use in production, insufficient storage facilities, excessive price fluctuations, and low rate of use in industry (Çalışkan et al., 2020).

The two main sources of sugar in the world are sugar cane and sugar beet, and only sugar beet is produced in Turkey. Sugar, which has an important place in eating habits, has been developing both production and trade, and this important industrial plant always finds a place for itself in changing world policies. Though sugar production dates back to ancient times, its widespread use in Europe coincided with the beginning of the 20th century and its importance in international trade increased with increasing consumption. Sugar beet gained importance as a sugar plant after the German chemist Andreas Margraff discovered in 1747 that the sugar in beet is the same as cane sugar. The first beet sugar factory was established in Cunern, Germany in 1802, and the number of beet sugar factories in various parts of Europe reached 400 by 1830. Several countries, especially the EU countries, continue to produce beet sugar with cost-cutting precautions, both to ensure sugar supply security through local production and to take into account the economic, social and agricultural contributions of the sugar industry. While practices related to sugar beet and sugar, which have been produced in Türkiye for more than 80 years, were carried out within the framework of the Sugar Law No. 6747 until the early 2000s, this law was replaced by the new Sugar Law, which entered into force in April 2001 due to national priorities and problems of adaptation to changing international policies (Kepoğlu, a., 2008). Under this law, the Sugar Authority and the Sugar Board were established to carry out the activities related to market regulations.

2. Potatoes

2.1. Potato Production in the World and Türkiye

While world potato production was 388,190 million tons in 2017, it decreased in 2019 and amounted to approximately 360,000 million tons in 2020 (Figure 1). About half of this production is in Asia, 31.6% in Europe, 12.3% in America, 7.1% in Africa and 0.5% in Oceania. carried out by the continent (Figure 2).

Table 1. World and Turkey potato cultivation area and production amounts (2011-2020)

	World		Türkiye	
Years	Harvested Area (ha)	Production (ton)	Harvested Area (ha)	Production (ton)
2011	18699491	368983872	143441	4648081
2012	18698238	362049542	171976	4821937
2013	18507223	366205244	125434	3955294
2014	18052210	370014215	128392	4166000
2015	18059210	366058316	153802	4760000
2016	17391028	353987204	144706	4750000
2017	17435959	370113980	142851	4800000
2018	17193567	365666172	135904	4550000
2019	16475816	354812093	140766	4979824
2020	16494810	359071403	147965	5200000

Source: FAO statistical database, http://www.fao.org/faostat

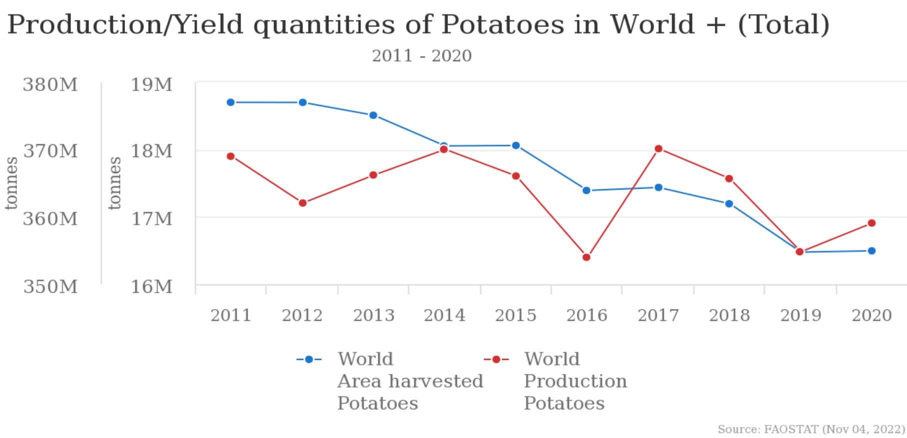


Figure 1: World Potatoes Production

Source: FAO statistical database, http://www.fao.org/faostat

Table 2. Potato production by regions and countries between 2013 and 2017 (x1000 tons)

	2013	**2014**	**2015**	**2016**	**2017**
World	374.070	380.264	376.577	374.252	388.190
Asia	186.148	186.710	189.623	187.378	195.668
Europe	115.397	124.574	116.573	117.646	121.761
N.America	24.370	24.632	24.342	24.346	24.429
South America	15.537	15.963	15.512	16.976	16.979
Africa	28.309	24.222	25.196	23.513	25.011
Oceania	1.782	1.620	1.631	1.611	1.575
EU	54.616	60.719	53.872	56.378	61.320
China	95.993	95.571	94.916	95.706	99.147
India	45.343	46.395	48.009	43.417	48.605
Russia	30.199	31.501	33.645	31.107	29.590
Ukraine	22.258	23.693	20.839	21.750	22.208
USA	19.715	20.056	20.012	20.022	20.017
Germany	9.670	11.607	10.370	10.772	11.720
Bangladesh	8.603	8.950	9.254	9.474	10.216
Poland	7.290	7.689	6.314	8.872	9.172
Netherlands	6.677	7.100	6.652	6.534	7.392
France	6.957	8.085	7.120	6.835	7.342
Türkiye	3.955	4.166	4.760	4.750	4.800

Source: Çalışkan ve ark.,2020 ve FAO statistical database, http://www.fao.org/faostat/

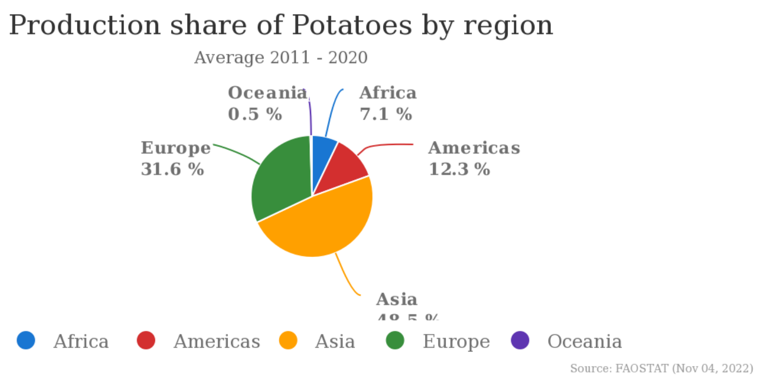


Figure 2: Production share of Potatoes by region
Source: FAO statistical database, http://www.fao.org/faostat

Potato production for 2013-2017 in the continents and the top 10 countries in the world are given in Table 2. While China, India, Russia, Ukraine and the United States consistently are top five potato production countries in the world, these countries also account for more than half of the world's total production (Figure 3).

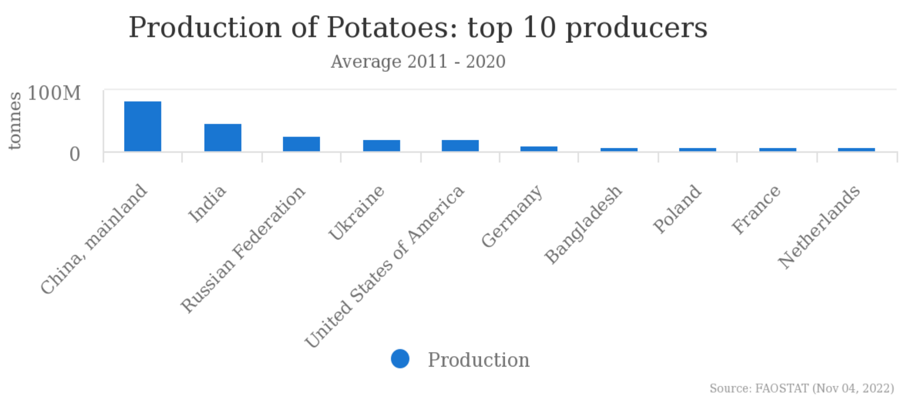


Figure 3: Production of Potatoes in Top 10 Countries
Source: FAO statistical database, http://www.fao.org/faostat

Over the years, India, Egypt and Ukraine have seen an increase in production, with China accounting for 22%, India 14%, Ukraine 6% and Russia 5% (Table 2). Production in India, the largest potato producer after China, reached 48.6 million tons in 2017. Among the top five of potato producer countries, only Russia and Ukraine have seen some decrease in production in recent years. Production in Russia, which increased until 2015, then began to decline, reaching the lowest level in the last five years in 2017. On the other hand, Ukraine reached the lowest production level in 2015 and then increased again and reached the level of 2013. Since potato production in Russia and Ukraine is largely based on rainfall, production amounts vary according to years, but in 2022, production amounts have decreased because the war between the two countries.

Among the top five countries, the average yield in the U.S. is more than twice the world average, while China, Russia and Ukraine have yields below the world average. India, on the other hand, has a yield close to the world average (Çalışkan et al.2020).

In Turkey; the production of potatoes, which has a history of about 150 years, showed a slow progress until the 1930s; afterwards, it started to increase. Especially the implementation of the National Potato Project in the 1970s and the mobilization of the private seed sector, which was encouraged by the decisions of the Monetary Credit Board since 1984, further accelerated the increase in potato production (Günel et al.2005).

As seen in Figure 4, potato production in Turkey was quite high in 2012 and 2017, but there was a sharp decline in 2013. Although there was a partial decrease in 2018, it recovered in 2109 and 2020. Turkey ranks 16th in world potato production with a share of 1%.

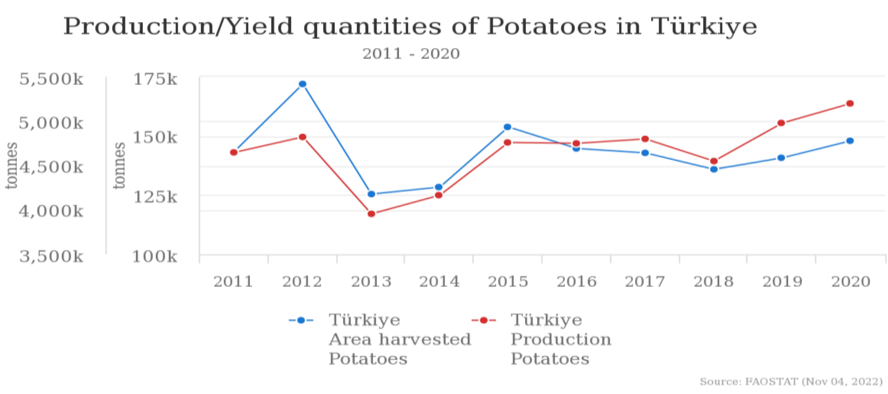


Figure 4: Potatoes Production in Turkey
Source: FAO statistical database, http://www.fao.org/faostat/en

Turkey has a very advantageous position for potato production in terms of climate and soil characteristics, and potato production can be made in almost all over the country and in almost every period of the year (main product, and second product). In Central and Eastern Anatolia and Gecit regions, potatoes are grown as the main product in the summer months. The main crop potato production covers 80% of the total production. In the coastal Mediterranean and Aegean regions, where the Mediterranean climate is dominant, peat potato production is carried out in winter and spring. Second crop potato production is still carried out only in Izmir/Odemis (Çalışkan et al. 2010).

Considering Turkey's ecology, climate situation and soil structure; potato cultivation is carried out more or less in almost all provinces. According to 2020 production data, potato cultivation was carried out in 148 thousand hectares of land in 71 provinces in Turkey and 5 million 200 thousand tons of potatoes were produced. The production amounts between 2013 and 2018 in the provinces with the highest potato production in Turkey are given in Table 3. When Table 3 is examined; it is seen that the top three provinces where the most production are Niğde, Konya and Afyonkarahisar.

Table 3: Production of Potatoes in Top 10 Provinces (1000 ton)

Provinces	2013	2014	2015	2016	2017	2018
Niğde	513	854	892	835	732	732
Konya	421	509	494	550	567	612
Afyon	306	302	435	477	473	455
Kayseri	299	286	288	305	351	386
İzmir	441	391	408	368	396	330
Nevşehir	178	219	301	256	250	270
Adana	180	206	219	221	241	219
Aksaray	174	240	242	211	208	202
Sivas	134	172	250	227	165	150
Bolu	247	281	250	227	165	150
Rest	1056	942	1199	1016	1149	1043
TURKEY	3.955	4.166	4.760	4.750	4.800	4.550

Source: Türkiye İstatistik Kurumu, http://www.tuik.gov.tr ,

2.2. Potato Trade in the World and in Turkey

Potato is an important industrial plant that is used in human nutrition as fresh or processed, in animal nutrition in the form of factory residues, as seed to ensure the continuity of production and in various ways in the food industry (Kadakoğlu and Karlı, 2021). Since potatoes are a voluminous product, international trade in the long distance as fresh product other than seeds is limited.

When we look at the top ten countries in the world trade, it is seen that mainly the European Union countries are important. The Netherlands is the most important actor in the world potato trade with approximately 1.8 million tons (Table 4). These countries are important seed producers and a significant part of their exports are seed exports. In addition, these countries, where the potato processing industry is well developed, export processed products by buying fresh potatoes and processing them (Çalışkan et al. 2020).

Table 4. Top Ten countries in Potatoes Trade (2018)

Country	Import (ton)	Import (1000 $)	Country	Export (ton)	Export (1000 $)
Belgium	2.170.113	507.856	France	2.038.305	594.729
Netherland	1.770.228	354.586	Germany	1.995.553	393.978
Spain	780.766	250.502	Netherland	1.821.595	798.312
Italy	619.241	191.928	Belgium	975.837	209.832
Germany	607.067	246.117	Canada	706.343	238.838
Russia	60.637	220.413	Egypt	671.287	272.730
USD	501.794	232.289	USD	546.658	239.857
France	431.551	135.757	Iran	512.954	144.335
Iraq	383.907	114.882	China	509.537	280.758

Source: FAO statistical database, http://www.fao.org/faostat/en

The trade volume of fresh and frozen potatoes, subject to world foreign trade, is 44 million tons and 23.4 billion dollars in 2020 (Anonymous, 2022). The most important owners of this market are France, Germany, the Netherlands, Belgium and Egypt (Figure 5). In China, India, Ukraine, Russia and the United States, producing 55.49% of the world's potatoes, production is more about domestic consumption, so their share of foreign trade is less.

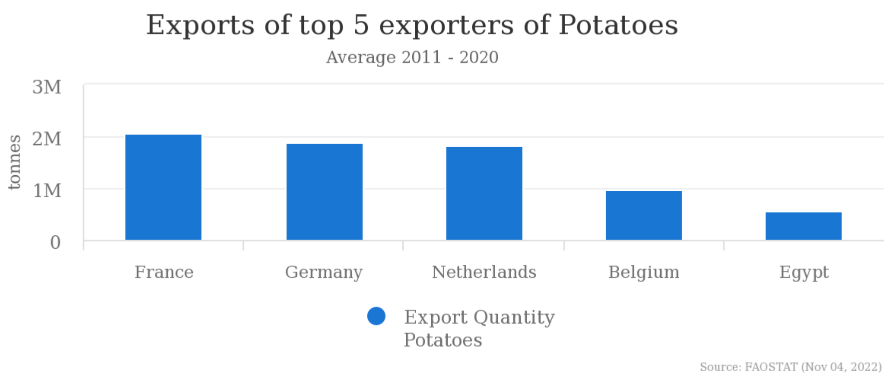


Figure 5: Exports of Potatoes in top 5 exporters
Kaynak: FAO statistical database, http://www.fao.org/faostat/en

Turkey is located in a highly advantageous geographic location for the trade potatoes. In Arab countries in the south of the country, potato imports are high because the climate structure is not very suitable for potato production. The nine countries in our south (Iran, Syria, Jordan, Lebanon, Israel, Yemen, Saudi Arabia, Kuwait and the United Arab Emirates) except Iraq, the imports of potatoes in are very high (Anonymous, 2022). Similarly, significant market potential exists in Balkan and Baltic countries and Central Asia Turkish Republics (Çalışkan et al 2020).

After the peak in 2013, Turkey's potato export amount was realized as 260,068 tons in 2018, slightly below this, while this figure was 144,917 tons in 2019 and 124,135 tons in 2020 (Figure 6). The crisis environment in Iraq and Syria in recent years and the embargoes imposed have also significantly affected our potato exports. Because countries such as Iraq, Syria, Tunisia and the UAE stand out as important importing countries. The countries we export as seeds are shown in Figure 7.

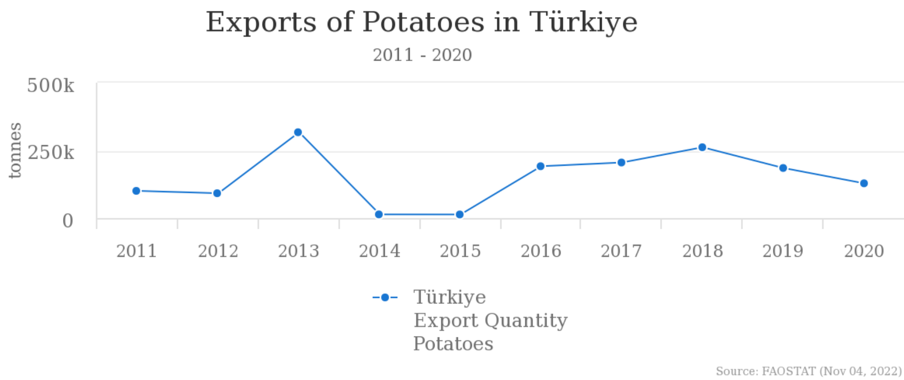


Figure 6: Exports of Potatoes in Turkey
Source: FAOSTAT, Kasım/2022

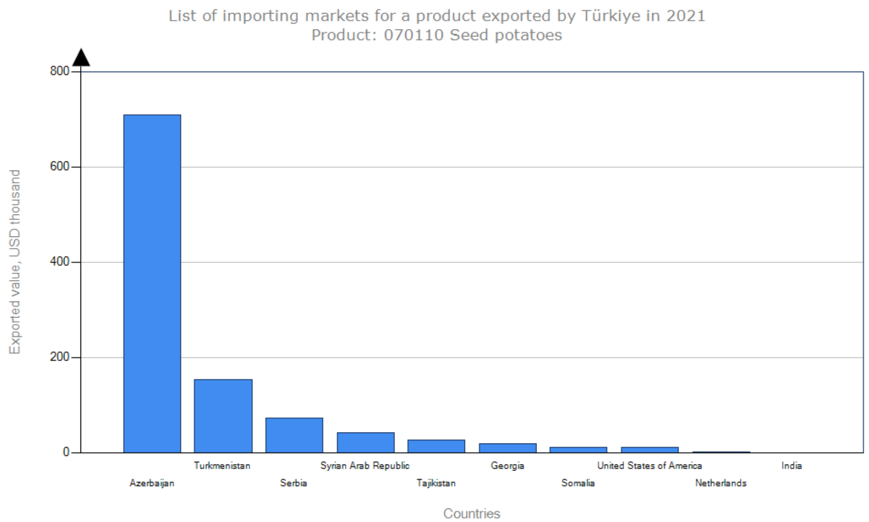


Figure 7: Top Ten Countries in Turkey’s Export of Seed Potatoes (2021)
Source: Trademap, Kasım/2022

Turkey's potato imports were mainly seed until 2019. The biggest factor in this is the high customs duty applied on the import of edible potatoes to protect the producer. Due to a slight decrease in production in 2018 and an increase in exports and potato prices, the customs duty, which was previously 19.3%, has been reset as zero for 200,000 tons of potatoes to be imported by 20

April 2019 by the President's Decree. Thus, while a total of 128,065 tons of seed potatoes were imported in the period between 2013 and 2018, a total of 80 603 tons of which were imported in the January-September 2019 period, a total of 64,039 tons of table potatoes were imported. The amount of table potatoes imported in the first nine months of 2019 was approximately 2.7 times the amount imported during the previous five years (Kadakoğlu and Karlı, 2021). In 2020, the amount of imports decreased to 24 852 tons (Figure 8).

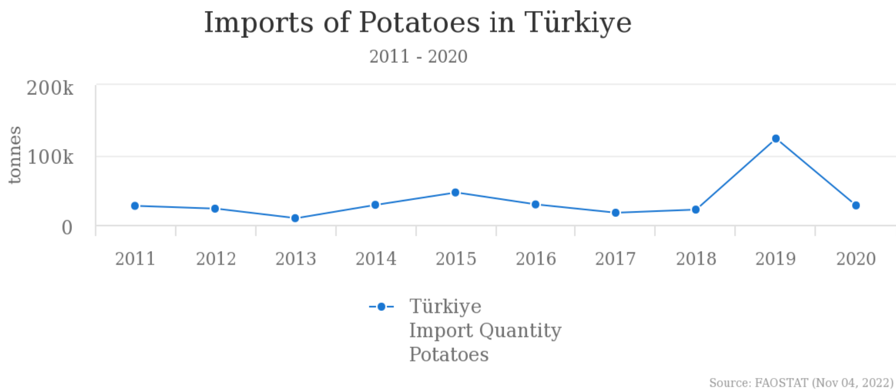


Figure 8: Imports of Potatoes in Turkey
Source: FAOSTAT, Kasım/2022

The countries from which Turkey imports seed potatoes are given in Figure 9. It is seen that the most of our imports here are from the Netherlands.

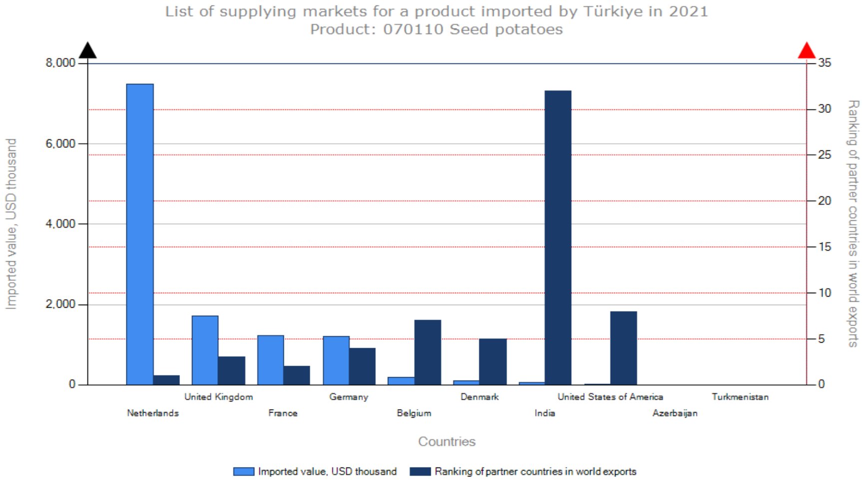


Figure 9: Top Ten Countries in Turkey's Imports of Seed Potatoes (2021)
Source: Trademap, Kasım/2022

The production and marketing of seed potatoes is carried out entirely by the private sector, and the Ministry of Agriculture and Forestry is in the supervisory position. Although some moves have been made in recent years in terms of seed potato production, we still continue to be dependent on imports. Considering that the country has large areas suitable for seed production and its proximity to seed markets due to its geographical location, Turkey has the potential to become a seed potato production base in the future. Another condition for increasing domestic seed production is the development of domestic varieties. In recent years, significant developments have been made both in public research, universities and in the private sector (Çalışkan et al.. 2020).

As in all countries, it is important to ensure the sustainability of agricultural production in Turkey and to use support policies as a tool to increase the productivity (Karlı et al., 2018). Supports for potato production can be divided into three: The first support is diesel-fertilizer support. This type of support varies according to the crop and the size of the cultivation area and is used as the main policy tool especially in field crops. The second support in potato production is intended for the use of certified seeds. This support, which was first was implemented in 2005, is still being implemented today and is seen as an important support for producers. The third support is aimed at supporting private sector seed organizations that produce and/or have certified seeds produced in the country in order to contribute to the development of the seed sector in Turkey and to increase the production of some varieties that are insufficient in seed production (Kadakoğlu and Karlı, 2021).

3. Sugar Beet

3.1 Production in the World and Turkey

Molasses and wet pulp by-products are formed from sugar beet production, and the use of these products in the food industry and animal husbandry has ensured that the economic value of sugar beet is high.(Duru et al.2021) Sugar Beet is used in 3 ways all over the world.

Food Industry: Sugar beets are mainly used for sucrose production, with as much as 13 - 22% sucrose content. Sugar beet pulp is used in the production of high fiber dietary food additives, and in certain countries, these supplements have been fused into new products such as breakfast cereals.

Livestock Feed: Sugar beet by-products, sugar beet pulp, and molasses are mainly used as livestock feed supplements, providing adequate fiber in portions and boosting the palatability of feeds. Sugar beet tops are also used as a feed for sheep and cattle grazing beet fields in the fall to consume small leftover beets in the post-harvest. Beet tops can be utilized as silage, and are a good source of protein, vitamin A, and carbohydrates, however, they are not as nutritious as alfalfa haylage or corn silage for cattle, but similar to alfalfa haylage or corn silage for sheep. Beet tops are windrowed in the field and left to wilt to 60-65% moisture before ensiling.

Industrial Uses: Molasses by-products are mainly used in the production of alcohol, pharmaceuticals, and baker yeast. Waste lime from the processing of sugar beets is considered a good soil amendment as it increases soil pH levels and is a good source of P & K plant nutrients (2021 Industry Report: Sugar Beet)

Table 5. World and Turkey sugar beet cultivation area and production amounts (2011-2020)

World			Turkiyeey	
Years	Sown area(ha)	Production Amount(tons)	Sown area(ha)	Production Amount(tons)
2011	5074334	278756561	293841	16126489
2012	4828580	269558344	208186	14919940
2013	4344285	247624316	290910	16488590
2014	4469091	270249852	287461	16743045
2015	4209450	240759023	275262	16462000
2016	4584596	278771758	321953	19592731
2017	4980532	313936939	338883	21149020
2018	4784905	273387904	290698	17436100
2019	4650878	280918827	310100	18085528
2020	4439073	252968843	336348	23025738

Source: FAO statistical database, http://www.fao.org/faostat

World sugar beet production decreased with the decrease in cultivation areas in 2013 and while it was 247624316 tons, it reached a production figure of 313936939 tons in 2017. In 2018, it started to decrease again.

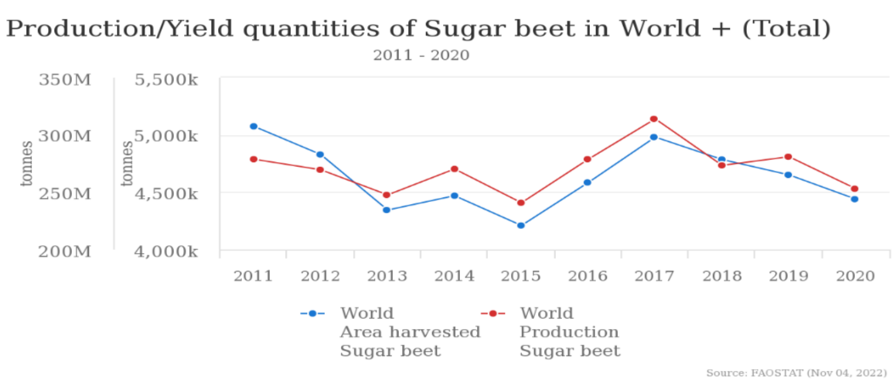


Figure 10: World Sugar Beet Production
Source: FAO statistical database, http://www.fao.org/faostat

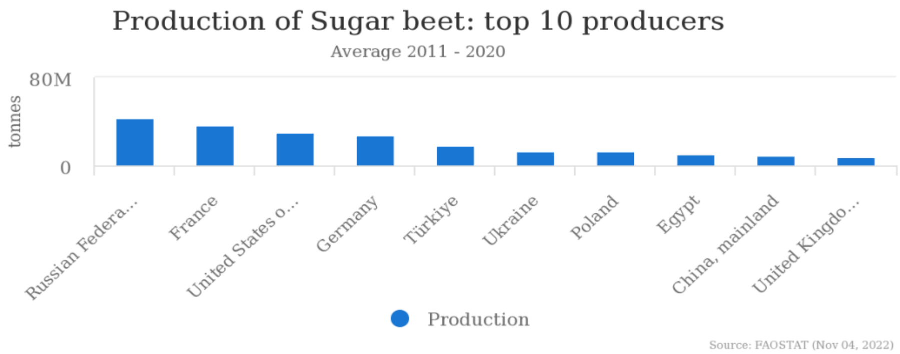


Figure 11 Production of Sugar Beet Top 10 Countries
Source: FAO statistical database, http://www.fao.org/faostat

In world sugar beet production; Russia, France, USA, and Germany have an important share. Europe has the largest share, followed by Asia, America and Africa, respectively.

Sugar cane; It is a plant that is easier to produce than sugar beet, cheaper in cost and can be harvested several times a year. Due to its geography, countries such as Turkey, the European Union, Russia and Ukraine; Countries such as the USA, Japan and China are made from both beet and cane; Countries such as Brazil, India, Mexico, Pakistan, Thailand and Australia produce sugar from cane (Şentürk, 2020) This situation facilitated sugar production in Brazil, India, Thailand and China, which are suitable for sugar cane production, and contributed to their having a say in the world. Thanks to these features, these countries have come to meet half of the world's sugar production (Duru etc,2021)

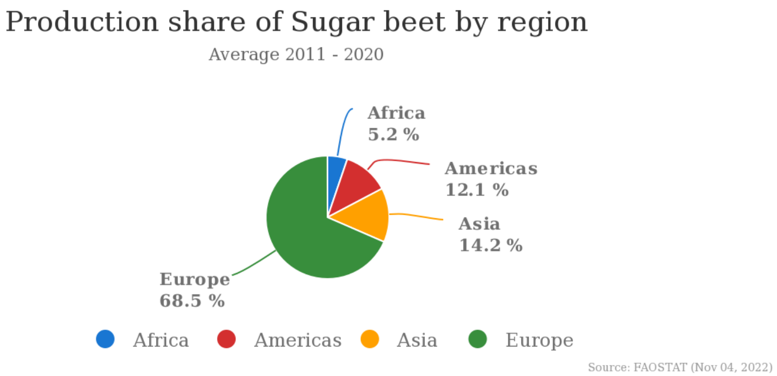


Figure12: Production share of Sugar Beet by region

Source: FAO statistical database, http://www.fao.org/faostat

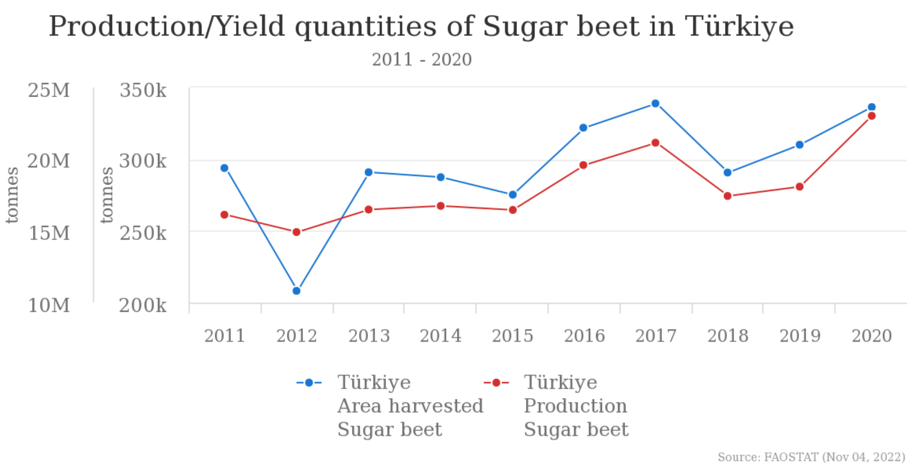


Figure 13: Sugar Beet Production in Turkey

Source: FAO statistical database, http://www.fao.org/faostat/en

In Turkey, 95% of the sugar is obtained by the production of sugar beet due to the favorable climate characteristics. While Turkey ranks fourth in the world in sugar production from sugar beet, it ranks third in Europe. Sugar beet production is also the first agricultural production model in which contract agriculture was applied in the republican period.

It is possible to summarize the contributions of sugar beet agriculture, which creates an important economic added value in the regions where it is grown, to Turkey's agriculture and economy.In addition to its economic value, sugar beet supports continuity in employment and agricultural production. • One decare of sugar beet production employs approximately 10 worker. It provides 20% yield increase in cereals planted after itself. • Approximately 350 thousand farmer families grow sugar beet on an area of over 300 thousand hectares. • The oxygen given to the air by photosynthesis of one decare is equivalent to the oxygen consumed by 6 people in a year, and it produces 3 times more oxygen than 1 decare of forest area. Sugar beet creates added value by playing an important role in the agriculture-based industry. • Sugar beet is an industrial plant. It ranks 2nd in terms of the added value it provides among industrial plants.

Table 15: Production of Sugar Beet in Top 10 Provinces (1000 ton)

Provinces	2014	2015	2016	2017	2018
Konya	4.865	4.571	5.665	6.008	5.079
Yozgat	1.531	1.564	1.786	1.912	1.445
Eskişehir	1.312	1.262	1.541	1.349	1.319
Aksaray	1.045	1.016	1.174	1.194	1.028
Kayseri	803	940	1.025	1.167	997
Afyonkarahisar	895	680	917	1.031	797
Sivas	587	713	767	828	680
Ankara	590	555	684	657	629
Karaman	489	520	587	634	554
Tokat	511	511	556	595	416
TURKEY	16743	16462	19593	21149	17436

Source: Türkiye İstatistik Kurumu, http://www.tuik.gov.tr,

According to 2018 data, sugar beet is produced in 56 provinces in Turkey, and Konya, where the highest sugar beet production is made, meets 25% of Turkey's cultivation area and 29% of its production. The province of Konya, where Ereğli and Ilgın factories belonging to Turkish Sugar Factories A.Ş. and Konya and Çumra factories belonging to Pankobirlik are located, is almost the sugar beet and sugar production base of Turkey (Çalışkan et al. 2020).

3.2. Sugar Beet Trade in the World and in Turkey

After the great depression in 1929, a quota was introduced in the sugar sector within the scope of protectionism measures. After the Second World War, the Sugar Agreement entered into force in 1953 to stabilize world sugar prices and production, and the International Sugar Organization (ISO) was established in 1968.

During the period until the establishment of the World Trade Organization (WTO) in 1994, many sugar agreements were made, and after the establishment of the WTO, the efforts of the WTO to liberalize the world sugar trade were insufficient. However, especially in the world's leading sugar producing countries, sugar protection and quota practices continue (Kepoğlu, 2008

Table 7. Distribution of World Sugar Exports by Country and Years (1000 tons)

Countries	**2001**	**2005**	**2010**	**2015**	**2019**
Brazil	11,173	18,147	28,000	24,012	18,049
Thailand	3,258	3,041	4,501	7,591	9,539
India	1299	108 1	1764 3	3038	5,180
France	2,766	2,383	2,339	2,287	2,457
Guatemala	1,130	1,287	1,742	2,138	2,029
Turkey	561	8	77	9	30
Others	17,072	19,873	17,980	21,201	18,930
TOTAL	37,259	44,847	56,403	60,276	56,214

Source: Duru vd 2021

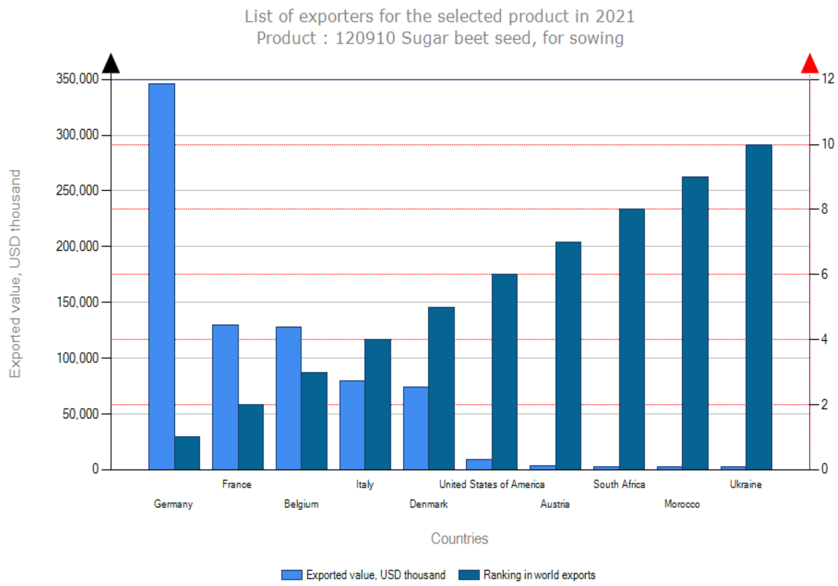


Figure 14: Sugar beet Exporting Countries

Source: FAO statistical database, http://www.fao.org/faostat/en

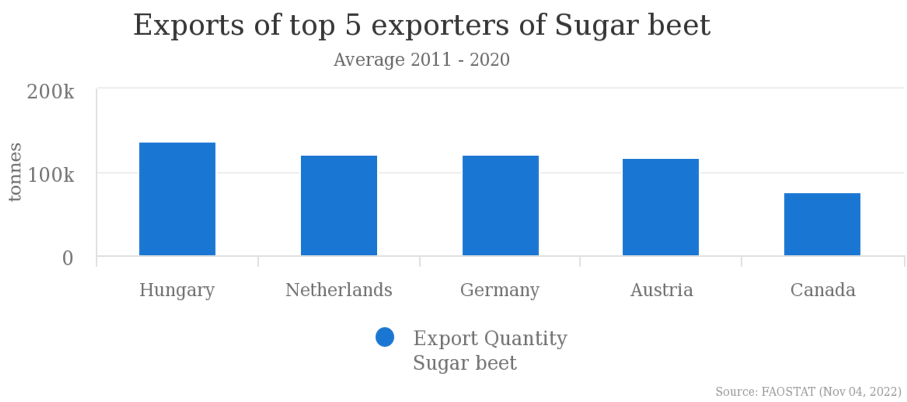


Figure 15: Exports of Sugar Beet in top 5 exporters
Source: FAO statistical database, http://www.fao.org/faostat/en

The European Union has created an independent system from the world with its production quota, trade mechanism and floor price application in sugar beet. Production in the EU, which realizes half of the world sugar beet production; Concentrated in France, Germany and Poland, 90% of the quota on the sugar market is controlled by seven associations in France, Germany, England and the Netherlands. The European Union has created an independent system from the world with its production quota, trade mechanism and base price application in sugar beet. However, in 2017, the EU abolished the quota application that limited sugar cane and glucose production, and abolished the beet production limit and minimum price support application that it had maintained for 50 years (Duru et al. 2021).

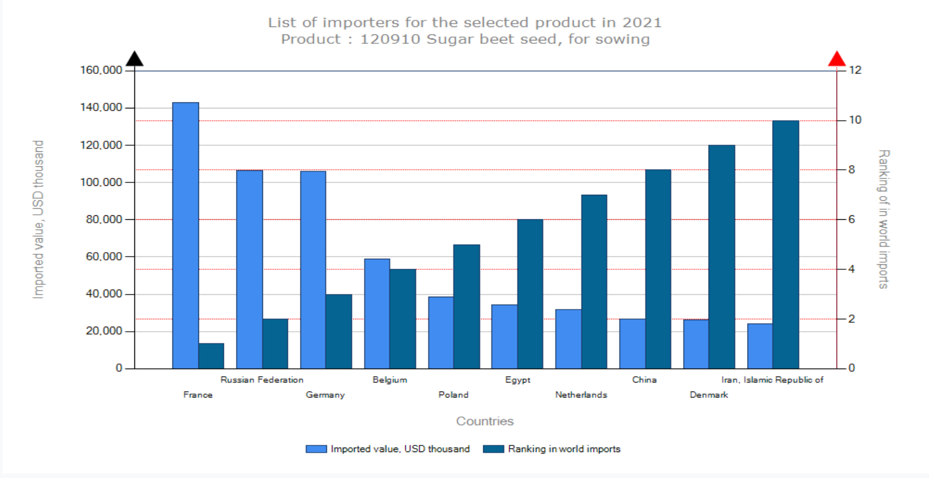


Figure 16: Sugar beet importing countries

Source: FAO statistical database, http://www.fao.org/faostat/en

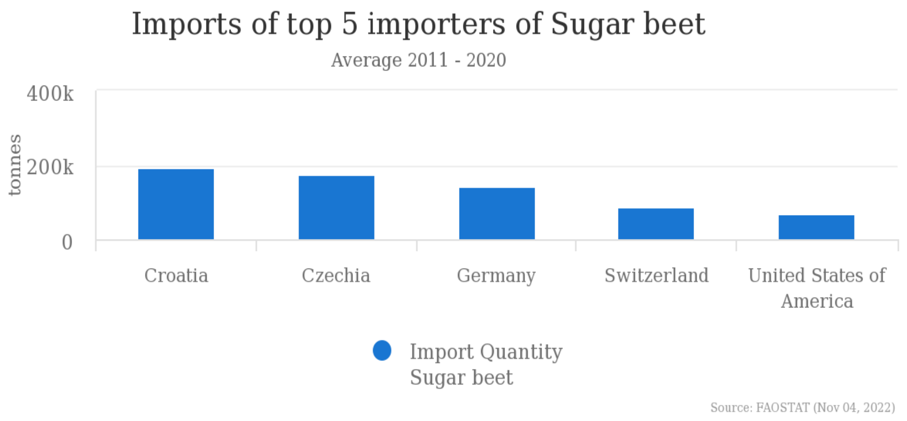


Figure 17: Countries that Import the Most Sugar Beet (2011-2020)

Source: FAO statistical database, http://www.fao.org/faostat/en

Looking at imports, Figure 17 shows that the most important5 countries are Croatia, Czech Republic, Germany, Switzerland and America.

Table 8: Changes in Turkey's Sugar Foreign Trade by Years

Years	Export		Imports	
	Quantity(Ton)	Value(USD)Thousands)	Quantity(Ton)	Value(USD)Thousands
2000	560,668	129,192	2,376	947
2005	8,101	4,662	3,926	2,626
2010	77,311	45,165	4,213	4,919
2015	9,877	6,004	169,693	76,606
2016	16,383	10,029	279,910	153,350
2017	3,838	3,196	229,863	120,227
2018	68,309	24,236	201,192	82,945
2019	30,344	10,334	132,571	65,091

Source: (Duru vd 2021)

While Turkey was the 8th largest exporter of sugar in the world in 2001, it fell to the 72nd place as of the end of 2019. Since 2015, Turkey's sugar exports have declined to very low levels alongside sugar imports. The main reason for this is that sugar C, which was determined for exporters of finished products within the scope of the Inward Processing Permit Certificate (DIIB), did not meet the need in 2015 and was supplied through imports (Duru et al. 2021).Sugar exports are carried out within the scope of the "Communiqué on the Issuance of Sugar Export and Preliminary Permit" published in the Official Gazette dated October 2, 2013 and numbered 28783. Within the scope of this communiqué, sugar exporters export within the scope of the pre-export permit obtained from the Sugar Department of the Ministry of Agriculture and Forestry (Anonymous, 2013).

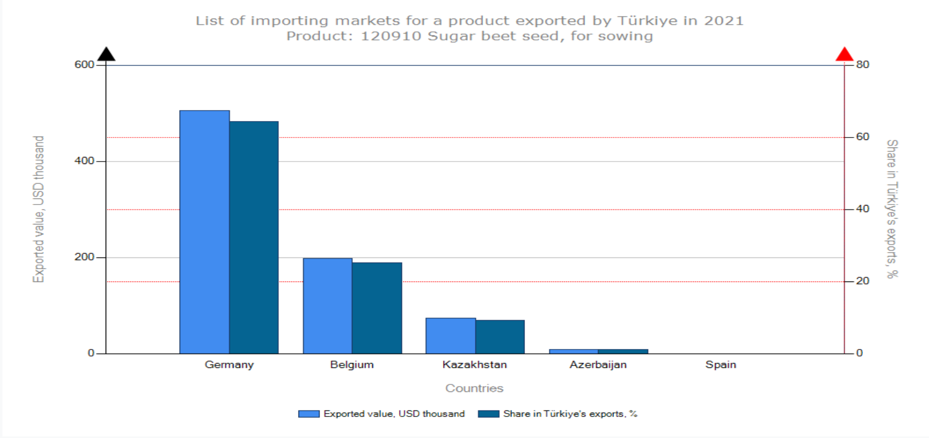


Figure 18: List of import markets of sugar exported by Turkey (2021)
Source: FAO statistical database, http://www.fao.org/faostat/en

With the entry into force of the Sugar Law in Turkey, a new process has begun in the sugar industry. In the EU, the sugar quota, which directly affects the market, limits production, and sets the sugar cane and isoglucose production limits, was abolished in 2017. After the quota was lifted, EU domestic market prices were balanced with world prices. After this situation, which was against Turkey, the privatization process of sugar factories in Turkey was accelerated. Sugar beet is important for Turkey in terms of agriculture, animal husbandry and agro-based industry (Şentürk, 2020)

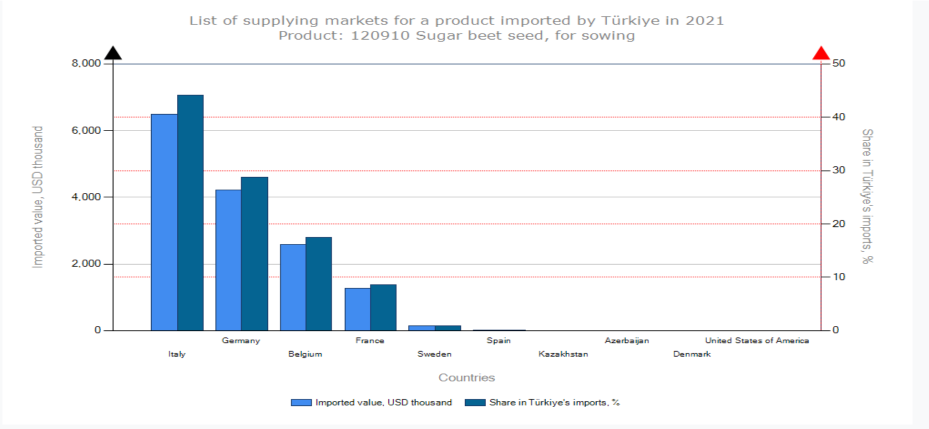


Figure 19: Countries from which Turkey imports sugar beet
Source: FAO statistical database, http://www.fao.org/faostat/en

Sugar beet R&D activities in Turkey were carried out only by Sugar Institute affiliated to Türkiye Şeker Fabrikaları A.Ş., research institutes affiliated to TAGEM were not conducting sugar beet research until 2017. Sugar beet research carried out in universities is relatively less compared to other plants. With the closure of the Sugar Authority and the establishment of the Sugar Department within the Ministry of Agriculture and Forestry in 2018, sugar beet researches were also started in TAGEM institutes. The most criticized issue in terms of sugar beet research in Turkey is the lack of domestic hybrid varieties used in production. Production is now completely done with hybrid varieties, all sugar beet seeds are imported or seeds are produced in Turkey by importing the parents. For this reason, sugar beet variety improvement studies should be included in the priority areas and should be supported as a priority (Çalışkan et al. 2020).

REFERENCES

Anonymous, (2013). Şeker İhracatı ve Ön İzin Belgesi Düzenlenmesine İlişkin Tebliğ. 2 Ekim 2013 Tarih ve 28783 Sayılı Resmi Gazete. Ankara.

Anonymous, (2019a) Türkiye İstatistik Kurumu, http://www.tuik.gov.tr ,

Anonymous, (2019b). Sektör Raporu 2018. Türkiye Şeker Fabrikaları A.Ş. Ankara

Anonymous, (2021). TMMOB Ziraat Mühendisleri Odası Patates Raporu Ocak/2021. http://zmo.org.tr/genel/bizden_detay.php?kod=3 1082&tipi=38&sube=0 (Erişim tarihi 8 Kasım 2022).

Anonymous, (2022). TMMOB Ziraat Mühendisleri Odası Patates Raporu Mayıs/2022 http://zmo.org.tr/genel/bizden_detay.php?kod=31082&tipi=38&sube=0 (Erişim8 Kasım 2022).

Çalışkan, M.E, Çalışkan,S., Demirel,U., Aksoy,E., Arıoğlu,H.(2020),Nişasta ve Şeker Bitkileri Üretiminde Mevcut Durum ve Gelecek, Türkiye Ziraat Mühendisliği IX.Teknik Kongresi, Bildiriler Kitabı ,Ocak/2020,Ankara

Duru,S.,Hayran,S.,Gül, A.,(2021) Türkiye Şeker Dış Ticaretinin Yapısı ve Rekabet Gücü, Eurasian Journal of Agricultural Economics 1(1), 2021

E. Günel , M.E. Çalışkan2 , A.İ.Tortopoğlu3 , N. Kuşman4 , K.M. Tuğrul5 , A. Yılmaz6 , Ö. Dede7 , M. Öztürk,(2005), Nişasta Ve Şeker Bitkileri Üretimi, Türkiye Ziraat Mühendisliği VI.Teknik Kongresi

FAO, (2022a). Food and Agriculture Organization of the United Nations (FAO) Bitkisel üretim verileri. http://www.fao.org/faostat/en/#data/QC (erişim tarihi: 04 Kasım 2022).

FAO (2022b)Istatistical database, http://www.fao.org/faostat/en/#home (Erişim tarihi: 08.11.2022).

ITC, (2022). International Trade Centre, Trade Map, https://www. trademap.org/Index.aspx (erişim tarihi: 08 Kasım 2022)

Karlı B, Gül M, Kadakoğlu B, Karadağ Gürsoy A (2018). Türkiye'de tarımsal desteklerin mısır tarımına etkileri. Akademia Sosyal Bilimler Dergisi, 307-317

Kadakoğlu, B, Karlı, B.(2021), Türkiye'de Patates Üretimi, İhracatı ve Destekleme Politikalarının Değerlendirilmesi, Isparta Uygulamalı Bilimler Üniversitesi Ziraat Fakültesi Dergisi, Cilt 16, Sayı 1, Sayfa 7, Isparta

Kepoğlu, A. (2008). Şeker Pancarında Kota Uygulamalarının Şeker Pancarı Üretimine Etkileri ve Üreticilerin Sosyo-Ekonomik Durumlarında Meydana Gelen Değişimler: Eskişehir İli Alpu İlçesi Araştırması [Yayınlanmamış Yüksek Lisans Tezi]. Ankara Üniversitesi

Industry Report: Sugar Beet (2021)

Şentürk,Ö.,(2020) Ürün Raporu Şeker Pancarı 2020, Tepge Yayın No: 328.

CHAPTER 6

AN OVERVIEW OF COTTON, JUTE, FLAX, HEMP FIBERS AND THEIR INDUSTRIAL APPLICATIONS

Assoc. Prof. Dr. Gozde ERTEKIN[1],
Assoc. Prof. Dr. Mustafa ERTEKIN[2]

[1] Ege University, Faculty of Engineering, Department of Textile Engineering, İzmir, Türkiye, 0000-0003-2150-9255, gozde.damci@ege.edu.tr
[2] Ege University, Faculty of Engineering, Department of Textile Engineering, İzmir, Türkiye, 0000-0002-5492-7982, mustafa.ertekin@ege.edu.tr

INTRODUCTION

Since the beginning of time, natural fibers have been utilized to create textiles. Nowadays, natural fibers, such as those derived from plants and animals (cellulose and protein), account for over 50% of the textile fibers produced worldwide each year. Plants are used to extract vegetable fiber. Vegetable fiber is commonly known as plant fiber or natural cellulosic fiber because cellulose makes up the majority of its composition. Among the various types of natural cellulose fiber are seed fibers (such as cotton, kapok, milkweed, etc.), bast fibers (such as flax, ramie, jute, kenaf, hemp, etc.) and leaf fibers (such as sisal, pineapple, abaca, etc.) (Figure 1). The most widely used natural vegetable fibers, in addition to cotton, are flax, hemp, jute, ramie, kenaf, and sisal (Sinclair, 2014; Markova, 2019). Natural plant fibers have a number of advantages over synthetic fibers, including cost and availability, fully biodegradable, environmental friendliness, low density and high specific properties, nonabrasiveness, and biodegradability.

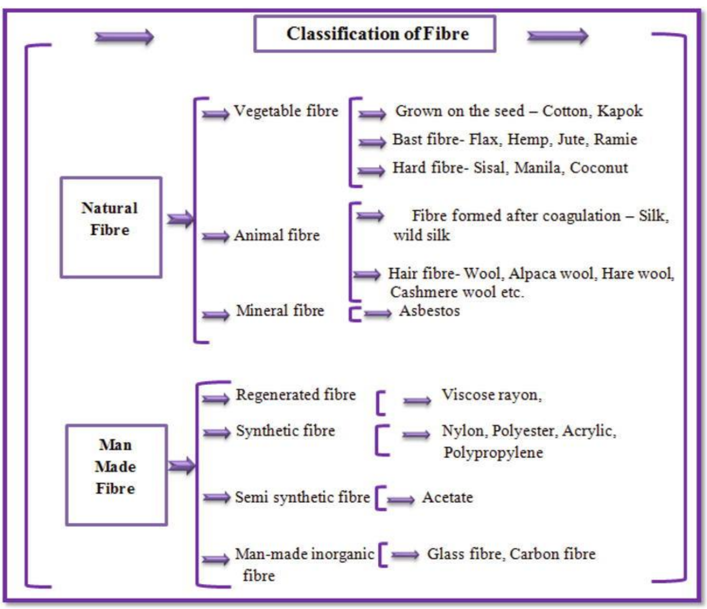


Figure 1. Classification of Textile Fibers (Guru et al., 2022)

The textile sector is currently expanding its search for green alternative fibers with the goal of delivering clean, comfortable apparel that is entirely recyclable and biodegradable at the end of its lifespan. The natural fibers such as bamboo, jute, hemp, kenaf and sisal, etc. are the present and will be the future raw materials not only for the textiles but also for modern eco-friendly composites used in various areas of application (Kozlowski and Manys, 1997; Kozlowski et al., 2004; Blackburn, 2005; Franck, 2005; Vandenhove and Van Hees, 2005; Muthu, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020).

In this chapter, the fiber structure, physical and chemical properties of the cotton, jute, flax and hemp that are the most commonly used natural cellulosic fibers in textiles are discussed. Additionally, spinning processes of these fibers and application areas are mentioned.

1. COTTON FIBER

Cotton is the most widely used natural fiber, accounting for approximately 90% of all natural fibers due to its desirable fiber characteristics. In India and the Middle East, cotton was initially used by humans more than 5000 years ago. Cotton didn't lose its position as the most significant textile fiber until the invention of man-made fibers in the twentieth century (Sinclair 2014; Kozlowski and Mackiewicz-Talarczyk, 2020). It is now only surpassed in volume by polyester, and this position is reached despite the diversity of form and physical attributes of polyester fibers. Cotton textiles' supremacy is due in part to the economics of manufacturing, distribution, and fabrication, but it also derives from the combination of structure and physical attributes (Gordon and Hsieh, 2007).

With almost 25.2 million tons produced per year, cotton is one of the most commonly used natural textile fiber crops, both in terms of agriculture and manufacture. China, the United States, India, Egypt, Sudan, Pakistan, Uzbekistan, Türkiye and Brazil produce the majority of the world's cotton, accounting for more than 80% of total production (Muthu, 2014; Sinclair, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020).

1.1. Structure of cotton fiber

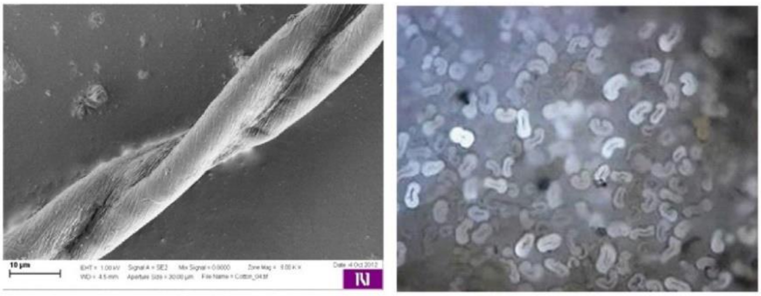
The soft, fluffy staple fibers of the cotton plant, belonging to the genus Gossypium, is collected from the cotton fruit capsule, or cotton boll, which grows from the plant's bloom. Cotton lint's biological function is to carry seed via wind, with the fine and light fibers acting as a transportation medium (Tobler-Rohr, 2011; Muthu, 2014). Raw cotton fiber comprises 90% or more cellulose (Table 1) and noncellulosics after ginning and mechanical cleaning.

Table 1. Chemical Composition of Cotton Fibers (in %) (Sinclair, 2014)

Constituent	Typical	Range
Cellulose	95	88.0-96.0
Protein (%Nx6.25)*	1.3	1.1-1.9
Pectic substances	0.9	0.7-1.2
Ash	1.2	0.7-1.6
Wax	0.6	0.4-1.0
Total sugars	0.3	0.1-1.0
Organic acids	0.8	0.5-1.0
Pigment	Trace	-
Others	1.4	-
*Standard method of estimating percent protein from nitrogen content (%N).		

Variations in composition of cellulose and noncellulosics occur because of changes in fibre maturity, cotton variety, and environmental conditions (soil, climate, farming practices, etc.). Noncellulosic elements of fiber are found mostly in the cuticle, primary cell wall, and lumen. Cotton fibers with a high surface area to linear density ratio have a greater noncellulosic content. Proteins, amino acids, other nitrogen-containing compounds, wax, pectic substances, organic acids, sugars, inorganic salts, and a trace of colours are among the noncellulosic ingredients (Sinclair, 2014).

Each cotton fibre is a single complete cell that grows in the cottonseed's surface layer. Cotton fibers consist of a cuticle, a primary wall, a secondary wall, and a central core or lumen. The cuticle is the cotton fiber's "very exterior" or "skin." It consists of a waxy coating (cotton wax) and has a significant impact on the fiber's characteristics, processing, and application. The lumen is a hollow channel that runs the length of the fiber and gives nutrients to the plant when it grows. The diameters of the lumen vary greatly depending on the maturity of the fiber. Mature fibers contain a thick layer of cellulose in the secondary wall, resulting in a narrow lumen, whereas immature fibers have a very thin wall structure and a big lumen. Cotton fiber shows as a ribbon-like structure with twists at regular intervals along its length in the longitudinal view (Figure 2(a)). Twists, also known as convolutions, give cotton an uneven fibre surface, increasing interfibre friction and allowing fine cotton strands of sufficient strength to be spun. The cross-section of cotton fiber is typically kidney-shaped; however, some are elliptical (Figure 2(b)). The fiber can swell, straighten, and become more cylindrical through the process of "mercerization," which also increases strength, dyeability, and luster (Heikinheimo, 2002; Degani et al., 2004; Sinclair, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020).



(a) (b)

Figure 2. (a) Longitudinal View (5000× magnification) and b) Cross-Section of Cotton Fibre (Sfiligoj Smole et al., 2013)

Individual cotton growing, harvesting, and ginning has an impact on a variety of fiber quality parameters as well as trash content and seed coat fragments. The most important criteria are staple length, strength, and micronaire, which are influenced by variety, growth methods, climate, and weather conditions. All of these elements influence the subsequent processing in spinning, weaving, and finishing, as well as the functionality of the various process steps. Poor fiber quality (seed coat fragments, low micronaire, neps, honeydew, and strength) is more likely to produce damage such as ends down, thin and thick places in spinning, and ends down in weaving. Low micronaire (of immature fibers) effects dyeability in finishing as well. The consequence of a high short fiber content and low fiber strength due to poor fiber processing manifests itself in the usage phase as faster abrasion and pilling of clothing (Robert et al., 2000; Tobler-Rohr, 2011).

1.2. Physical properties of cotton fiber

Fiber length (fiber length uniformity, short fiber contens), fiber strength, fineness, maturity, elasticity (or elongation) and color are the primary attributes examined when cotton is categorized or graded, and they also influence further processing and end-product quality (Sinclair, 2014). The physical characteristics of cotton are given in Table 2.

Table 2. The Physical Characteristics of Cotton (Muthu, 2014; Sinclair, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020)

Physical properties	
Fiber length	12-60 mm
Fiber diameter	12.22 μm
Tenacity	2.6 to 4.4 (cN/dtex) (dry), 3.2 to 5.3 (cN/dtex) (wet)
Fineness	2.8-4.5 micronaire
Stretch and elasticity	3-7% elongation at break. At 2% elongation, recovery is 70%
Resiliency	Low
Abrasion resistance	Fair to good
Dimensional stability	Fabrics may shrink during laundering
Moisture regain	8.5% (21°C, 65% – relative humidity)
Fiber density	1.51- 1.54 g/cm^3
Colour	Generally white, may be cream-coloured or brown

Cotton fiber is divided into three basic commercial groups according to its length:

- Fibers of the highest caliber with a staple length of 30 to 65 mm. Staple cottons are included in this category and include well-known varieties like Egyptian and Sea Island. Long staple cotton accounts for 3-5% of global production and is used for delicate fabrics with specific weights of 100 g/m^2 in the production of high-quality shirts and blouses, bed linen and underwear, etc.
- Fibers with a staple length in the 20 to 30 mm range. The American upland variety of cotton is one of these medium-length fibers, which are the most widely used kind of cotton.
- Cotton fibers with a staple length of less than 20 mm, which includes a large number of Asian and Indian fibers Short fibre content is an important aspect in processing. In HVI (high volume instrument) testing, fibre less than 12.7 mm in length is termed short fibre, and the higher the short fibre content, the worse the fibre processing ability and end-product quality.

Cotton fiber used in textiles has an average length of 25 to 37 mm. The longer the fiber, the easier it is to process and the higher the quality of the product. Longer fibers can be spun into finer counts of yarn, which can result in higher profits. It produces stronger yarn as well.

Cotton fiber has a fineness range of 5000-7000 metric count, making it the finest of all natural vegetable fibers. Finer fibers result in yarn with a finer count and help produce stronger yarns (Gordon and Hseih, 2007; Wakelyn et al., 2007; Kolanjikombil, 2018; Swicofil, 2022).

In terms of tenacity, durability, and product quality, the higher the strength, the more processing the fiber can withstand without being damaged. As opposed to long-staple cotton, which has a strength of 4-6 g, medium-staple cotton has a strength of between 3.5 and 4.5 g per single fiber. Typically, the strength or tenacity of cotton decreases with temperature and rises with moisture content. Cotton fiber has a 20% greater wet strength than dry strength Cotton has low elasticity in comparison to other fibers, with elongation of only 3-7%. Due to its little tenacity, products manufactured from pure cotton wrinkle easily and do not recover well from wrinkling. It has a 74% elastic recovery at 2% extension and a 45% elastic recovery at 5% extension. The major effect on elongation is caused by moisture. When the relative humidity is almost at saturation point, an elongation that is roughly 5% at low relative humidity increases to roughly 10%.

Cotton's maturity is a crucial characteristic; the higher the maturity, the thicker and stronger the fiber will be, or the higher the linear density, which is typically correlated with better dyeability, processing simplicity, and final product quality. Micronaire is a commonly used maturity indicator that evaluates both maturity and fineness. Lower micronaire fibers are more brittle when subjected to mechanical action, and because they are generally more flexible, they entangle and produce neps more readily. In general, it is believed that both too low (immature) and too high (over matured) micronaire cottons should be avoided, with the optimal range could be between around 3.8 and 4.2.

Raw cotton is typically white or grey, but there are also colored varieties like reamy white, blue-white, yellow-white, reddish, chamois, and tawny, among others. The main factors for grading cotton fiber are its external attributes, brightness, and color (Muthu, 2014; Sinclair, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020).

1.3. Chemical properties of cotton fiber

Cotton fiber is extremely resistant to alkalis. The use of caustic soda on cotton improves the luster and strength of the fiber.

Cold concentrated acids or even hot diluted acids cause cotton fiber to become damaged and disintegrate. In cold temperatures, weak acids have no effect on it. Concentrated sulfuric acid at a 70% concentration can dissolve cotton.

Cotton is very resistant to organic cleaning solvents. Cotton fiber can be dissolved by copper complexes like cuprammonium hydroxides, cupriethylene diamine, and similar substances.

Microorganisms have an impact on cotton fiber because they can cause bacterial, fungal, and mildew growth in hot, humid environments. The development of microorganisms can cause cotton materials to weaken.

After several hours of heating at 120°C, the fiber begins to degrade noticeably at 150°C, and after a few minutes at 240°C, it suffers severe damage. When exposed to sunlight, it turns yellow and gradually loses strength. Additionally, cotton is highly flammable (Table 3) (Muthu, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020).

Table 3. The Chemical Properties of Cotton Fiber (Muthu, 2014; Sinclair, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020)

Chemical properties	
Effects of bleaches	Highly resistant to all bleaches
Acids and alkalies	Highly resistant to alkalies. Strong acids and hot dilute acids will cause disintegration.
Organic solvents	Resistant to most organic solvents
Sunlight and heat	Withstands high temperatures well. Prolonged exposure to light will cause yelloqwing due to oxidation.
Resistance to stains	Poor resistance to water-born stains.
Dyeability	Good affinity for dyes. Dyed with direct, vat and basic dyes. Vat dyeing produces excellent wash and light fastness
Biological properties	
Effects of fungi and moulds	Highly susceptible to attack by mildew. Mildew will promote odour and discolouration and results in rotting and degradation
Effects of insects	Starched cotton are attacked by silverfish
Flammability behaviour	Burns rapidly. Smouldering red afterglow
Electrical and thermal conductivity	Good heat conductor

2. JUTE FIBER

Jute is one of the most significant and adaptable fibers of economic and technical significance among all other types of fiber. In terms of usage, worldwide consumption, production, and availability, it is the second most significant vegetable fiber after cotton. It is a long, soft fiber with a shiny appearance that is extracted from the stem of the jute plant. Due to its golden and silky sheen and high monetary value, jute is the least expensive natural fiber and is known as the "golden fiber".

Jute is a perennial herbaceous plant that is mostly grown in equatorial, tropical, and subtropical regions. India, Bangladesh, China, Myanmar, Nepal, and Thailand are the primary producers of jute. India and Bangladesh account for more than 93% of global jute fiber production. Only two of the more than 30 significant species in the genus Corchorus capsularis (whitish shine), also called "White jute," and Corchorus olitorius (golden shine), often called "Tossa jute"—are used on a large scale for the manufacture of fiber (Franck, 2005; Muthu, 2014; Annapoorani, 2018; Kozlowski and Mackiewicz-Talarczyk, 2020).

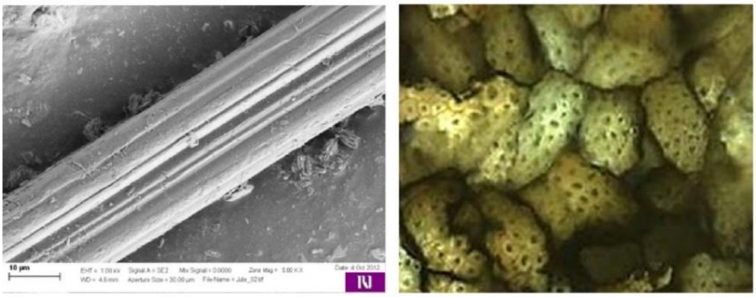
2.1. Structure of jute fiber

Jute fibers mainly consist of alphacellulose, hemicellulose, and lignin. It has secondary ingredients like lipids and waxes (0.4–0.8%), inorganic matter (0.6–1.2%), nitrogenous matter (0.8–1.5%), and traces of colors in addition to the three main components. These comprise around 2% of the total (Table 4). Due to its higher lignin content than flax and ramie, making jute harder to process and only able to yield coarser and heavier yarn and fabric. Jute is also much coarser and stiffer than flax and ramie (Franck, 2005; Muthu, 2014; Sinclair, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020).

Table 4. Chemical Composition of Jute Fibers (in % of bone dry weight of the fibre) (Kozlowski and Mackiewicz-Talarczyk, 2020)

Constituents	Jute	
	C. capsularis	*C. olitorius*
Alphacellulose	60.0-63.0	58.0-59.0
Hemicellulose	21.0-24.0	22.0-25.0
Lignin	12.0-13.0	13.0-14.0
Fats and waxes	0.4-1.0	0.4-0.9
Pectin	0.2-1.5	0.2-0.5
Proteins/nitrogenous matter, etc.	0.8-1.9	0.8-1.6
Ash	0.7-1.2	0.5-1.2

Jute fiber is a multicellular fiber. The fiber in the jute plant is created as a cylindrical sheath consisting of single fibers (ultimate cells), which are connected in a three-dimensional network from the top to the bottom of the stem. The meshy or network structure of the fiber elements holds the commercial fibers, which make up just a relatively tiny fraction (4-6%) of the entire plant, together as a unit. These fiber bundles, known as reed, are 1.5–3 m long. Each fiber component of these raw jute reed meshes is essentially a collection of ultimate cells that are joined laterally and longitudinally by components that are primarily non-cellulosic in nature. Thus, a single jute fiber contains a bundle of ultimates. The final cells have a spindle shape and vary in length and width, measuring 2.5 mm on average and 0.02 mm in the centre. The final cells' cross-sections are discovered to be polygonal with rounded corners. The middle lamella refers to the layer of natural gum that is in between the final cells. Each final cell has a thick cell wall, a central canal with an oval or slightly round cross-section, and a lumen (Kozlowski and Mackiewicz-Talarczyk, 2020). As shown in Figure 3(a), the longitudinal appearance is also straightened with striations and gums and the cross-section of jute is polygonal in shape with a central lumen (Figure 3 (b)) (Sinclair, 2014).



(a) (b)

Figure 3. a) Longitudinal View (5000×magnification) and b) Cross-Section (180×magnification) of Jute Fibre (Sfiligoj Smole et al., 2013)

2.2. Physical properties of jute fiber

As with other bast fibers, jute has a "composite-like" structure with densely aligned long chain molecules, making it a robust fiber with very little flexibility. They have a high initial modulus but just a little amount of recovered elasticity. The breaking elongation of jute fiber is quite low, ranging between 1.0% and 1.8%. Based on single fiber test lengths of 10 mm or shorter and a time to break of 10 sec, a tenacity of 70 g/tex is a good medium value for a wide variety of jute fibres. This tenacity number is ideal for fibers with a linear density of 1.8 tex. The jute filament is comparable to steel in terms of tenacity. Due to its coarseness and inelastic structure, jute fiber has much higher flexural and torsional rigidities than cotton or wool. For this, jute textile material wrinkles and creases rapidly (Table 5). They have a light lustre as well. Its luster determines its quality; the more it shines, the higher the quality. Jute has excellent insulating and antistatic qualities, as well as low heat conductivity (Franck, 2005; Annapoorani, 2018; Kozlowski and Mackiewicz-Talarczyk, 2020).

Table 5. The Physical Characteristics of Jute Fiber (Muthu, 2014; Sinclair, 2014; Mather and Wardman, 2015)

Physical properties	
Fiber length	0.5-6.0 mm
Fiber diameter	0.015-0.020 mm
Tenacity	30-45 cN/tex
Fineness	26-30 μm
Stretch and elasticity	1.7 % elongation at break. Low elastic recovery
Resiliency	Poor
Abrasion resistance	Poor to fair
Dimensional stability	Good
Moisture regain	12.6 %, but it can absorp up to 23% of water under conditions of high humidity
Fiber density	1.3-1.5 g/cm^3
Colour	Yellow to brown to grey. May be bleached to white

2.3. Chemical properties of jute fiber

Alphacellulose, hemicellulose, and lignin, which together make up more than 97% of the total jute contents, are primarily responsible for the chemical qualities of jute fiber. It is completely biodegradable and recyclable, making it environmentally sustainable. The chemical properties of jute are summarized in Table 6.

Jute has excellent resistance to bleaching agents. Both sodium chlorite and hypochlorite are the most often used bleaches for jute. Since lignin is that gives jute its natural yellow to reddish color, sodium chlorite or hypochlorite dissolves away lignin, making jute whiter. Bleaching treatment weakens jute by partially removing lignin, which weakens the middle lamella (a main location of lignin between the final cells). As a result, as the multicellular structure partially disintegrates, the jute fibers likewise get finer. Acids deteriorate and degrade jute fibers. Jute is more negatively affected by inorganic acids than by organic acids because inorganic acids hydrolyze cellulose chains more quickly. Due to the presence of hemicelluloses, jute fibers have weak resistance to alkali.

Table 6. The Chemical Properties of Jute Fiber (Muthu, 2014; Sinclair, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020)

Chemical properties	
Effects of bleaches	Not affected by oxidizing or reducing bleaches
Acids and alkalies	Easily damaged by hot dilute or cold concentrated acids. Resistant to alkalies
Organic solvents	Resistant to organic solvents
Sunlight and heat	Poor sunlight resistance. Scorches at high temperatures.
Resistance to stains	Poor resistance to water-borne stains.
Dyeability	Easily dyes, but light- and washfastness are poor.
Biological properties	Scoured jute has good to excellent resistance to microrganisms and insects
Flammability behaviour	Burns rapidly. Smouldering red afterglow
Electrical and thermal conductivity	Moderate conductor of electricity and heat

Because of the carboxylic acid, the fiber has a great affinity for basic dyes like methylene blue and can bind cationic ash minerals. The ability to be dyed is simple; basic dyes are typically used.

The presence of lignin in sunlight causes a slight change in the color of jute fiber. Mildew's impact resistance outperforms cotton and linen. It also has some heat and fire resistance. Liquid ammonia has a comparable effect on jute, as well as the added attribute of boosting flame resistance when treated with flame proofing chemicals (Rowell and Stout, 2007; Muthu, 2014; Mather and

Wardman, 2015; Annapoorani, 2018; Kozlowski and Mackiewicz-Talarczyk, 2020).

3. FLAX FIBER

Flax is the earliest natural fiber employed by our ancestors dates back to the Neolithic period, between 10,000 and 8,000 years ago, when people transitioned from a nomadic lifestyle of hunting and gathering to a more settled, agrarian way of life. Linum usitatissimum, which literally translates as "useful linen," is derived from the Latin name for the flax plant and recognizes the intrinsic usefulness of this simple species. The term "line" comes from linen thread, which was used to draw a straight line.

Fibre flax is a plant that is commonly cultivated in the Mediterranean region of Europe (Swiss lake region) and is mostly grown in moist temperate areas. The Soviet Union, Poland, and France are the world's top linen producers. Outside of Europe, China and Egypt grow fibre flax.

Two forms of "flax" are typically recognized in the agricultural sector from an economic perspective: fibrous flax and oleaginous flax (linseed). Oleaginous flax, commonly known as linseed or oil flax, is successfully grown in Egypt and is currently grown on considerable scales in Canada, Argentina, the United States, and India. Its seed crop is far more profitable than the textile flax crop since it does not require labor-intensive processing procedures and is in strong demand on the global linseed markets at steadily growing prices (Blackburn, 2005; Franck, 2005; Hallett and Johnston, 2014; Muthu, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020).

3.1. Structure of flax fiber

Flax fibers mostly consist of cellulose, with minor amounts of hemicellulose, lignin, pectins, oils, and waxes. The cell walls contain cellulose, hemicellulose, and pectins (Franck, 2005). Lignin makes cellulose stiff by acting as an inlaying component within amorphous portions of cellulose. Lignin can be found in the primary wall and outer portion of the secondary wall of the elementary fiber. Lignin is unsuitable for processing because it makes fiber touch and elasticity worse. Lignin makes fibers more brittle and causes a decline in the mechanical properties of tenacity and resilience. Additionally, the presence of lignin reduces the fiber's divisibility. Flax fiber consists of cells connected by a lamella, which is primarily made of pectins. The fineness of the fiber and its suitability for spinning are determined by the divisibility, which is determined by the proper removal of pectin compounds during preparatory processing. In terms of technological characteristics, waxes and lipids establish low friction, a pleasant touch, and the ease of manipulating the fiber. Waxes are mostly found on the outside portion of the stem, in the epidermis, and in smaller quantities in the fiber cells of flax fiber (Table 7).

Table 7. Chemical Composition of Flax Stems and Fibers at Maturity (in %) (Franck, 2005; Kozlowski and Mackiewicz-Talarczyk, 2020)

Constituents	Flax	
	Stem	*Fiber*
Cellulose	49-60	85-87
Hemicellulose	10-25	7-9
Lignin	17-23	2.5-4
Pectin	3-4	1.5-2.5
Fats and waxes	1.5-3	-
Ash	1	1

Flax fibers are found inside the plant as discrete filaments of various lengths, which vary depending on the size of the leaf they support on the plant's stem. Each filament consists of a number of single tapered-ended fiber cells that are joined lengthwise in an even pattern such that each cell covers 50% of the one before it and overlaps 50% of the one after it. These cells are then tightly bound together to form single filaments that are the same regular fine thickness but vary in length. Each plant leaf is served by a group of ten identically sized single filaments that descend from the leaf's height to the soil's surface. Each time, the ten filaments are the same length as the plant's served leaf's height. The ten filaments are arranged in bundles, completely encircled by a holding tissue that fills the interior space between the wooden cylinder and the outer skin, and distributed in a circular pattern around a central wooden cylinder that supports them rather than adhering to one another. These traits are what give fine textiles their best chances of producing regular fine yarn successfully and without significant spinning issues. The longitudinal view, as shown in Figure 4(a), reveals that, unlike cotton, flax fiber has no convolutions, but rather longitudinal lines or striations with protuberances termed nodes scattered unevenly along the length. A cross-section of the individual fibres reveals that they are polygonal in shape, with a thick, fleshy wall enclosing a central hollow core, or lumen (Figure 4 (b)). The lumen in mature fibers, however, is not as evident as it is in cotton (Sinclair, 2014; Kozlowski and Mackiewicz-Talarczyk, 2020).

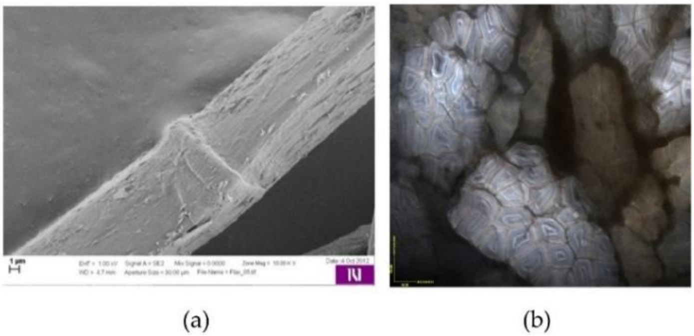


Figure 4. a) Longitudinal View (10000×magnification) and b) Cross-Section (30×magnification) of Flax Fibre (Sfiligoj Smole et al., 2013)

3.2. Physical properties of flax fiber

Because of its short single cell, flax is typically used in textile processing in bundle fibres (several single cells bonded together by gums); thus, flax bundle fibre is longer (usually 300-700 mm) and coarser (200-500 metric count) than cotton. They range in length from 8 to 51 inches (20 to 130 cm) and have a micron count (diameter) of 12 to 16.

Because of the high content of gums, flax fiber is stronger, more rigid, and has less elasticity than cotton. Wet flax, like cotton, is stronger than dry. Linen is resistant to abrasion; however, it can "crack" if continually folded in the same area and wrinkles easily.

An individual fibre has a diameter of 15-20 m on average. The fiber's color ranges from creamy white to yellowish brown to grey. The residual wax from the flax stem contributes to the shiny appearance of linen. The fiber's cross section consists of irregular polygon forms, giving it a gritty and sharp appearance.

After the contaminants are removed from the fiber, it becomes hygroscopic, absorbing up to 20% of its weight in moisture or perspiration and swiftly releasing it into the atmosphere, leaving it dry to the touch. The material has no insulative characteristics and does not lock in or retain air, allowing the linen wearer to stay cool. It regulates body temperature and encourages acclimatization in hot situations. To become trans-seasonal, linen can be combined with more insulating fibers such as cashmere or wool. Another advantage of flax fibre is that it does not gather an electrostatic charge, which is good for human health and gives psychophysical comfort (Table 8) (Blackburn, 2005; Franck, 2005; Hallett and Johnston, 2014; Sinclair, 2014).

Table 8. The Physical Characteristics of Flax Fiber (Muthu, 2014; Sinclair, 2014)

Physical properties	
Fiber length	20 to 130 cm
Fiber diameter	12 to 16μm
Tenacity	4.8-5.8 cN/dtex
Stretch and elasticity	2.7-3.3% elongation at break. At 2% elongation, recovery is 65%
Resiliency	Poor resiliency; creases and wrinkle badly.
Abrasion resistance	Fair to good
Dimensional stability	Fibers will not stretch or shrink, but fabrics are subject to relaxation during laundering
Moisture regain	11-12 % at 65% relative humidity
Fiber density	1.4-1.5 g/cm^3
Colour	May vary from light ivory to dark tan or grey

3.3. Chemical properties of flax fiber

Flax's characteristics and uses are determined by its chemical composition and the distribution of its constituents within the stem. Only concentrated acids will cause significant damage on flax fiber. It is extremely resistant to alkalis. In cold temperatures, chlorine and hypochlorite bleaching agents have no effect on the flax fiber. It has strong resistance to organic solvents. Flax, like cotton, is susceptible to mildew if stored in high humidity, albeit to a lesser extent. Because of the higher level of gum in the fiber, flax is more resistant to insect attack than cotton. Because of the finer surface of the fiber, it is resistant to stains and can be cleaned at lower temperatures than cotton. The surface of linen cloth responds nicely to steaming and pressing, resulting in an almost polished appearance (Table 9) (Müssig, 2010; Muthu, 2014; Hallett and Johnston, 2014).

Table 9. The Chemical Properties of Flax Fiber (Sinclair, 2014)

Chemical properties	
Effects of bleaches	Not affected by common household bleaches
Acids and alkalies	Easily damaged by hot dilute or cold concentrated acids. Highly resistant to all alkalies.
Organic solvents	Resistant to organic solvents
Sunlight and heat	Extended exposure to sunlight weakens fibres. Scorches at high temperatures.
Resistance to stains	Is not as harmed by water-borne stains as cotton and will give up stain more readily.
Dyeability	Linen does not have a good affinity for dyes. It is dyed with direct and vat dyes.
Biological properties	
Effects of fungi and moulds	Very vulnerable to damage by mildew
Effects of insects	Not damaged by insects.
Flammability behaviour	Burns rapidly. Smouldering red afterglow
Electrical and thermal conductivity	Good electrical and heat conductivity

4. HEMP FIBER

For centuries, hemp (Cannabis sativa) has been used to produce fiber for a variety of products, including textiles, ropes, sails, and modern-day industrial product matrices. It has been grown and used in numerous nations throughout the world, in both the northern and southern hemispheres (Kozlowski and Mackiewicz-Talarczyk, 2020).

Hemp was widely produced in Britain during the eighteenth century. Hemp's primary use was in shipping, where there was a high demand for ropes, sails, and sacking. However, production fell during the nineteenth century as jute and cotton prices dropped and these markets were served. Today, hemp's versatility has recently become popular. China, Spain, Korea, and Russia are the top four nations for hemp fiber production. The plant can withstand a wide range of climatic conditions, but it needs humus-rich soil with a pH that is just on the alkaline side of neutral. It is claimed that hemp produces about 2-3 times as much fiber per acre as cotton does, despite growing quickly and reaching maturity in about 3–4 months. Despite the fact that the plants typically do not require pesticide or insecticide spraying, certain insects can feed on the plant and weaken the stem.

4.1. Structure of hemp fiber

Similar to flax, hemp is a bast fiber that is derived from the plant's stem. The same retting procedure used for flax is used to extract the fibers. The resulting fibers contain hemicelluloses and lignin but have much lower cellulose contents than cotton. These two substances frequently coexist in the cell walls of plants, giving them strength, which is a crucial quality for the stems of plants (Mather and Wardman, 2015). At almost 77% of the total weight, cellulose is the main component of hemp fiber. Pectins, lignin, vegetable waxes and lipids, different water-soluble compounds, and around 10% hygroscopic water make up the remaining portion (Table 10).

Within the hemp stalks, there are multiple layers of fiber bundles. A bundle consists of many fibers, and unit cells join bundles together. In contrast to the outer layers, the bundles in the inner layers are often shorter and finer. Unit cells might be triangular or heptagonal in shape, with rounded corners and a big pith. Hemp processing is based on loosening and dissolving the lignified pectin link that holds unit cells together. The unit cells' diameter ranges from 15 to 50 microns. The cells typically measure 35 mm by 40 mm, however they can be any length between 5 and 100 mm. The fiber bundles are between 1500 and 2500 mm long (Franck, 2005). The central lumen of hemp fibers is wider than that of flax, and the cells of the fibers have thick walls and polygonal cross sections (Figure 5) (Fangueiro, 2011).

Table 10. The Chemical Compostion of Hemp Fiber (in %) (Mather and Wardman, 2015)

Constituents	Hemp
Cellulose	77.9
Water	6.6
Hemicellulose	6.1
Solubles	4.3
Protein	2.7
Lignin	1.7
Pectins	1.4
Waxes	1.5
Ash	1.2

Figure 5. a) Longitudinal View (10000×Magnification) and b) Cross-Section (200×Magnification) of Hemp Fibre (Sfiligoj Smole et al., 2013)

4.2. Physical properties of hemp fiber

Hemp fibers typically have lengths of 13 to 15 mm and diameters of 15 to 20 µm. Hemp fiber has a slightly better breaking strength than flax fiber, but has a lower elongation (2–3%). The fineness of the bundle affects the flexibility of the material. The fibers are 30% more resistant to abrasion than cotton fibers.

Hemp fibers are stiffer and more brittle than cotton fibers, and they handle more harshly due to the presence of lignin. While some hemp fibers are fairly shiny and bright, others are darker, which lessens their appeal.

Because hemp is hygroscopic, it regains moisture well, which is advantageous for processing all fibers. The moisture regain is 12%. In addition, it has good sound absorption (Table 11) (Franck, 2005; Fangueiro, 2011; Tobler-Rohr, 2011; Mather and Wardman, 2015; Zhang et al., 2016; Kim and Kim, 2018; Sauvageon et al., 2018).

Table 11. The Physical Characteristics of Hemp Fiber (Franck, 2005; Muthu, 2014; Mather and Wardman, 2015)

Physical properties	
Fiber length	1500-2500 mm
Fiber diameter	15-50 µm
Tenacity	53-62 cN/tex
Fineness	20 µm
Stretch and elasticity	Hemp is not very extensible and stretches only 1.5%. Poor elastic recovery

Resiliency	Good
Moisture regain	12 %
Fiber density	1.54 g/cm^3
Colour	Yellowish grey to dark brown

4.3. Chemical properties of hemp fiber

Hemp fiber can dissolve in a hot, concentrated alkaline solution. Inorganic acid, alkali, or cold diluted alkali have no effect on it. However, cold concentrated sulfuric acid and hot dilute acid can both damage it. It has resistance to beetles or grubs that feed on moths. Since dyeing hemp is difficult, the majority of hemp is sold in its natural color.

Hemp can withstand the test of a high temperature of 370°C and has good permeability, and heat resistance. Additionally, hemp fiber has good absorption qualities against IR and UV radiation and long-lasting mildew resistance. They are not conductive and have a natural low flammability (Table 12) (Dupeyre and Vignon, 1998; Wang and Postle, 2004; Wang and Ramaswamy, 2005; Batra, 2007; Tobler – Rohr, 2011; Shahzad, 2012, 2013; Muthu, 2014; Mather and Wardman, 2015; Zhang et al., 2016; Kim and Kim, 2018).

Table 12. The Chemical Properties of Hemp Fiber (Marther, Wardman, 2005)

Chemical properties	
Acids and alkalies	Easily damaged by hot dilute or cold concentrated acids and by a hot, concentrated alkaline solution
Organic solvents	Resistant to organic solvents
Sunlight and heat	Stable, but prolonged exposure gradually weakens it. Excellent thermal degradation resistance
Dyeability	Poor
Resistance to decay	More resistant to decay than flax
Flammability behaviour	Low

5. SPINNING OF COTTON AND BAST FIBERS

Fibres are generally categorised as staple fibers, filaments and tow. A staple fiber is one that is relatively short in length, like the majority of natural fibres, which can be as small as a few millimeters (like the shortest cotton fibres, known as linters) to as long as a metre (e.g. fibres from bast plants).

Typically, the length of staple fibres ranges from 3 to 20 cm. A fiber with an indefinite length is called a filament. The only natural filament fibres is the silk. The majority of synthetic and recycled fibres are created as filaments. These come in mono-filament and multifilament varieties. Some of these are also put together to form a "tow," which is cut or broken into the necessary short lengths to create staple fibres appropriate for blending with other fibres, particularly cotton or wool. A tow is an extensive collection of filaments used to make shorter (staple) fibers in the synthetic fiber industry. In another word, when the stalks are processed to remove the fibers, the shorter fiber generated is known as tow in the processing of natural fibers (flax) (the long fibres are called line flax).

The functionality of a staple yarn is governed by the fiber quality parameters, yarn construction, and quality attained by the selected spinning process through particular machinery settings. For the desired yarn quality, the fiber qualities must be chosen carefully. For example, the most important fiber qualities for yarn creation in ring spinning technology are staple length and micronaire for fiber embedding. Fiber characteristics determine traditional staple yarn qualities such as strength, elongation, and hairiness.

After being processed, yarns must to put together in some way to produce a fabric. A manufactured assembly of fibers and/or yarns with a significant surface area relative to its thickness and enough cohesion to provide the assembly with practical mechanical strength is refered to as a fabric. A fabric or textile surface can be made in a variety of ways by combining different yarns. Among the most significant are weaving, knitting and nonwoven. Weft and warp yarns for woven fabrics and yarns for knitwear are the two main fabric categories. Priorities include fineness and strength, as well as low abrasion. While fineness must be tailored to the intended fabric weight (knit or woven), strength is determined by the purpose of the garment. The spinning technology (ring spinning for very fine yarns), the proper machinery settings, and the yarn construction are used to regulate the fineness. Strength can be increased by twisting the yarn correctly and using specific yarn architectures such as ply yarns or core yarns. As a result, yarn construction and machinery settings have an impact on the structure of the yarn. The spinning technology used (ring spinning, compact spinning, OE spinning, and friction spinning) determines the function of the yarn and resulting fabric's characteristics such as strength and hand (harshness or softness), and thus its suitability for underwear or upperwear (jeans, trousers, skirts, jackets) (El Mogahzy et al. 1998; Lloyd and Taylor 1998; Tobler-Rohr, 2011; Sinclair, 2014).

5.1. Spinning of cotton fibers

Spinning is a catch-all word for all of the procedures that fibers will go through to form yarn, ready for weaving or knitting. Once at the spinning mill, the bales are opened and cleaned to remove any residual vegetable matter and short lint. A picker machine beats, loosens, and mixes the fibers, which are then pushed through toothed rollers of varied sizes to remove the vegetable matter residue. Finally, the fibers exit the machine as batts, which are large bundles of several strands of fiber that are ready to be carded. The short lint is sold and used in other processes and applications. The carding machine properly aligns the fibers, making them easier to spin. This is accomplished by running the batts through various-sized rollers, which yield slivers, or untwisted strands of fibers. Combing is typically performed after carding to provide a nicer, smoother finish to the fibers and eventual fabric. Combs are used to remove the short strands, known as noils, and arrange the remaining fibers in a flat bundle so that they all face the same direction. After that, several slivers are joined to balance the thicker and thinner regions of the slivers, resulting in a more constant size. Because these are now too thick, they are split into rovings, which are long, narrow bundles of fiber with twist to keep them together. The rovings are then spun into threads (Hallett and Johnston, 2014).

5.2. Spinning of jute fibers

The most conventional jute spinning system includes two steps of carding, three stages of drawing, and finally a spinning stage (Figure 6). Long lengths of fibre are passed through a breaker card in the first carding stage, which breaks the continuous mesh of fibres into discrete pieces, aptly called 'entities,' which are similar to single fibres of cotton and wool. In addition to fragmentation, the breaker card pins clean the fibre proper by eliminating loosely clinging non-fibrous debris.

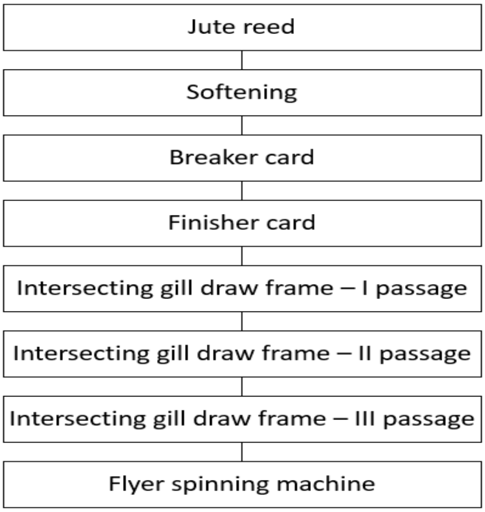


Figure 6. Flow chart of conventional jute yarn production (Franck, 2005)

Jute spinning has experienced numerous technological advancements. Detailed information can be obtained from the reference (Franck, 2005).

5.3. Spinning of flax fibers

According to traditional view, flax fibers have naturally heterogeneous textile properties that make spinning them a challenging and difficult task that can only be completed by highly skilled spinners.

For flax spinning, consistency in length and fineness are two key components. The straw's good maturity results in less variability between the top and bottom fibrils. After extraction and hackling, both short and long fibers can be spun, but short (tow and noils) and long fibers require different spinning methods (Kozlowski and Mackiewicz-Talarczyk, 2020). There are two ways to spin flax. Scutched-flax spinning is one method that involves spinning the long strands. The other method is tow spinning, which is used for shorter fibers or tows.

Spinning consists of several steps that allow the fibres to be transformed into yarn. The procedures utilised differ depending on the raw ingredients used and the type of yarn to be produced. To summarise, the spinning process entails drafting and doubling, or carding and pulling out the long or short fibres into sinuous 'ribbons' that are then put together on spinning looms in various weights and thicknesses. Wet, dry, or semi-wet spinning processes can be used to spin both the long fibers and the tow. Wet spinning long fibers yields a very fine yarn suitable for fine garments and the finest bed linen. Dry spinning produces coarser, less regular yarn with some naps, which is primarily used in home textiles. A last step removes faults and impurities before knotting and splicing the yarn together (Blackburn, 2005; Hallett and Johnston, 2014).

5.4. Spinning of hemp fibers

The two main types of hemp fiber traditionally produced during the removal of the fibers from the stems and capable of being spun into yarns are long staple fibers and shorter tow fibres. A certain amount of short fiber is eliminated during the scutching and hackling processes as part of the extraction and preparation of the long fibers.

Depending on the quality of the hemp being processed and the uniformity of fineness, length, and cleanliness, this fiber can be processed in order to be spun into a variety of yarns. Contrary to long fibers, hemp tow fiber is typically processed and spun using more traditional fiber preparation and spinning machinery. Scutched tow or hackled tow are the two main types of this fiber. In contrast to tow fiber hemp, which can be used to produce finer yarns and is frequently blended with other fibers before spinning, long staple fiber is typically spun to produce a relatively coarse yarn.

Wet spinning or dry spinning methods can both be used to spin long fiber hemp rove. Nowadays, dry spinning is the most popular method for producing hemp fibers because wet spinning is significantly more expensive. On frames similar to those used for spinning long fiber hemp but with a smaller drafting zone, short-fibre hemp prepared for spinning as a sliver is typically spun using a dry spinning method as opposed to a wet spinning method. The maximum yarn fineness that can be produced using this method is about 65 tex due to the fact that the fibers, despite being partially subdivided, still exist in groups. The finished yarns are typically open-structured and soft.

The spinning processes used to create long-staple fibers, flax, and hemp are relatively specialized processes that have not attracted the same level of innovation as shorter-staple systems. The majority of recent advancements in spinning technology have focused on techniques like warp, ring, open-end, and friction spinning, as well as the use of cotton and short-staple synthetic fibers.

However, there has been some advancement in the production of hemp fiber with short staples that is long enough to be processed alone or in blends with other fibers with short staples.

In the past ten years, there has been an increase in interest in the use of hemp fiber in blends with cotton and synthetic fibers in fabrics, both woven and knitted, primarily due to the production of hemp fiber's potentially attractively low environmental impact. In dry spinning, hemp can be combined with cotton, the majority of synthetic materials, and wool. Flax fibers should be between 20 and 60 mm in length for cotton spinning systems, while hemp fibers should be between 60 and 120 mm for wool spinning systems. In general, there are several options for how hemp fibers can be spun on short-staple systems with other fibers and in what proportions. Hemp fiber combined with cotton and polyester, in amounts ranging from 10% to 60%, is the most crucial blend for the production of yarns used in clothing fabrics. Additionally crucial is how it blends with viscose. Hemp and wool blends are simpler to achieve and can result in coarse yarns with up to 90% of wool.

Most hemp yarns are produced for weaving and range in count weight from 3.5 to 5 Nm. Hemp yarn is spun and then wound on cone winders. A large container, typically a cone, is used to immediately transfer spun yarns after they have been spun. In order to create a package of uniform density and preserve the structure of the yarn, this procedure, known as winding, is typically carried out quickly. Winding offers the chance for quality control and the correction of flaws even though the process itself is not productive. Typically, comb winders are used to wind fine hemp yarns with counts ranging from Nrn 1 to Nm 6 that are made from both long and short hemp fibers. On significant weight cross winders up to 10 kg, thicker hemp yarns with a count of between 0.20 and 1 Nm are wound (Figure 7) (Kozlowski and Mackiewicz-Talarczyk, 2020).

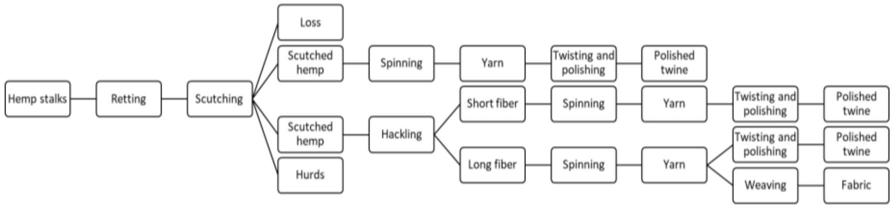


Figure 7. Flow chart of long fiber hemp production (Kozlowski and Mackiewicz-Talarczyk, 2020).

6. APPLICATION AREAS

6.1. Application areas of cotton fiber

Cotton is one of the most commonly used textile fibers because of its adaptability. It is used in textile products in thousands of different ways (approximately 100 major uses), from nappies to the fanciest skirts, coats, and jackets. These applications can be divided into three primary groups: Clothing industry, home furnishings and industrial products.

- Clothing industry: Cotton is used most frequently in underwear, followed by trousers and shirts, particularly for casual wear, thanks to its comfort and ease of laundering. Cotton is used more often in denim and jeans than in any other type of clothing.
- Home furnishings: Cotton's absorbency makes it an ideal fabric for home items like blankets, towels, sheets and pillowcases.
- Industrial products: Tarpaulins, bookbindings, and zipper tapes are just a few examples of the industrial goods that employ cotton. Medical and hygienic supplies like hydrophilic cotton (cotton wool), compress, gauze bandages, tampons or sanitary napkins, cotton swabs and industrial threads are two of the main industrial uses for cotton (Muthu, 2014; Sinclair, 2014).

6.2. Application areas of jute fiber

Jute is one of the most versatile natural fibers, with applications in packaging, textiles, non-textiles, building, and agriculture etc. It can be used for a variety of applications summarized below:

- Packaging material: The jute business has been around for over 150 years, and despite its ups and downs, its goods effectively matched the global share of packaging. Jute is primarily used to make items for packaging grains, sugar, cocoa, coffee, and other food crops, as well as cement, fertilizers, salt, cotton, and other textile products. Sacking, ropes, twines, and other packaging materials, as well as carpet backing cloth, have been made from jute.

- Home textiles: For a variety of household textiles, such as bed linens, pillows, tablecloths, tableware, cushion covers, curtains, blankets, carpets, flooring, decorative fabrics and wallpaper.
- Geotextiles: It is extensively used as a geotextile for a variety of purposes, including soil stabilization, erosion control, and other uses.
- Building materials: Chipboard and other composites (pseudo-wood) can be made from jute and used in the construction of buildings.
- Structural composites used in construction: False ceilings, panels, partitions, doors, windows, furniture, and prefabricated shelters.
- Textiles for automobiles: Jute felts are used in composite form in door panels, dashboards, headliners, brake linings, parcel shelves, auto trims, and other interior components. They are also used as seat backing and carpet underlay.
- Protective textiles: For aprons and gloves with special fireproof, oil- and water-repellent finishes to safeguard personnel working in refractories, oil refineries, fire departments, and engineering plants.
- Medical applications: Non-woven jute fabrics with antibacterial finishes are used in medical apparel such as sterile applications.
- Clothing: Hessian cloth. Jute is also used to make ghillie suits, which are used as camouflage and look like grass or bushes.
- Additional uses: Shopping bags, carrier bags, handicrafts, letter boxes, sign boards, and packing boxes, cordage, felts and paddings (Franck, 2005; Müssig, 2010; Muthu, 2014; Annaporani, 2018; Kozlowski and Mackiewicz-Talarczyk, 2020).

6.3. Application areas of flax fiber

Many elements of the flax plant, including the seeds, leaves, straw, bast, and the woody core, have the potential to yield valuable textile fibers and are also suited for technological uses. Additionally, raw materials from flax can be used to make biopolymers, in the aerospace and automotive industries, geotextiles, as well as for insulation, building materials, the manufacturing of agro-fine chemicals, pharmaceuticals, cosmetics, and food. Pulp, cigarette paper, packaging, laminates, coatings, particleboards, and nonwovens are further uses for short coarse fibers. Some of the application areas is summarized below:

- Clothing: Suits, dresses, skirts, shirts, etc. To improve the feel of denim in hot and humid weather, flax/cotton blended yarns are currently being produced.
- Household textiles: This includes tablecloths, table damasks, handkerchiefs, serviettes, placemats, bed and bath fabrics such as dish towels, and bed sheets, towels, tea towels, glass and floor cloths, as well as sheets, pillowcases, and duvet covers.
- Industrial (technical) products: Luggage, sail and tent canvases, fishing lines, fishing nets, book binding thread, leather working threads, sewing thread, agricultural twines, butcher's and other food-processing strings, ropes and cordage, and occasionally coupled with hackled tow to increase spinning to produce heavy industrial items such as tarpaulins, awnings, and post bags.
- Furnishing items: Wallpaper/wall coverings, upholstery, window treatments, etc.
- Additional uses: Flax fabric has traditionally been used as an oil painting support due to its superior strength, durability, and archival integrity when compared to cotton. Bakers use flax cloth to keep the dough in shape before baking (Blackburn, 2005; Franck, 2005; Müssig, 2010; Muthu, 2014; Annapoorani, 2018; Kozlowski and Mackiewicz-Talarczyk, 2020).

6.4. Application areas of hemp fiber

Hemp is one of the fundamental fibers that has produced a variety of significant goods, including pulp and paper as well as textile fibers. It has been used in modern times for a variety of applications, including:

- The production of durable clothing, nutritional supplements, and cordage (string, twine, cord, and rope) with varying tensile strengths.
- Industrial uses for hemp include paper, textiles, clothing, canvas for sails, biodegradable plastics, construction, body products, etc. (Franck, 2005; Muthu, 2014; Sinclair, 2014; Kim and Kim, 2018).

Hemp has historically been grown for its three main products: fiber, seeds, and psychoactive compounds (Table 13).

Table 13. Main Uses of the Hemp Plant and Its Fractions (Müssig, 2010)

Hemp seeds (Oil, food, feed)	Food applications, industrial applications, detergents, cosmetics, paints, lecithins, fatty acids
Long bast fiber bundles	Quality papers, technical fiber bundles, textiles, ropes/twines, geotextiles, composites
Short bast fibre bundleds	Building sector, paper pulp, MDF, building blocks
Hurds	Paper boards, energy, particle boards, animal bedding

7. FUTURE TRENDS

7.1. Future trends for cotton

Some of the major trends in cotton research and development are its fibre properties, development of cotton cultivation and processing to reduce environmental impact, improvement and standardisation of methods for evaluating the quality of cotton fibre and yarn, promotion of cotton as a desirable natural fibre, and discovery of new uses for cotton seeds and by-products. Reducing the use of fertilizers and other chemicals in agricultural production is an important trend in this industry, both to manage costs and lessen the environmental impact of cotton processing. Later steps of cotton processing, like bleaching and dyeing, which have had a large environmental impact, are also undergoing similar initiatives. For instance, non-impact dyes might use less water; set the dyes at lower temperatures and chemical processing is also being replaced by enzyme technology.

7.2. Future trends for jute

Jute and jute products have been shown to be completely innocuous in terms of global warming, a problem that is very important in the current world. Natural fiber products are growing more popular as consumers worldwide become more aware of the pollution that synthetic materials produce. Nevertheless, given its low cost, production from renewable resources, and complete biodegradability, jute is likely to be a significant fiber in the future (Mather, Wardman, 2015; Kozlowski and Mackiewicz-Talarczyk, 2020).

7.3. Future trends for flax

Flax offers several ecological and health benefits. Compared to other textile fibers, its cultivation and processing require less fertilizer and weed control chemicals. Although customers generally may not be aware of these benefits of flax or the products manufactured from its fibers, individuals who have used them in the past are beginning to appreciate them. Their interest in linen items should rise as these ecological and health concerns gradually gain more weight in the minds of the average customer in industrialized countries.

7.4. Future trends for hemp

As environmental protection becomes more important, it is expected that use of hemp products will increase. In addition to the traditional end-uses, the development and consumption of specialized products may flourish. In the realms of manufacturing technology and product development, there is and will continue to be a need for tighter collaboration between research and development institutes and industrial hemp enterprises (Franck, 2005).

REFERENCES

Annapoorani, G. S. (2018). Agro Textiles and Its Applications. Woodhead Publishing.

Batra S.K. (2007). Other long vegetable fibers: Abaca, banana, sisal, henequen, flax, ramie, hemp, sunn and coir. In: Lewin M. (ed) Handbook of Fiber Chemistry, Taylor & Francis Group, Boca Raton.

Blackburn, R. S. (2005). Biodegradable and Sustainable Fibers, The Textile Institute.

Degani, O., Gepstein, S., & Dosoretz, C. G. (2004). A new method for measuring scouring efficiency of natural fibers based on the cellulose-binding domain-β-glucuronidase fused protein. Journal of biotechnology, 107(3), 265-273.

Dupeyre, D., & Vignon, M. R. (1998). Fibres from semi-retted hemp bundles by steam explosion treatment. Biomass and Bioenergy, 14(3), 251-260.

El Mogahzy, Y., Broughton Jr, R., Guo, H., & Taylor, R. A. (1998). Evaluating staple fiber processing propensity: PART I: Processing propensity of cotton fibers. Textile research journal, 68(11), 835-840.

Fangueiro, R. (Ed.). (2011). Fibrous and composite materials for civil engineering applications. Elsevier.

Franck, R. R. (Ed.). (2005). Bast and other plant fibres (Vol. 39). CRC Press.

Gordon, S., & Hsieh, Y. L. (Eds.). (2007). Cotton: Science and technology. Woodhead Publishing Ltd, Cambridge.

Guru, R., Kumar, A., & Kumar, R. (2022). Basic Functional Application for Natural Fibers and Types. In (Ed.), Natural Fiber. IntechOpen. https://doi.org/10.5772/intechopen.102998.

Hallett, C. & Johnston, A. (2014). Fabric for Fashion, The Complete Guide: Natural and Man-made Fibres. Laurence King.

Heikinheimo, L. (2002). Trichoderma reesei cellulases in processing of cotton, dissertation for the degree of Doctor of Technology, Tampere, University of Technology, December, VTT Technical Research Centre of Finland. Available from: https://publications.vtt.fi/pdf/publications/2002/P483.pdf

Kim, H. A., & Kim, S. J. (2018). Hand and wear comfort of knitted fabrics made of hemp/tencel yarns applicable to garment. Fibers and Polymers, 19(7), 1539-1547.

Kolanjikombil, M., (2018), The Substrates — Fibres, Yarn and Fabrics, Handbook of Textile Processors Series, Woodhead Publishing India PVT Ltd., New Delhi.

Kozlowski, R., & Manys, S. (1997, May). Coexistence and competition of natural and man-made fibres. In Proc. of the 78th World Conference of the Textile Institute. P. 3-52, Thessaloniki, Greece.

Kozlowski, R., Kozlowska, J., Rawluk, M., & Barriga, J. (2004). Potential of lignocellulosic fibrous raw materials, their properties and diversified applications. Nonlinear optics quantum optics, 31, 1-4, 61-90.

Kozlowski, R., & Mackiewicz-Talarczyk, M. (Eds.). (2020). Handbook of natural fibres: volume 1: types, properties and factors affecting breeding and cultivation. Woodhead Publishing.

Lloyd, M. O. & Taylor, R. A. (1998). Breeding cottons with higher yarn tenacity. Textile Research Journal, 68(4), 302-307.

Markova, I. (2019). Textile fiber microscopy: a practical approach. John Wiley & Sons.

Mather, R. R., & Wardman, R. H. (2015). The chemistry of textile fibres. Royal Society of Chemistry.

Muthu, S. S. (Ed.). (2014). Roadmap to sustainable textiles and clothing: Eco-friendly raw materials, technologies, and processing methods. Springer.

Müssig, J (Ed.) (2010). Industrial applications of natural fibres: structure, properties and technical applications. John Wiley & Sons Ltd, United Kingdom.

Robert, K. Q., Price, J. B., & Cui, X. L. (2000). Cotton Cleanability: Part II: Effect of Simple Random Breakage on Fiber Length Distribution. Textile Research Journal, 70(2), 108-115.

Rowell R.M. & Stout H.P. (2007) Jute and kenaf. In: Lewin M. (ed) Handbook of fiber chemistry. Taylor & Francis Group, Boca Raton.

Sauvageon, T., Lavoie, J. M., Segovia, C., & Brosse, N. (2018). Toward the cottonization of hemp fibers by steam explosion–Part 1: defibration and morphological characterization. Textile Research Journal, 88(9), 1047-1055.

Sfiligoj Smole, M., Hribernik, S., Stana Kleinschek, K., & Kreže, T. (2013). Plant fibres for textile and technical applications. Advances in agrophysical research, 369-398.

Shahzad, A. (2012). Hemp fiber and its composites–a review. Journal of composite materials, 46(8), 973-986.

Shahzad, A. (2013). A study in physical and mechanical properties of hemp fibres. Advances in Materials Science and Engineering, 2013.

Sinclair, R. (Ed.). (2014). Textiles and fashion: materials, design and technology. Elsevier.

Swicofil (2022). Cotton www.swicofil.com/products/001cotton.html., Accessed at Oct 4, 2022.

Tobler-Rohr, M. I. (2011). Handbook of sustainable textile production. Elsevier.

Vandenhove, H., & Van Hees, M. (2005). Fibre crops as alternative land use for radioactively contaminated arable land. Journal of environmental radioactivity, 81(2-3), 131-141.

Wakelyn P.J., Bertoniere N.R., French A.D., Thibodeaux D.P., Triplett B.A., Rouselle M.A., Goynes W.R., Edwards J. V., Hunter L., McAlister D.D. & Gamble G.R. (2007) Cotton fibers. In: Lewin M (ed) Handbook of fiber chemistry, Taylor & Francis Group, Boca Raton.

Wang, H. M., & Postle, R. (2004). Improving the color features of hemp fibers after chemical preparation for textile applications. Textile research journal, 74(9), 781-786.

Wang, J., & Ramaswamy, G. N. (2005). Effects of Chemical Processing on Hemp and Kenaf Dyeing Properties. AATCC review, 5(3), 21-24.

Zhang, H., Zhong, Z., & Feng, L. (2016). Advances in the performance and application of hemp fiber. International Journal of Simulation Systems Science & Technology, 17(9), 18-1.

CHAPTER 7

SEWAGE SLUDGE USE IN INDUSTRIAL CROPS

Assoc. Prof. Dr. Ali Rıza ONGUN[1]
Assoc. Prof. Dr. Mahmut TEPECİK[2]

[1] Ege University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, İzmir, Turkey.
ORCID ID: 0000-0002-5244-2770, e-mail: ali.riza.ongun@ege.edu.tr
[2] Ege University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, İzmir, Turkey.
ORCID ID: 0000-0001-6609-4538, e-mail: mahmut.tepecik@ege.edu.tr

INTRODUCTION

The increase in the world population and the rapid developments in the industry have brought along many environmental problems. The use of chemical fertilizers has increased in agricultural areas in order to meet the nutritional needs of the increasing population and to obtain more products. With the agricultural production made with intensive chemical fertilization, the yield has been increased up to a point, but problems such as soil, water and environmental pollution or salinization (desertification) have also begun to emerge. The excessive use of chemical fertilizers has also led to the increase of plant nutrients in surface and ground waters, resulting in eutrophication and loss of naturalness of waters. In recent years, the use of organic fertilizers has come to the fore in many countries against soil, water and environmental pollution caused by excessive use of chemical or artificial fertilizers. This orientation has brought the concepts and practices of organic agriculture, biological agriculture, ecological agriculture or sustainable agriculture to the agenda. Organic matter contributes to the improvement of the physical, chemical and biological properties of the soil, as well as being a nutrient for soil creatures. The preservation of the natural fertility of the soil is possible with the application of materials with high organic matter content to soils with low organic matter content.

In this study, the use cases of sewage sludge containing a significant amount of organic matter in the production of industrial plants were investigated.

1. SEWAGE SLUDGE

1.1. What is Sewage Sludge

Sewage sludge (SS), rich in organic matter, is the main by-product from wastewater treatment facilities (Eid and Shaltout, 2016). Over the years, agricultural soil applications of SS have been reported increasingly in literature so that the nutrients (nitrogen, phosphorus) in sewage sludge can be beneficially used to grow crops or other vegetation (Gubisova et al., 2020). The management of sewage sludge has great importance from both an environmental and agricultural point of view (Eid et al., 2017). Sewage sludge, as a real source of plant nutrients promoted several studies to evaluate its impact on soil functioning and plant development by land application (Chia et al., 2020). In wastewater treatment, liquid wastes containing 0.25-12% solid matter, which are obtained as a result of removing the substances removed by floating or settling out of the wastewater in the physical and chemical treatment processes, and the dissolved substances at the end of the biological treatment, by transferring the microorganisms from the system by floating or settling, are referred to as “raw treatment” (Filibeli and Büyükkamacı, 2001; Tchobanoglous et al., 2003). After the raw sludge is stabilized and made suitable for ecological use, it is defined as "processed sewage sludge" or briefly "sludge sludge". Primarily the USA "Biosolid" is used synonymously with sewage sludge in the UK and some European Union countries. (Üstün et al., 2002).

30% of the raw sludge formed in a biological treatment plant consists of mineral substances and 70% consists of organic substances. The organic substances that make up the sewage sludge can be reduced by various stabilization methods, while the minerals cannot be reduced. (Jatzkowski, 2000). Sewage sludge is a good source of nitrogen and phosphorus. Even in soils with high phosphorus fixation capacity, the phosphorus in its content can be easily taken. (Sommers and Sutton, 1980; McLaughlin and Champion, 1987). Many researchers (Gupta and Hani, 1979; Furrer et al., 1984) have stated that the amount of available phosphorus in the sewage sludge is the same or more than in the mineral phosphorus fertilizer. The presence of high uptake of P by plants in sludge applied soils may be due to the effect of organic compounds that are effective in the release of insoluble phosphorus in the soil. This effect is especially seen in acidic soils containing calcareous or non-crystalline Fe and Al compounds to which phosphorus is bound (Ayuso et al., 1992). It is known that sewage sludge is a usable source in terms of N and P, but remains poor in potassium, and that especially hydrated sludge is a very valuable source in terms of N and P useful for plants. In general, the potassium (K^+) content of sewage sludge is low. In the application of sewage sludge to the soil, it is taken into account that the plant meets the N and P nutrients, and in some cases, an unbalanced nutrient situation may occur due to the low K^+ content of the sludge. It is suggested that when organic waste is added to the soil, the amount of available K^+ in the soil decreases, because there is a negative relationship between the amount of available K^+ and soil organic matter (Liu et al., 1994).

1.2. Disposal Methods of Treatment Sludges

Various alternatives can be offered for the final removal of sludge. The final disposal methods applied according to the characteristics of the treatment sludge and the available economic and technical possibilities also differ. Safe disposal and recycle of sewage sludge are major environmental concerns worldwide. Sewage sludge disposal methods include incineration, landfills and agricultural applications (Cristina et al., 2020)

Landfill: Landfill is the process of storing and covering solid wastes and treatment sludge in a way that does not harm public health and safety. The first purpose in the implementation of sludge storage processes is to increase the quality of the storage area by reducing the volume of sludge. For this reason, sludge to be given to landfill should be stored after dewatering by applying natural or mechanical methods (Aksu, 2008).

Incineration: This method consists of incineration of solid wastes in specially designed furnaces. The main objectives in the incineration process are to stabilize solid wastes in a way that does not harm the environment and to reduce the waste volume. In addition to reducing the volume, urban wastes are disposed of by incineration in a controlled manner in order to obtain steam and electrical energy. With this method, solid wastes can be reduced by 90% in volume and 75% in weight (Palabıyık, 1998). In this application, sewage sludge should be incinerated alone or together with other wastes.

Composting: Composting can be viewed as the recovery and reuse of the biodegradable part of the waste. The purpose of the composting process is that the waste can be biodegraded without harming the environment. This process reduces the volume, mass and moisture of biodegradable waste and transforms it into a valuable soil conditioner (Öztürk et al., 2005).

This method is an expensive method of disposal compared to landfill, and a cheap disposal method without incineration. Composting of sewage sludge is widely practiced, especially in the USA (Arıkan and Öztürk, 2008).

Thermal Methods: Thermal methods remove water from the sludge by applying heat. Thermal drying reduces the moisture content of the sludge well below that obtained by mechanical dewatering methods. Advantages of thermal drying; lower transportation costs, reduction of pathogens and better storage and marketing opportunities of dried sludge. Thermally dried sludge can be easily marketed as fertilizer or soil improver, and storage and incineration are also accepted.

Use in Agriculture: Sewage sludge is used in soils as an alternative source of organic matter. All sewage sludges, especially those of industrial origin, are not suitable for use in agriculture. For this reason, sewage sludge must meet some criteria and these criteria differ from country to country.

EurEau (European federation of national associations of water services) conducted an extensive survey among its members in 2020 to discover where the treated sludge goes. According to the results of the survey, total European production of sludge is 8.7 Million tonnes dry solids (DS)/y.

The destinations of these sewage sludge produced are as follows.

~ Agriculture: 4.1 Mt DS/y
~ Incineration: 2.4 Mt DS/y
~ Recultivation/land reclamation: 0.7 Mt DS/y
~ Landfill: 0.5 Mt DS/y
~ Other destinations: 1 Mt DS/y

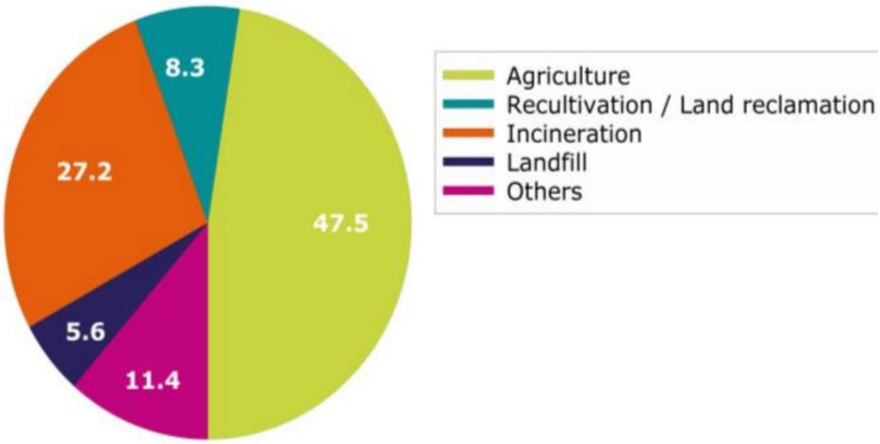


Figure 1: Sludge destination in percentages according to the 2021 EurEau Survey ‘Europe’s Water in Figures’ (Anonymous, 2021).

As can be seen from Figure 1, about half of the sewage sludge produced in Europe is used in agriculture.

Due to the plant nutrients and organic matter they contain, sewage sludge is successfully used in plant production in many countries and studies are carried out on these issues(BÆrug and Martinsen, 1977; Furre et al., 1984; Okur et al., 2005; Delibacak et al., 2009a; Delibacak et al., 2009b; Pakhnenko et al., 2009; Delibacak and Ongun, 2015, Delibacak and Ongun 2016a; Delibacak and Ongun 2016b; Belhaj et al., 2016; Ongun and Delibacak, 2017; Ongun and Delibacak, 2018a; Ongun and Delibacak, 2018b; Melo et al., 2018; Delibacak and Ongun, 2018, Kayıkçıoğlu and Delibacak, 2018; Kayıkçıoğlu et al., 2019, Tepecik et al., 2022).

2. USE OF SEWAGE SLUDGE IN SOME INDUSTRIAL PLANTS

2.1. Sunflower (*Helianthus annuus* L.)

In a study with sunflower to examine the effects of sewage sludge on sunflower yield and the accumulation of plant nutrients and metals in soil and crop in Argentina, the applications were control, 7 and 14 tons of dry matter sewage sludge per hectare. It was determined that only P and N increased in the soil after the treatment sewage sludge application. It was stated that the use of sewage sludge according to standard regulations did not affect toxic metal uptake or sunflower quality. In the same study, the grain yield was determined as 3792 kg/ha in the control application, 4938 kg/ha in the 7 t/ha sewage sludge application, and 4950 kg/ha in the 14 t/ha sewage sludge application. It was determined that the grain yield increased by 30% with the application of 7 t/ha of sewage sludge, whereas the yield remained constant in the application of 14 t/ha of sewage sludge (Lavado, 2006).

In another study with sunflower, a 2.5-5-7.5% sewage sludge-soil mixture was prepared in pots. While soil pH decreased, electrical conductivity, organic matter, total N, available P and exchangeable Na, K and Ca increased in soil treated with sewage sludge compared to control. Sewage sludge caused a significant increase in Pb, Ni, Cu, Cr and Zn concentrations in the soil. Sewage sludge led to increases in shoot and root concentrations of Cr, Cu, Ni and Zn in the plant. For most of the heavy metals, the accumulation was determined to be in the roots rather than the shoots.

Findings from the study reveal that the sunflower plant has the ability to tolerate heavy metal toxicity and accumulates significant amounts of heavy metals in roots and has the capacity to migrate to shoot tissues. Overall, this study indicates the existence of an efficient heavy metal deposition mechanism in sunflower roots and is thought to represent a new and interesting phenomenon for the establishment of phytoremediation strategies (Belhaj et al., 2016).

2.2. Flax (*Linum usitatissim*um L.)

In a study conducted in Russia, it was determined that the use of sewage sludge-based fertilizers while optimizing their doses ensures the sustainable productivity of perennial grasses and flax, increases the productivity of sod-podzolic soils, protects their biological activities and biodiversity. In this study, it was concluded that it did not cause heavy metal accumulation in soil and plant production. In the study, considering the 4 t/ha treatment sludge application and 3-year yield values, it was determined that there was a 26% increase in the straw yield of flax and a 30% increase in the seed compared to the control (Merzlaya et al., 2016).

Another study conducted in the Czech Republic was carried out in pots placed in the field to a depth of 50 cm, in simulated natural conditions with variations of the graded mix of natural sediment and soils. Sewage sludge was added to the sediment - soil mixture in the following proportions: sludge - soil = 1:2 (var. K1), 1:3 (var. K2), 1:4 (var. K3), 1:5 (variable K4), 1:6 (var. K5). Control variant (K0) without sewage sludge was also planted with all cultivars. At the end of the study, it was determined that flax plant accumulated heavy metals in various ways and the highest concentration was recorded for Zn. Then it was seen that Pb and Cd came. The lowest Cd and Pb concentrations were analyzed in the seed (0.121 $mg \cdot kg^{-1}$), and the highest Cd and Pb concentrations were found in the stem (Cd = 0.396 $mg \cdot kg^{-1}$) and capsules (Pb = 1.881 mg). The highest Zn concentration was found in the capsule (115,015 $mg \cdot kg^{-1}$) and the lowest in the root (33.782 $mg \cdot kg^{-1}$). Cd accumulation trend was determined as stem>capsule>root>seed, Pb: capsule>stem>root>seed, Zn: capsule>seed>root>stem. The study showed that fiber and flaxseed varieties have different variability in their ability to absorb heavy metals from the soil and consequently different phytoremediation potential Bjelkova et al 2011.

2.3. Cotton (*Gossypium hirsutum* L.)

In a study carried in Turkey, sewage sludge was applied to the cotton plant at the rates of 10, 20 and 30 t/ha per year. When 30 t/ha treated sewage sludge (TSS) (TSS3) sludge was applied, seed cotton yield (71.4%), lint yield (67.7%) and cotton seed yield (74.1%) increased significantly. It has been reported that the effects of TSS applications on seed yield, lint yield and cottonseed yield are listed as TSS3 > TSS2 > CF > TSS1 > C according to the applications. In the study, it was determined that the Na content in the plant tissue increased with increasing sludge application dose compared to the control soils. On the other hand, it was observed that increasing TSS doses did not have a significant effect on iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and boron (B) concentrations in cottonseed. In this study, it was determined that the concentrations of non-essential elements (Ni, Cd, Cr, Pb, Hg and As) in the cotton seed were below the permissible limits (Tepecik et al., 2022)

In the two-year field trial, 0, 26, 42, 58 and 77 t/ha of sewage sludge was applied to clay loam soil (calcixerrolic xerochrept) every year. In this study conducted in Greece, sequential extraction was used in this study in which different forms of metals (changeable, organically bound, carbonates and residue) in soil-sludge mixtures were investigated. Most of the metals studied [cadmium (Cd), zinc (Zn), copper (Cu), and nickel (Ni)] were found in organically bound, carbonate or residual forms. Elements in the soil fractions, only residual Zn was associated with the Zn content of cotton leaves. In this study, where the levels of the elements found in plants showed a simple linear correlation between diethylenetriaminepentaacetic acid (DTPA) extraction, concentration in soil and cotton leaves only for Cd, yield increased compared to chemical fertilizer application. This increase was 11.5% in the first year of the study and 20% in the second year (Samaras and Kallianou, 2000).

2.4. Potatoes (*Solanum tuberosum* L.)

Treatments and yield results in a study conducted with potatoes and sewage sludge in the city of Ulan-Ude (Russia) are given in Table 1.

Table 1: The effect of SS and mineral fertilizers on the yield of potatoes

Treatment	Yield oftubers, t/ha	Gain inthe yield oftubers, %	Potato, t/ha marketable	Potato, t/ha nonmarketable	Output of marketable tubers, %	Biomass of byproducts, t/ha	Ratio of tubers to marketable nonmarketable
Control	14.58		10.32	4.26	70.8	5.16	1:0.35
$N_{60}P_{60}K_{60}$	16.65	+17.6	12.14	4.51	72.9	4.85	1:0.29
SS 7.5 t/ha	16.72	+11.6	11.52	5.20	68.9	6.02	1:0.36
SS 15 t/ha	16.37	+19.8	12.36	4.01	75.5	5.61	1:0.34
SS 7.5 t/ha + NPK	16.87	+29.3	13.35	3.52	79.1	5.58	1:0.33
SS 15 t/ha + NPK	18.66	+41.8	14.65	4.02	78.4	6.05	1:0.32

60 kg/ha of each element; SS: Sewage Sludge

In this study, the researchers reported that sewage sludge applications increased the yield of potatoes, and there was a slight decrease in the marketable product, then an increase. In addition, they reported that the application of sewage sludge separately and together with mineral fertilizers did not have a negative effect on the agrochemical properties of the soil, and the heavy metal concentrations in the soil after the potato harvest remained well below the maximum allowable concentrations (Pakhnenko et al., 2009).

BÆrug and Martinsen (1977) cultivated potatoes using two types of sewage sludge, rich in heavy metals and poor in heavy metals. In the study where they determined the treatment sludge doses as 10-20-40-80 t/ha, they also applied $N_{13}P_6K_{16}$ 05-1-1.5-2 tons per hectare. In this study, researchers reported that chemical fertilizers give better results.

2.5. Peanut (*Arachis hypogaea* L.)

In a study conducted in Brazil, 3 different rates of Pb were applied to the soil together with the sewage sludge. In the study, it was determined that when sewage sludge containing high levels of Pb was applied, it did not harm the biomass and yield of the plant, but the Pb content of extractable Pb in the soil with HCl and the Pb content in shoots, roots and bean pods increased (Camilotti et al., 2012).

In another study conducted in Turkey, the effects of different treatment sludge levels on yield, trace element and heavy metal accumulation in peanuts were investigated. Researchers who reported that increasing sewage sludge application to the typical Xerofluvent soil significantly increased the peanut yield, the Fe, Cu and Ni content of the edible part of peanuts, but did not significantly affect the Mn, Zn, Cd, Cr, Pb contents of peanuts with trace elements and heavy metals (Fe, Cu, Mn, Zn, Co, Cd, Cr, Ni, Pb) concentrations were reported to be below the threshold values. In the same study, treatment sludge applications increased the efficiency significantly in the first year compared to the control, while the efficiency of the treatment sludge decreased in the second year of the experiment (Table 2) (Delibacak et al., 2008).

Table 2: Effects of sewage sludge applications on fresh peanut (with shell) yield

Sludge (ton/ha)	Fresh peanut with shell (kg/ha)	
	first year	second year
0	7631	6404
30	8151	6612
60	8623	6783
90	8943	6774

CONLUSION

In this chapter, information about sewage sludge is given and its use with industrial crops is investigated. Before using it, it is important to know the sewage sludge well, to know the soil conditions and to consider the wishes of the plant. Changes in heavy metals accumulation in soils depend largely on the characteristics of the sewage sludge, the rate applied and soil texture, it is also necessary to pay attention to the legal regulations. From the examples, it is seen that depending on the conditions, the treatment sludge can sometimes have positive effects and sometimes negative effects. However, it should not be forgotten that successful results are achieved when the right industrial crops and appropriate treatment sludge are combined.

REFERENCES

Aksu, T. (2008). Isparta Belediyesi Atık Su Arıtma Tesisinde Oluşan Çamurun Bertaraf Stratejilerinin Araştırılması, Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Tezi

Anonymous (2021) Waste water treatment – sludge management. Briefing note. https://www.eureau.org/resources/briefing-notes/5629-briefing-note-on-sludge-management/file , (Access: 09.09.2022).

Arıkan, O. A. ve Öztürk, İ. (2008). Arıtma çamuru Kompostlaştırılmasında Organik Evsel Katı Atık İlavesinin Etkisi, İTÜ Fen Bilimleri Enstitüsü, Çevre Bilimleri ve Mühendisliği Programı, İstanbul.

Ayuso, M., Hernández, T., García, C., & Costa, F. (1992). Utilizacion de un lodo aerobio como substitutivo de fertilizantes fosforados inorganicos. Suelo y Planta, 2, 271-280.

BÆerug, R., & Martinsen, J. H. (1977). The influence of sewage sludge on the content of heavy metals in potatoes and on tuber yield. Plant and Soil, 47(2), 407-418.

Belhaj, D., Elloumi, N., Jerbi, B., Zouari, M., Abdallah, F. B., Ayadi, H., & Kallel, M. (2016). Effects of sewage sludge fertilizer on heavy metal accumulation and consequent responses of sunflower (*Helianthus annuus*). Environmental Science and Pollution Research, 23(20), 20168-20177.

Bjelkova, M., Vetrovcova, M., Griga, M., & Skarpa, P. (2011). Effect of sewage sludge in soil on Cd, Pb and Zn accumulation in Linum usitatissimum L. Proceedings of ECOpole, 5.

Camilotti, F., & Marques, M. O. (2012). Biomass and yield of peanut grown on tropical soil amended with sewage sludge contaminated with lead. Applied and Environmental Soil Science, 2012.

Chia, W.Y., Chew, K.W., Le, C.F., Lam, S.S., Chee, C.S.C., Ooi, M.S.L., Show, P.L. (2020). Sustainable utilization of biowaste compost for renewable energy and soil amendments. Environmental Pollution 267: 115662.

Cristina, G., Camelin, E., Tommasi, T., Fino, D., Pugliese, M. (2020). Anaerobic digestates from sewage sludge used as fertilizer on a poor alkaline sandy soil and on a peat substrate: Effects on tomato plants growth and on soil properties. Journal of Environmental Management. 269; 110767.

Delibacak, S., & Ongun, A. R. (2015). Influence of treated sewage sludge applications on total and available heavy metal concentration of sandy loam soil. Fresenius Environmental Bulletin, 24(6), 2039-2045.

Delibacak, S., & Ongun, A. R. (2016a). Influence of treated sewage sludge applications on corn and second crop wheat yield and some soil properties of sandy loam soil. Fresen. Environ. Bull, 25(1), 43-51.

Delibacak, S., & Ongun, A. R. (2016b). Influence of treated sewage sludge applications on corn and second crop wheat yield and some properties of sandy clay soil. Turkish Journal of Field Crops, 21(1), 1-9.

Delibacak, S., & Ongun, A. R. (2018). Influence of treated sewage sludge applications on total and available heavy metal concentration of sandy clay soil. Desalination and Water Treatment, 112, 112-118.

Delibacak, S., Okur, B., & Ongun, A. R. (2009a). Effects of treated sewage sludge levels on temporal variations of some soil properties of a Typic Xerofluvent soil in Menemen Plain, Western Anatolia, Turkey. Environmental monitoring and assessment, 148(1), 85-95.

Delibacak, S., Okur, B., & Ongun, A. R. (2009b). Influence of treated sewage sludge applications on temporal variations of plant nutrients and heavy metals in a Typic Xerofluvent soil. Nutrient Cycling in Agroecosystems, 83(3), 249-257.

Delibacak, S., Okur, B., Yagmur, B., & Ongun, A. R. (2008). Effects of sewage sludge applications on the yield and trace element and heavy metal accumulation in peanut (Arachis hypogaea L.). Asian Journal of Chemistry, 20(1), 563.

Eid, E.M., Shaltout, K.H. (2016). Bioaccumulation and translocation of heavy metals by nine native plant species grown at a sewage sludge dump site. International Journal of Phytoremediation 18 (11):1075–1085.

Eid, E.M., El-Bebany, A.F., Alrumman, S.A., Hesham, A., Taher, M.A., Fawy, K.F. (2017). Effects of different sewage sludge applications on heavy metal accumulation, growth and yield of spinach (*Spinacia oleracea* L.). International Journal of Phytoremediation 19 (4): 340-347.

Filibeli, A. ve Büyükkamacı, N. (2001). Arıtma çamurlarının kompostlanabilirliğinin değerlendirilmesi, UKAK 2001- Ulusal Katı Atık Kongresi, Arıtma Çamurları, 18-21 Nisan 2001, İzmir.

Furrer, O. J., Gupta, S. K., & Stauffer, W. (1984). Sewage sludge as a source of phosphorus and consequences of phosphorus accumulation in soils. In Processing and use of sewae sludge: proceedings of the third international symposium held at Brighton, September 27-30, 1983/edited by P. L'Hermite and H. Ott. Dordrecht: D. Reidel Pub. Co.

Gupta, S. K., & Hani, H. (1979). Estimation of available phosphate content of sewage sludge. In Treatment and use of sewage sludge. Proceedings of the first European Symposium held in Cadarache (pp. 261-268).

Gubisova, M., Hornik, M., Hrckova, K., Gubis, J., Jakubcova, A., Hudcovicova, M., Ondreickova, K. (2020). Sewage sludge as a soil amendment for growing biomass plant Arundo donax L. Agronomy 10 (5): 678.

Jatzkowski, K. (2000), Arıtma Çamurunun Stabilizasyonu ve Miktarının Azaltılması İmkanları, Bölüm 2, Arıtma Çamuru Sempozyumu, 20 Mart 2000, Bursa.

Kayıkçıoğlu, H., & Delibacak, S. (2018). Changes in soil health and crop yield in response to the short-term application of sewage sludge to typic xerofluvent soil in Turkey. Appl. Ecol. Environ. Res, 16(4), 4893-4917.

Kayikcioglu, H. H., Yener, H., Ongun, A. R., & Okur, B. (2019). Evaluation of soil and plant health associated with successive three-year sewage sludge field applications under semi-arid biodegradation condition. Archives of Agronomy and Soil Science.

Lavado, R. S. (2006). Effects of sewage-sludge application on soils and sunflower yield: quality and toxic element accumulation. Journal of Plant Nutrition, 29(6), 975-984.

Liu, W. T., Mino, T., Nakamura, K., & Matsuo, T. (1994). Role of glycogen in acetate uptake and polyhydroxyalkanoate synthesis in anaerobic-aerobic activated sludge with a minimized polyphosphate content. Journal of fermentation and bioengineering, 77(5), 535-540.

McLaughlin, M. J., & Champion, L. (1987). Sewage sludge as a phosphorus amendment for sesquioxic soils. Soil science, 143(2), 113-119.

Melo, T. M., Bottlinger, M., Schulz, E., Leandro, W. M., de Aguiar Filho, A. M., Wang, H., ... & Rinklebe, J. (2018). Plant and soil responses to hydrothermally converted sewage sludge (sewchar). Chemosphere, 206, 338-348.

Merzlaya, G. Y., & Smirnov, M. O. (2016). Sustainability of Agrocenoses in the Use of Fertilizers on the Basis of Sewage Sludge. In Temperate Crop Science and Breeding (pp. 479-494). Apple Academic Press.

Okur, N., Kayıkçıoğlu, H.H., Delibacak, S. (2005). Kentsel arıtma çamuru uygulamalarının topraktaki mikrobiyal biyokütle ve enzim aktivitesi üzerine etkisi. XIV. Ulusal Biyoteknoloji Kongresi. 31 Ağustos- 2 Eylül 2005, Eskişehir. pp. 157-161.

Ongun, A. R., & Delibacak, S. (2017). Effect of treated sewage sludge applications on heavy metal concentrations of corn and second crop wheat grown in sandy loam soil. Fresenius Environmental Bulletin, 26(8), 5147-5152.

Ongun, A. R., & Delibacak, S. (2018a). Effect of successive two years treated sewage sludge applications on corn and second crop wheat yield and some soil properties of sandy clay soil. Fresenius Environmental Bulletin, 27(10), 6742-6750.

Ongun, A. R., & Delibacak, S. (2018b). Successive two years treated sewage sludge applications: effect on total and available heavy metal concentration of sandy loam soil. Fresenius Environmental Bulletin, 27(12A), 8779-8786.

Öztürk, İ., Timur, H., & Koşkan, U. (2005). Atıksu arıtımının esasları evsel, endüstriyel atıksu arıtımı ve arıtma çamurlarının kontrolü. TC Çevre ve Orman Bakanlığı, İstanbul.

Pakhnenko, E. P., Ermakov, A. V., & Ubugunov, L. L. (2009). Influence of sewage sludge from sludge beds of Ulan-Ude on the soil properties and the yield and quality of potatoes. Moscow University Soil Science Bulletin, 64(4), 175-181.

Palabıyık, H. (1998). Çevre Sorunu Olarak Kentsel Katı Atıklar (Çöpler) ve Entegre Katı Atık Yönetimi, Türk İdare Dergisi, 70(420):45-64, Ankara.

Samaras, V., & Kallianou, C. (2000). Effect of sewage sludge application on cotton yield and contamination of soils and plant leaves. Communications in soil science and plant analysis, 31(3-4), 331-343.

Sommers, L. E., & Suttona, A. L. (1980). Use of waste materials as sources of phosphorus. The role of phosphorus in agriculture, 515-544. In: F.E. Khasawneh, E.C. Sample, and E.J. Kamprath (eds.), The Role of Phosphorus in Agriculture. American Society of Agronomy, Madison, WI.

Tchobanoglous, G., Burton, F. L., & Stensel, H. D. (2003). Treatment, reuse, and disposal of solids and biosolids. Wastewater engineering: Treatment and reuse. 4th edition. Boston: McGraw-Hill.

Tepecik, M., Ongun, A. R., Kayikcioglu, H. H., Delibacak, S., Elmaci, O. L., Celen, A. E., & İlker, E. (2022). Change in cotton plant quality in response to application of anaerobically digested sewage sludge. Saudi Journal of Biological Sciences, 29(1), 615-621.

Üstün, H., Eyüboğlu, H., &Bilgin, N. (2002). “Biyokatıların (Arıtma Çamurlarının) Arazide Kullanımı” ASKİ Arıtma Tesisi Daire Başkanlığı – Köy Hizmetleri Genel Müdürlüğü Ankara Araştırma Enstitüsü, Ankara 2002.

CHAPTER 8

FATTY ACID COMPOSITION OF OILSEED PLANTS

Prof. Dr. Pelin GÜNÇ ERGÖNÜL[1]

Prof. Dr. Bülent ERGÖNÜL[2],

Chemical Engineering MSC Deniz DINÇER[3]

[1] Manisa Celal Bayar University, Faculty of Engineering, Department of Food Engineering, Manisa-Turkey,
ORCID no: 0000-0003-4993-7219, pelingunc81@hotmail.com
[2] Manisa Celal Bayar University, Faculty of Engineering, Department of Food Engineering, Manisa-Turkey,
ORCID no: 0000-0003-0338-302X , bulent.ergonul@hotmail.com
[3] Food & Feed Izmir Private Food Control Laboratory, Kemalpaşa, İzmir, Türkiye,
ORCID no: 0000-0003-2943-7540, deniz-dincer@hotmail.com

1. INTRODUCTION

Turkey is known as the world’s seventh largest agricultural producer, especially cereal crops and oil seeds. Oilseeds from plants are used to produce vegetable oils, which are primarily used in the food industry (e.g., preparation of nutritional food products, healthy snacks).

According to an estimate from the Organization for Economic Cooperation and Development (OECD), global oilseed production in 2029 will be 581.1 million tons. It is anticipated that developed countries will produce 43% of this amount, while developing countries will produce 57%. (Gergin et al., 2022). Among Turkey's oilseed crops, the sunflower plant ranks first in terms of harvested area, production, and oil consumption. Turkey is effectively foreign-dependent in terms of supplying its vegetable oil demands. This position has given oil crop production strategic importance. Soybean, Cotton, peanut, poppy, sesame, safflower, rapeseed, flaxseed and camelina seeds are among the oilseed crops following the sunflower plant (Yılmaz et al., 2021). These oils are rich in vitamins, peptides, proteins, n-3 and n-6 UFAs, as well as various bioactive substances (such as tocopherols, phenolic compounds, and phytosterols). Since oil is a substantial component of seeds, the fatty acid content in particular may be thought of as a critical determinant in determining the seed quality. Saturated fatty acids (SFAs) prevent the clearance of low-density lipoprotein (LDL) in the blood, and therefore LDL is popularly known widely as “bad” cholesterol (Asil and Konuşkan, 2021). Unsaturated fatty acids (UFAs) are called fatty acids that contain alpha carboxylic acids, often with one or more double bonds in the cis configuration, and are essential for higher organisms. UFAs, found in most plants, have very important roles because they are deeply related to both abiotic and biotic stresses (He et al., 2020). A rich monounsaturated oleic acid (C18:1) diet has recently demonstrated a variety of positive effects, including lowering cholesterol levels, reducing risks of coronary heart disease (CHD), avoiding type 2 diabetes, and treating inflammatory disorders (Xiao et al., 2022).

Both the quantity and the quality of fat in the diet can help lower the risk of CHD. The high fat diet with a high UFA/SFA ratio and the low fat diet both have the potential to reduce LDL cholesterol levels (Orsavova et al., 2015). SFAs and trans-fatty acids have been demonstrated to raise LDL cholesterol levels. As a result, rather than reducing total fat intake, replacing SFAs and trans-fatty acids with monounsaturated-fatty acids (MUFAs) and polyunsaturated-fatty acids (PUFAs) may minimize the development of CHD (Shad et al., 2012). Oleic acid is a MUFA, and a diet high in MUFA may also protect against atherosclerosis, lower serum cholesterol levels by reducing oxidative stress and inflammatory mediators, and promote antioxidant defense (Moreno & Mitjavila, 2003).

The degree of unsaturation of dietary fatty acids effects lipoprotein composition, the generation of adhesion molecules and other pro-inflammatory factors, and the thrombogenicity associated with atherosclerosis progression. Thus, an increase in high-density lipoprotein cholesterol levels and a decrease in low-density lipoprotein cholesterol levels, as well as an increase in low-density lipoprotein susceptibility to oxidation, cellular oxidative stress, thrombogenicity, and atheroma plaque formation, may explain the protective effects of a MUFA-rich diet on atherosclerosis. PUFAs may have a beneficial effect on atherosclerosis prevention due to an increase in high-density lipoprotein cholesterol levels and a decrease in thrombogenicity, atheroma plaque formation, and vascular smooth muscle cell proliferation (Moreno & Mitjavila, 2003). PUFAs are important components of cell membranes and are important for numerous cellular processes. Fatty acids (n-3) have an anti-inflammatory effect because they decrease the production of cytokines and adhesion molecules. Rheumatoid arthritis, Crohn's disease, ulcerative colitis, cystic fibrosis, asthma, diabetes, allergic illnesses, multiple sclerosis, atherosclerosis, and obstructive pulmonary disease are all putative therapeutic uses for omega-3 fatty acids (Hlinková et al., 2012). As a result, oils from oilseed crops (soybean, sunflower, olive, and rapeseed) are key sources of edible oils for human consumption in the global market, with high n-3 and n-6 fatty acid levels as well as other biological components (Adeleke and Babalola, 2020).

Properties of vegetable oils; Since it varies according to the plant from which it is obtained and the ratios and types of fatty acids it contains, it is necessary to produce for the purpose of consumption. For this reason, knowing the fatty acid composition of the oils, which must be included in the nutrition chain according to experts, will enable them to be used for more appropriate purposes.

2. FATTY ACID COMPOSITION OF OILSEED PLANTS

Sunflower Seed

Sunflower (*Helianthus annuus*) is one of the top five oil crops cultivated globally (Konuskan et al., 2019). Sunflower oil, the fourth-most significant edible oil in the world after soybean, rapeseed, and cottonseed oil, has recently seen a sharp increase in both production and use (Kabutey et al., 2022; Wang et al., 2019). Due to its high oil content (45–50%) and oil quality, sunflowers account for around 65% of the production of vegetable oil, with the remainder coming from cottonseed, olive, soybean, and other oil seeds (Öztürk, 2022). The sunflower is quite adaptable to many latitudes, longitudes, and photoperiods. The sunflower crop has unique qualities that satisfy farm needs. It is more resistant to drought than maize and sorghum, has a high level of disease and pest resistance, and also improves soil conditions for subsequent crops (Rosa et al., 2009)

There are two methods to manufacture sunflower: as oil and as a snack. In Turkey, it is mostly planted for the manufacture of vegetable oil, while some confectionary types are also produced in minor quantities (Gürsoy, 2019). Sunflower oil, like other oil crops, contains carotenoids, tocopherols, tocotrienols, and sterols (Adeleke & Babalola, 2020). Sunflower genotypes are classified into three major groups based on their oleic acid content: (i) conventional (traditional) sunflowers with oleic acid levels ranging from 14 to 39% (ii) mid-oleic sunflowers with 42-72% oleic acid, and (iii) high-oleic sunflowers with 75-91% oleic acid (Menderes et al., 2019). Traditional sunflower has a high linoleic acid content, but the demand for oleic-type sunflower has been steadily rising globally. Temperature is the most critical factor influencing plant development and fatty acid synthesis (Akkaya, 2018). Turkey has significant potential for oleic-type sunflower oil since the population of Turkey consumes roughly 600–700 tons of the approximately 10 million MT of sunflower oil used worldwide (Aşkın, 2018). Some sunflower cultivars grown in Turkey are known to have different fatty acid contents depending on the growing circumstances. At all phases of sunflower seed growth, linoleic acid can rise from 50% to 70% after fertilization at physiological maturity under optimum temperature circumstances (Karaca & Aytac, 2007).

In the edible oil sector, conventional sunflower oil that is high in linoleic acid is utilized most often. Significant advancements have recently been achieved in the modification of sunflower oil's fatty acids. The high oleic variety of sunflower, which has an oleic acid content of >85%, is regarded as being extremely useful for both the food business and for a variety of technical purposes, such as serving as a primary component in the oleochemical industry (Hasan Baydar & Erbaş, 2005). Oleic acid (14-43%), linoleic acid (44-75%), and other fatty acids (0.7%) make up the UFAs in sunflower oil.

In sunflower, rapeseed, olive, mustard, and peanut oils, (Konuskan et al., 2019) measured the fatty acid composition. The primary fatty acids that were present in all of the vegetable oils examined were palmitic acid (C16:0), oleic acid (C18:1), and stearic acid (C18:0). Among the other fatty acids, oleic acid was the one with the greatest concentration, followed by linoleic acid. Sunflower and mustard oils were found more stable than rapeseed, peanut, and olive oils.

Linoleic acid (C18:2) and oleic acid (C18:1) make up around 90% of the oil's total fatty acid content, together. Palmitic and stearic acids make up the remaining 8–10% (Aly et al., 2021). In his research, (Öztürk, 2022) examined the yield, oil content, and fatty acid composition of sunflowers cultivated in Diyarbakır with several genotypes. Thirteen distinct genotypes of sunflowers were employed in the study as plant material. The findings demonstrated that genotypes differed significantly in yield and oil quality components. The genotypes Tunca (55.7%) and LG-5580 (55.3%) had the most significant levels of linoleic acid content, whereas Bosfora (37.8%) genotypes had the highest levels of oleic acid (Table 1). The effects of genotypes, planting date, and climatic conditions on various Romanian sunflower hybrids were studied by Popa et al. (2017). Climate had a significant detrimental effect on oleic acid content in all sunflower hybrids evaluated. The oleic content was found to be low (22.95% for the early planting date and 21.10% for the late planting date). Low rainfall during seed maturity could be attributed to this. The fraction of linoleic acid in sunflower fatty acids ranged from 59.02-64.11% for early planting dates to 66.85% for late planting dates.

(Akkaya, 2018), in his study, indicated that the fatty acid compositions of sunflower oils may vary depending on genotype and geography. Climate conditions, particularly high temperatures and minimal rainfall during seed filling, enhance oleic acid content. As a result, the oleic acid concentration of oils derived from sunflowers growing in the East Mediterranean region is higher. The fatty acid composition of the Bosfora variety is given in Table 1 as an example.

Table 1. Fatty acid composition (%) of some sunflower seed cultivars grown at different regions in Turkey

Fatty acid	Bosfora from Diyarbakır Region (Öztürk, 2022)	Sirena from Diyarbakır Region (Öztürk, 2022)	LG5400 from Edirne Region (Aşkın, 2018)	Colombi from Edirne Region (Aşkın, 2018)	Bosfora from Tarsus region (Akkaya, 2018)
Palmitic (C16:0)	5	5.7	4.83	3.34	5.82
Palmitoleic (C16:1)	-	-	0.17	0.02	-
Heptadecenoic (C17:1)	-	-	0.03	0.01	-
Stearic (C18:0)	3.5	3.8	2.75	3.08	3.38
Oleic (C18:1 *n-9*)	37.8	36.8	72.36	87.23	43.70
Linoleic (C18:2 *n-6*)	50.7	51.6	19.3	5.72	41.23
ϒ-Linolenic (C18:3 *n-6*)	-	-	0.29	0.36	0.16
Arachidic (C20:0)	-	-	-	-	0.2
α-Linolenic (C18:3 *n-3*)	-	-	0.24	0.23	-

Canola seed (Rapeseed)

Canola is a member of the *Cruciferae* family. It is an annual plant that comes in spring and fall varieties (Vanak, 2020). Canola is the second most produced lucrative oil crop in the world after soybean. 57.86 million tons of canola seeds were grown worldwide in 2008 on an area of 30.30 million hectares, and 57.86 million tons of the approximately 392 million tons of vegetable oil produced worldwide were derived from canola. The most significant canola oil producers and users worldwide are China, Germany, India, England, and Canada. After World War II, Bulgarian and Romanian immigrants in Turkey began cultivating canola in the Thrace Region. Over time, it spread to other regions, and by 1979, it covered a total of 27,000 acres. Rapeseed cultivars have since been banned from usage because of their high amounts of fatty erusic acid, and by 1985, just 100 hectares were left to be farmed. However, it has started to be replicated after the introduction of 00-type rapeseed varieties (canola) that do not contain erusic acid and glucosinolate, especially in the Cukurova and Thrace areas (Baran et al., 2016).

In a three-year research conducted in Australia, (Batley & Vecchies, 2003) found that rapeseed produced in hotter climates had lower ratios of SFAs. According to the study, rapeseed includes palmitic and stearic acid in addition to a total of 7% SFAs. With the genetic reduction of palmitic and stearic acid content, the total SFA content of rapeseed will drop, and it will be a healthier edible oil (Karaca & Aytac, 2007).

Rapeseed is often harvested one to two months sooner than other oil crops. As a result, by supplying the industry's need for oil and enabling the production of the second product, agriculture, it enhances the operating capacity of the companies. Rapeseed has an about 50% crude oil content, 30% carbohydrate content, and 45% crude protein content. While oil and protein content are the primary determinants of rapeseed quality, oil quality also plays a significant role in terms of fatty acid composition and vitamin content (Altıntop & Gıdık, 2019).

According to several experts, the width of the adaption region, high oil rate, oil output, and oil quality all play significant roles in the production potential of rapeseed. Rapeseed's relevance has grown due to its winter and summer forms, 38–50% oil content, 16–24% protein content, short vegetative time, high seed and oil output, and extremely high ratio of UFAs (Gürsoy, 2019). Canola oil's distinctive qualities have lately enhanced consumer interest in the product (Vanak, 2020). There are many parallels between canola farming and wheat growth practices, as they are both planted and harvested virtually simultaneously. Therefore, it becomes unworkable as a substitute for cereals, especially in farming regions with high grain output (Baran et al., 2016).

Through conventional breeding, cultivars with lower levels of glucosinolates and erusic acid were created (Woodfield & Harwood, 2016). Human health is negatively impacted by erusic acid-rich oils, while animal health is negatively impacted by glucosinolate-rich crops. Canola, also known as low-glucosinolate, low-erusic acid rapeseed, is a significant oilseed crop across the world as a result (Baydar & Erbaş, 2005; Vanak, 2020). These cultivars were first created in Canada under the trade name Canola. The crop is still referred to as "rapeseed" in Europe, where cultivars with high and low erusic acids are designated as HEAR and LEAR, respectively. Since then, more cultivars with different oil compositions, such as low-linolenic and high-oleic types, have been produced (Woodfield & Harwood, 2016).

On average, canola oil has 65% oleic acid, 20% linoleic acid, 9% linolenic acid, 4% palmitic acid, and 2% stearic acid. With an oleic acid level of more than 60%, it varies from other vegetable oils (including sunflower, soybean, and maize oils) and resembles olive oil (Baran et al., 2016; Mihai et al., 2020). Eicosenoic acid (C20:1n9, gondoic acid) was discovered in rapeseed oil to be higher (1.14%) than the other oil studied. One research compared the fatty acid content of refined and cold-pressed rapeseed oil and discovered that gondoic acid was contained in a higher percentage in refined oil (1.55%) than it was in cold-pressed oil (1.47%). The examined rapeseed oil had high levels of MUFA and PUFA (67.49% and 24.74%) and low levels of SFAs (7.77%) (Mihai et al., 2020). α-linolenic and oleic (50%–66%) acids are abundant in canola, making its fatty acid profile particularly health-promoting from a nutritional standpoint. Additionally, the proportion of omega-3 to omega-6 fatty acids is not very high (about 2:1). In comparison to other vegetable oils, it also has a low percentage of SFAs (around 7%) in it. Rapeseed and canola oils include some linoleic acid (11%-30%), some α-linolenic acid (5%-14%), and modest quantities of SFAs (4%-9%), as well as large levels of UFAs (90%-95%). Canola oil therefore contains the ideal proportion of omega-6 (linoleic acid) to omega-3 (linolenic acid) fatty acids (2:1) for human health (Vanak, 2020). High quantities of MUFA and α-linolenic acid are typical of rapeseed oil (Kolláthová et al., 2019). The amount of oleic acid in rapeseed varieties in drought-affected regions is lower than in other regions, and amounts of linoleic acid and linolenic acid are higher. (Naveed et al., 2020) reported that rapeseed containing high oleic acid can be used for industrial purposes and is also interesting in terms of nutrition. The amount of oleic acid in rapeseed varieties in drought-affected regions is lower than in other regions, and the amounts of linoleic acid and linolenic acid are higher, according to a study that claims that rapeseed with high oleic acid can be used for industrial purposes in addition to being crucial for nutrition (Karaca & Aytac, 2007). (Khalatbari et al., 2022) investigated the impact of planting dates and irrigation regimes on the fatty acid composition of various winter canola cultivars over two cropping years. Natali had the highest levels of oleic acid and linolenic acid (63.7% and 16.3%, respectively) among the cultivars examined, while Danube had the lowest levels (63.2% and 15.5%, respectively). Furthermore, the Danube cultivar had the highest levels of linolenic and erusic acids by 6.38% and 0.36%, respectively, while the Natali cultivar had the lowest levels by 5.91% and 0.29%, respectively. The mean comparison of the interaction impact of irrigation and planting dates on linolenic acid revealed that irrigation termination and delayed planting date had the greatest linolenic and erusic acid levels by 7.5 and 0.48%, respectively. The results showed that planting the canola plants earlier resulted in the highest palmitic acid content in the seeds at 5.2%, which was 14% higher than planting the canola plants later. When compared to the irrigation termination treatment, the fully-irrigated treatment resulted in a 10% increase in the SFA content of the seeds.

(Kumar Rai et al., 2018) evaluated the fatty acid contents of the 26 Brassica species. They found that *Brassica juncea*, *Brassica napus*, and *Brassica rapa* have palmitic acid contents that vary from 3.08 to 3.85%, 3.70 to 5.15%, 2.75 to 3.73%, and oleic acid contents that ranged from 0.80 to 48.70%, 16.15 to 37.98%, and 6.21 to 16.15%, respectively. The amount of linoleic and linolenic acids both showed significant variation ($p<0.05$). *Brassica juncea*, *Brassica napus*, and *Brassica rapa* had linoleic acid contents ranging from 11.00 to 45.30%, 18.57 to 26.93%, and 14.08 to 18.18% and linolenic acid contents ranged from 11.10 to 26.72%, 9.99 to 17.23%, and 9.82 to 26.66%, respectively. (Tan & İş, 2017) investigated the fatty acid composition of some summer and winter rapeseed cultivars and cultivar candidates grown in experimental fields of the Aegean Agricultural Research Institute. As given in Table 2, the amount of erusic acid was found below the limit value of 2% in both cultivars. According to the results obtained by (Öztürk, 2022), Sygenta Linus oil had significant levels of oleic, arachidic, linolenic, and behenic acid when compared to PR44W29 variety (Table 2). Rapeseed oils constituted 4.36-4.57% palmitic, 1.59-1.82% stearic, 61.89-64.21% oleic, 18.50-19.91% linoleic, and 8.52-10.70% linolenic acids, according to (Szydłowska-Czerniak et al., 2019).

Table 2. Fatty acid composition (%) of some canola seed cultivars grown in different regions in Turkey

Fatty acid	Westar from Isparta Region (Hasan Baydar & Erbaş, 2005)	Linetta from Isparta Region (Hasan Baydar & Erbaş, 2005)	ETAE-K-521 from İzmir Region (Tan & İş, 2017)	Licord from İzmir Region (Tan & İş, 2017)	PR44W29 variety from Konya Region (Öztürk, 2022)	Sygenta Linus variety from Konya Region (Öztürk, 2022)
Palmitic (C16:0)	6.1	7	4.68	4.63	4.49	4.93
Stearic (C18:0)	3.2	4.3	1.92	1.82	5.36	1.93
Oleic (C18:1 *n-9*)	66.6	72.5	61.64	55.97	61.93	63.96
Linoleic (C18:2 *n-6*)	18.2	14.3	17.99	18.21	19.06	19.02
α-Linolenic (C18:3 *n-3*)	6	1.8	8.94	9.85	8.38	9.33
Arachidic (C20:0)	-	-	-	-	0.52	0.55
Behenic (C22:0)	-	-	-	-	0.26	0.28
Erusic acid (C22:1)	-	-	0.61	1.85	-	-

These variations are most likely caused by factors such as location, variety, meteorological factors, harvest time, growth conditions, and fertilization (Öztürk, 2022). (Nasiri et al., 2021) revealed that agronomic practices impact the fatty acid composition of canola oil; they demonstrated that humic acid treatment lowered erusic acid and glucosinolate concentration.

Soybean Seed

Soybean seeds are the species of grain and other legumes with the greatest levels of protein (35–45%) and oil (20–25%) (Eren et al., 2012). In addition to its oil and protein content, soybean seed plays a significant role in the nutrition of both humans and animals thanks to its 30% carbohydrate and 5% mineral content, as well as its abundance of vitamins and vital amino acids (Kaya, 2020). Although soybean oil is 99% triacylglycerol after refining, crude soybean oil still includes large amounts of phospholipids (1.5-2.5%), unsaponifiable materials (1.6%), and traces of metals. Lecithin, a useful byproduct of the degumming process that removes the phospholipid concentration, is a major source of commercial phospholipids. About 50% of crude lecithin is composed of phospholipids, 34% of it of TAG, 7% of glycolipids, and 7% of carbohydrates. In a variety of culinary goods, animal feed, cosmetics, and medicinal preparations, lecithin is employed in different formulations (Woodfield & Harwood, 2016). In 2015, the output of all oil seeds worldwide included 60% of soybean seeds. Because legume crops fix atmospheric nitrogen, soybeans increase soil fertility. Depending on the growing seasons and varietals, soybeans have different agronomic and qualitative characteristics (Bakal et al., 2017).

The primary SFA in soybean oil were palmitic (12.01%) and stearic (4.88%) acids, with behenic (0.7%) and arachidic (0.60%) acids, respectively, in terms of concentration (Mihai et al., 2020). 15% of the fatty acids in soybean oil are saturated, 25% are monounsaturated, and 60% are polyunsaturated. Omega-6 linoleic acid made up 55% of soybean oil, followed by Omega-9 oleic acid at 25%, palmitic acid at 10%, and omega-3 linolenic acid at 5%. Its nutritional value is further increased by the presence of omega-fatty acids. However, because linolenic acid, which is present in soybean oil at substantial levels, has an unpleasant smell when it is heated, its usage as frying oil is restricted. Since it has a high unsaturation level, it is particularly popular in the production of hydrogenated margarine, mayonnaise, and sauces. As a result, the industry changed from using tropical oils like palm and coconut oils to soybean oil nearly immediately (Eren et al., 2012). (Mihai et al., 2020) showed that soybean oil was the only oil that contained 0.03% trans-vaccenic acid, and that the two primary MUFAs in soybean oil were oleic acid (17.68%) and cis-vaccenic acid (1.33%). Additionally, this oil provides a significant amount of LA (54.50%). The oil's ALA content was 7.21%, indicating that it offers nutritional value due to its high concentration of omega-3 fatty acids (more than 0.6 g of ALA per 100 g and 100 kcal).

The fatty acid levels of a few soybean cultivars were measured by (Eren et al., 2012). For all cultivars, linoleic acid concentrations were greatest as given in Table 3. (Gölükcü et al., 2019) determined the fatty acid composition of some soybean varieties developed at the Batı Akdeniz Agricultural Research Institute (Table 3). The ratios of palmitic, stearic and arachidic acids in the composition of soybean oils as SFAs ranged between 11.28-11.97%, 3.62-4.45%, 0.31-0.37%, respectively. The amounts of linoleic acid ranged from 49.99% to 55.28% in the varieties and lines analyzed within the scope of the research. It may be advantageous to have high levels of linoleic acid, an essential fatty acid, in directly consumed foods. The amount of oleic acid in the samples ranged between 22.68% and 27.92%. (Galão et al., 2014) revealed that the fatty acid composition of soybean oil differs according to the growing region and variety. The researchers determined that the palmitic, stearic and arachidonic acid ratios of soybean oil varied between 10.06-13.48%, 3.19-4.62%, 0.00 0.23%, respectively, according to these factors. They also reported the oleic, linoleic and linolenic acid ratios of soybean oil as 13.46-20.63%, 53.32-59.34% and 7.38-11.89%, respectively (Galão et al., 2014).

Table 3. Fatty acid composition (%) of some soybean seed cultivars grown in different regions in Turkey

Fatty acid	Harran Region (Boydak et al., 2002)	Ata 139 from Antalya Region (Eren et al., 2012)	Ata 105 from Antalya Region (Eren et al., 2012)	BATEM-201 from Antalya Region (Gölükcü et al., 2019)	BATEM-308 from Antalya Region (Gölükcü et al., 2019)	Ataem-7 from Kahramanmaras Region (Kaya, 2020)
Myristic (C14:0)	-	-	-	-	-	0.06
Palmitic (C16:0)	10.9	11.16	11.89	11.6	11.64	10.61
Palmitoleic (C16:1)	0.2	-	-	-	-	0.08
Stearic (C18:0)	4.5	3.99	4.4	3.99	3.88	4.31
Oleic (C18:1 *n-9*)	27.4	27.37	21.72	24.9	25.45	26.25
Linoleic (C18:2 *n-6*)	50	51.79	55.72	52.99	52.72	51.24
Arachidic (C20:0)	0.4	-	-	0,34	0.32	-
α-Linolenic (C18:3 *n-3*)	6	5.68	6.28	5.94	5.77	-
Eicosenoic (C20:1)	0.1	-	-	0.24	0.23	-
Behenic (C22:0)	0.4	-	-	-	-	-

The physical and oxidative stability of the oil, which is important in determining the usage areas, can also change due to the difference in the fatty acid composition (Gölükçü et al., 2019).

Cotton Seed

The most common natural source of fiber and one of Turkey's most significant commercial crops is cotton seed (*Gossypium hirsutum L*). Over the years, China has consistently ranked first in the world for cottonseed output (Yang et al., 2019). Cottonseeds oil content ranged from 12 to 25%. Cottonseed oil is produced as a byproduct and provides a significant portion of Turkey's oil needs. After sunflower oil, cottonseed oil is the most widely used oil today. Crude cottonseed oil has a murky look and a smell that is similar to peanut and walnut. The significant quantity of color pigment that is transferred to oil during extraction causes the color of crude cottonseed oil to fluctuate, ranging from light yellow to dark red. In addition to triglycerides, this oil also contains nonglyceride elements, including gossypol, phospholipids, sterols, pigments, and tocopherols, in amounts of around 2%. It also contains tocopherols, a natural antioxidant, vitamin B, oil-soluble vitamins, and a wealth of minerals. However, throughout the refining process, tocopherol levels in oil drastically decrease (Konuşkan et al., 2017). The major reason the cotton plant is cultivated is for the cotton, which is used in the textile industry to make clothing and other household items. Cottonseed oil is particularly well suited for the manufacturing of non-yellowing, oil-modified alkyd resins, which is a precursor for the creation of white gloss alkyd paints due to its high level of unsaturation and unique fatty acid makeup (Isaac & Ekpa, 2013). Cottonseed oil could be used for cooking or frying if it is treated appropriately.

It is a significant oil plant since It could be crucial in bridging the gap in vegetable oil production (Gürsoy, 2019). Cottonseed oil, sometimes known as "heart oil," is regarded as the greatest edible oil in the world due to its lack of cholesterol. Cottonseed oil has an unusual flavor and cooking quality due to the specific ratios of SFAs and UFAs in it. UFAs make up 65-70% of cottonseed oil whereas SFAs make up 26-35%. Linoleic acid makes up the majority of UFAs (55%) followed by oleic acid (15%) and linolenic acid (less than 1%). Cottonseed oil includes small amounts of numerous fatty acids, such as myristic, lignoceric, arachidic, cis-vaccenic, malvalic, palmitoleic, behenic, and linolenic acids, in addition to the main fatty acids (0.1–1% each) (Sharif et al., 2019).

Cottonseed oil differs from other vegetable oils due to its distinct fatty acid composition; it has a relatively high amount of unsaturation (Shah, 2017). The fatty acid composition of cottonseed oil includes minor levels of 2.33% stearic acid, 1% myristic acid, 0.6% palmitoleic acid, and 0.17% linolenic acid along with 52.89% linoleic acid, 25.39% palmitic acid, and 16.35% oleic acids (Isaac & Ekpa, 2013; Yang et al., 2019). Public worry about the harmful consequences of free gossypol and cyclopropenoid fatty acids. The greatest obstacle to the use of cottonseed, particularly in feed products, is free gossypol (Yang et al., 2019).

According to (Isaac & Ekpa, 2013)'s study, hexadecanoic acid (14.77%) was the most abundant SFA of cottonseed oil. 77.68% and 22.32% of fatty acids were found to be saturated and unsaturated respectively. According to analysis, cottonseed oil contains 2.12% linoleic acid, 14.77% palmitic acid, 75.56% oleic acid, and low quantities of 6.05% stearic and 1.50% myristic acids. However, the results of this current study are different in terms of particular fatty acids, with oleic acid being the most abundant while linoleic acid, which is the most prevalent UFA in this work, is the least abundant. (Konuşkan et al., 2017) examined fatty acid composition of three cotton genotypes, Cukurova 1518, PAUM 15, and BA 119 from Çukurova Region (Table 4). For all genotypes investigated, the main fatty acids were linoleic, palmitic, oleic, and stearic acids. Miristic, palmitoleic, linolenic, and arachidic acid levels were all less than 1%. According to genotypes, the oleic acid percentage in cottonseed oil ranged from 14.06 to 17.00%. Oils from genotypes BA 119 (17.00%) and PAUM 15 (55.82%) had the highest oleic and linoleic acid concentrations, respectively.

Table 4. Fatty acid composition (%) of some cottonseed cultivars grown in different regions in Turkey

Fatty acid	Nazilli-84 from Nazilli Region (Nergiz et al., 1997)	PAUM-15 from Çukurova Region (Konuşkan et al., 2017)	BA-119 from Çukurova Region (Konuşkan et al., 2017)	Nazilli-84S from Aydın Region (Menderes et al., 2019)	Akdemir from Aydın Region (Menderes et al., 2019)
Myristic (C14:0)	0.85	0.78	0.8	0.73	0.54
Palmitic (C16:0)	24.1	24.85	25.63	22.8	23.89
Palmitoleic (C16:1)	0.84	0.54	0.57	0.04	0.11
Stearic (C18:0)	2.04	3.01	3.12	2.02	1.71
Oleic (C18:1 *n-9*)	16.44	14.06	17	15.07	14.94
Linoleic (C18:2 *n-6*)	55.26	55.82	52	58.93	58.61
Arachidic (C20:0)	0.06	0.3	0.31	-	-
α-Linolenic (C18:3 *n-3*)	0.41	0.14	0.12	0.41	0.19

Peanut Seed

The peanut, commonly known as "The King of Oilseeds," is a member of the Leguminosae family, sometimes known as the Fabacae, and has the scientific name *Arachis hypopgaea*. It is the world's fifth most important oil-seed crop, producing roughly 40 million tons (Mora-Escobedo et al., 2015). Both the quantity and the caliber of the oil in the peanuts vary depending to a number of variables, including genotype, seed maturity, season, and production region (Shad et al., 2012).

Peanut (*Arachis hypogaea L.)* is a prominent oilseed for nutritional characteristics, with oil content ranging from 47% to 50%, protein content ranging from 27% to 29% and other natural components such as tocopherols, dietary fibers and minerals (Juan-Polo et al., 2022; Matthaus & Özcan, 2015; Zhang et al., 2020). In many country, peanuts are typically used to make oil, eaten as a snack, made into peanut butter, and utilized as a component in confectionary items (Bonku & Yu, 2020; Kazemian-Bazkiaee et al., 2020) . The top two peanut producers are China (17 MMT) and India (4.7 MMT). Meanwhile, these countries predominantly utilize peanut oil. From 2020 to 2021, worldwide peanut oil output is 6.14 million metric tons, with China and India using 3.28 and 1.12 million metric tons, respectively, accounting for 71.66% of total global production (USDA, 2022; Zhang et al., 2022)

13 different fatty acids are present in peanuts (palmitic, palmitolic, heptadecylic, heptadecenoic, stearic, oleic, linoleic, linolenic, arachidic, eicosenoic, behenic, nervonic and lignoceric) (Gulluoglu et al., 2016). UFAs, primarily oleic acid and linoleic acid, account for approximately 80% of the total fatty acid content, mainly oleic acid (42-52 %) and linoleic acid (32-37 %), of peanut oil (Juan-Polo et al., 2022; Shad et al., 2012). The fatty acid composition of peanut oil can affect its storage and nutritional qualities (as well as flavor). The oleic-to-linoleic acid ratio is a shelf-life index for industrial purposes and is regarded an indicator of peanut oil stability (Mondragón et al., 2009). In addition, due to the presence of natural antioxidants, peanut oil with a high oleic acid (OA) also has a longer shelf life (Kamdar et al., 2020). As a result, the health-conscious food market has given peanut types with high oleic acid (OA) more attention for their nutritious qualities (Xiao et al., 2022). These fatty acids have been related to a lower risk of heart disease (CVD). Several studies have indicated that oleic acid, a MUFA, decreases LDL cholesterol

while boosting good HDL cholesterol (Mora-Escobedo et al., 2015). In order to prevent thrombogenesis, MUFAs may increase fibrinolysis while decreasing platelet aggregation. Compared to SFAs, MUFAs have lower levels of total and LDL cholesterol, higher levels of HDL cholesterol, and lower levels of plasma triglycerides (Acids & Disease, 2009). The amount of vitamin E in peanuts could also be utilized as a sign of their oxidative status. By stabilizing PUFAs in membrane lipid bilayers, it protects them against radical scavenging and lipoxygenase degradation (Silva et al., 2010).

High-OA peanut materials are often generated by screening mutants of fatty acid desaturase 2 (FAD2), which is based on the OA biosynthesis concept. According to (Wang et al., 2019) AhFAD2 genes for FA desaturase, which controls the conversion of OA into linoleic acid. Recessive allele mutants, however, demonstrate deficiencies in this conversion pathway, leading to OA build up (Wang et al., 2019; Xiao et al., 2022). A 4-week randomized clinical trial with 43 males between the ages of 18 and 50 found that eating high-oleic peanuts on a regular basis as part of a hypocaloric diet increased fat oxidation and decreased body fatness in overweight and obese men, and attenuated inflammation linked to obesity by strongly moderating postprandial glucose, insulin, and TNF- concentrations (Bonku & Yu, 2020)

Peanut is appropriate for nutritional use due to its high concentration of UFAs compared to SFAs (Shad et al., 2012). (Mora-Escobedo et al., 2015) determined the fatty acid composition of eight varieties grown in Mexico. Palmitic acid was found to be the most abundant SFAs, while oleic acid levels ranged from 45.2% to 53.8%, whereas linoleic acid levels ranged from 25.1% to 29.2%. When looking at the fatty acid contents of raw peanut seeds, the Ranferi Daz cultivar had the highest oleic acid content, a high linoleic acid content, and a high O/L ratio, whereas the Gerardo Uribe had a lesser percentage of these fatty acids. The oleic/linoleic ratio (O/L) assesses the susceptibility of oil to oxidative degradation during refining and storage (Fayyaz-Ul-Hassan & Ahmed, 2012; Mora-Escobedo et al., 2015) According to the study realized by Fayyaz-Ul-Hassan and Ahmed (2012), a negative relation between oleic and linoleic acids has been found in peanut seeds as a result. The oleic/linoleic acid ratio is affected by changes in climatic conditions. Several factors influence the fatty acid content of peanut oil, including variety, seasonal variation, genotype, location, air and soil temperature, planting date, soil nutrient, moisture availability, growing conditions, and maturity (Fayyaz-Ul-Hassan & Ahmed, 2012; Gulluoglu et al., 2016; Mora-Escobedo et al., 2015). The highest O/L ratio was reported in NC-7 with 3.41% and Batem-5025 with 3.03% from Osmaniye/Turkey varieties (Ergun and Zarifikhosroshani, 2020). The cultivar is typically classified as high oleic peanuts when the O/L ratio is equal to or greater than 9 (Davis et al., 2016). Lower temperatures during seed development are typically associated with higher unsaturated oil due to the increased function of oleatedesaturase, which stimulates linoleic acid production. With increasing seed maturity, oleic acid concentrations rise, while palmitic, linoleic, arachidic, eicosenic, behenic, and lignoceric acid concentrations fall (Gulluoglu et al., 2016).

(Xiao et al., 2022) investigated the fatty acid composition of high-oleic acid peanut seed after different cooking methods. Major of the fatty acids in the seed were linoleic acid (18:2) and oleic acid (18:1, cis-trans isomerism), both of which increased after frying in comparison to raw materials. However, boiling seemed to be an unsatisfactory technique of processing high-OA peanut seed because it reduced the levels of most fatty acids, including stearic acid (18:0), oleic acid (18:1), and linoleic acid (18:2). Additionally, the variance of 16:0 and 18:0 in the frying and baking groups was not significant. (Shad et al., 2012) were examined the fatty acid composition of 4 peanut varieties namely, Golden, Bari 2000, Mongphalla and Mongphalli 334 belonging to the regions of Pakistan. The findings show that all four types of pea nuts have relatively higher percentages of UFAs (82.06% - 85.93%) than SFAs (12.64%- 16.31%).

(Gulluoglu et al., 2016) were investigated fatty acid composition of some peanut cultivars grown in Cukurova region, Turkey. The fatty acid ranges were 5.85-12.80% palmitic acid, 2.36-4.80% stearic acid, 1.17-1.93% arachidic acid, 2.11-3.11% behenic acid, and 1.01-1.88% lignoceric acid. The percentages of oleic acid and linoleic acid in peanut cultivars ranged from 39.42 to 81.81% and 1.73 to 36.38%, respectively. In Table 1, only the fatty acid composition results of Halisbey and Sultan cultivars are given. (Kirbaşlar et al., 2012) determined the fatty acid composition of peanut samples from Osmaniye region (Table 5). The most abundant fatty acid was oleic acid (55.41%), followed by linoleic, palmitic and stearic acids. Additionally, they detected the fatty acid which are rather too few amounts such as myristic, palmitoleic, heptadecenoic, ϒ-linolenic, α-linolenic, eicosenoic, eicosedienoic, behenic and docosadienoic acids.

Table 5. Fatty acid composition (%) of some peanut seed cultivars grown at different regions in Turkey

Fatty acid	Osmaniye region (Kirbaşlar et al., 2012)	ÇOM from Osmaniye region (Özcan & Seven, 2003)	NC-7 from Osmaniye region (Özcan & Seven, 2003)	Halisbey from Adana region (Gulluoglu et al., 2016)	Sultan from Adana region (Gulluoglu et al., 2016)	Batem-5025 from Osmaniye region (Ergun, Z.; Zarifikhosroshani, 2020)
Myristic (C14:0)	0.03	0.13	0.23	-	-	-
Palmitic (C16:0)	9.48	8.70	13.03	10.40	10.02	8.69
Palmitoleic (C16:1)	0.20	0.30	0.23	-	-	0.07
Heptadecenoic (C17:1)	0.07	-	-	-	-	-
Stearic (C18:0)	2.98	3.77	4.53	3.19	3.43	3.26
Oleic (C18:1 *n-9*)	55.41	55.07	43.13	52.62	54.46	62.43
Linoleic (C18:2 *n-6*)	26.51	25.13	35.20	26.19	24.35	18.27
ϒ-Linolenic (C18:3 *n-6*)	1.46	-	-	-	-	-
Arachidic (C20:0)	-	1.90	1.53	1.17	1.82	1.62
α-Linolenic (C18:3 *n-3*)	0.06	-	-	-	-	0.03
Eicosenoic (C20:1)	1.01	1.37	0.40	-	-	0.99
Eicosadienoic (C20:2 *n-6*)	0.12	-	-	-	-	-
Eicosatrienoic (C20:3 *n-6*)	2.00	-	-	-	-	-
Arachidonic (C20:4 *n-6*)	-	-	-	-	-	0.03
Behenic (C22:0)	0.54	3.17	2.40	2.82	3.11	2.56
Docosadienoic (C22:2 n-6)	0.13	-	-	-	-	-

These findings were consistent with those observed in other investigations (Aljuhaimi & Özcan, 2018; Grosso et al., 1999; Qu et al., 2022; Shad et al., 2012; Shokri et al., 2022) The changes in the results could be caused by variations in the weather, soil moisture, and ambient temperature as peanut seeds were maturing (Özcan & Seven, 2003). According to the (Zhang et al., 2022), after dark roasting , the total fatty acid composition decreased from 1266.78 µg/g to 781.75 µg/g with 32.99 % rate of reduction. The fatty acids that showed the most decrease were palmitic, stearic, oleic and linoleic acids.

Poppy seed

Poppy (*Papaver somniferum*) is grown as an annual crop in China, India, Czech Republic-Slovakia, and Turkey (Erinç et al., 2009). It is grown primarily for its opium and oil seed content (Aksoylu Özbek & Günç Ergönül, 2020). Alkaloids from opium are used in pharmaceutical products. However, poppy seeds have been studied as a diet component because they don't contain opium (Muhammad et al., 2021). Poppy seeds, which are mostly consumed as food, have a high seed yield, a wide range of bloom colors, including blue, blue-gray, and white, and a low alkaloid content (Muhammad et al., 2021). Similar to sesame seeds, poppy seeds are mostly used in confectionery in Europe. The seeds are an excellent source of energy. They are also widely used in baking and as a topping for bread and rolls. Poppy seed oil looks to be of high quality for human consumption due to its high concentration of PUFAs (Bozan & Temelli, 2008). According to some reports, *P. somniferum* seeds can be used to treat dysentery, constipation, cough, and asthma (Erinç et al., 2009). Poppy seed oil is light yellow in color, fixed, flavorless, and greasy, and it is beneficial as salad oil because it is less susceptible to rancidity than olive oil. The oil is also used in the production of margarine and salad dressings, as well as in cooking (Muhammad et al., 2021). Linoleic acid is present in poppy seed oils in the highest concentrations (56.4–69.2%), oleic acid is present in the range of 16.1%–19.4%, and palmitic acid is present in the range of 10.6%–16.4%. Smaller amounts of stearic and alpha-linolenic acids are also found (Azcan et al., 2004; Erinç et al., 2009). These results are in agreement with many authors (Aksoylu Özbek & Günç Ergönül, 2020; Bajpai et al., 1999; Hlinková et al., 2012; Lančaričová et al., 2016; Musa Özcan & Atalay, 2006; Wei et al., 2022). Because of its high linoleic acid content and low linolenic acid content, poppy seed is an excellent crop for the food business (Hlinková et al., 2012). On the other hand, poppy oil has other beneficial compounds such as phytosterols, tocopherols, and phenolics (Ghafoor et al., 2019; Dąbrowski et al., 2020). The references show a wide range of variance in the content and composition of these chemicals, which for the same seed material can be influenced primarily by the process of oil production (Dąbrowski et al., 2020).

(Hlinková et al., 2012) determined the fatty acid composition of eight poppy genotypes grown in Slovak Republic. As a result, the three main fatty acids in all of the oil samples examined were linoleic (C18:2), oleic (C18:1), and palmitic (C16:0) acids. Alpha-linolenic acid (ALA) (C18:3) and stearic acid (C18:0) were used to describe minority fatty acids. Linoleic acid was the fatty acid that was most prevalent. All oil samples contained minor amounts of gadoleic (C20:0), myristic (C14:0), arachidic (C20:0), and palmitoleic (C16:1) fatty acids (C20:1). According to (Özcan and Atalay, 2006), the oils of seven different poppy seed cultivars grown in Afyon (Turkey) contained 52.60-71.50% linoleic acid, 13.11-24.13% oleic acid, and 12.85-18.70% palmitic acid. (Dąbrowski et al., 2020) were determined the effect of different extraction methods on fatty acid composition of poppy seed oils. Despite the extraction method or solvent utilized, the fatty acid profile of all extracted poppy seed oils was similar with other researches (Bozan & Temelli, 2008; Lančaričová et al., 2016; Rahimi et al., 2011). (Ghafoor et al., 2019) investigated the effect of pre-treatment of poppy seeds, including oven and microwave roasting, on the physicochemical properties and fatty acid content of poppy seeds and oil. Linoleic acid, which is contained in blue, yellow, and white seeds, was reduced by roasting; its contents in raw seed oil were 57.91, 61.91, and 64.83%, respectively, in oven-roasted seed oil, and 56.97, 60.08, and 60.84% in microwave-roasted seed oil.

(Rahimi et al., 2011) identified a wide range of fatty acid levels in 18 different poppy cultivars. The fatty acid composition of three varieties from them is given in Table 6. While major fatty acid linoleic acid ranged from 68.76% to 64.22%, oleic acid is ranging between 13.30%-17.80%. From this, it is concluded that the region where they are grown and environmental factors are effective on the fatty acid levels of poppy genotypes grown in different regions. According to the studies, fatty acids such as myristic, gadoleic, eicosadienoic, triosanoic and lignoseric acids which are found in trace amounts in poppy seed oil, were not identified by (Rahimi et al., 2011; Özbek and Ergönül, 2020) (Table 6). (Erinç et al., 2009) are also determined the fatty acid composition of different poppy seeds varieties from Afyon province. Their results revealed that all of the poppy seeds examined had high linoleic acid levels (68.7-73.9%). The fatty acid composition of the Office-96 variety used in the study is given in the Table 6 as a sample. This tendency can be explained by the fact that the fatty acid content can be influenced by the planting location, extraction method, and other factors (Wei et al., 2022). Even among seed samples from the same location, the fatty acid contents of oils vary greatly

(Azcan et al., 2004). For Indian poppy seed oil, the values for the major fatty acid components were recorded as palmitic: 8.9-21.5%; oleic: 13.2-36.8%; and linoleic: 41.0-68.0% (Singh et al., 1998).

Table 6. Fatty acid composition (%) of some poppy seed cultivars grown in different regions in Turkey

Fatty acid	Ofis-96 from Afyon region (Erinç et al., 2009)	TMO-1 from Soil Products Office, Ankara (Aksoylu Özbek & Günç Ergönül, 2020)	Ofis-8 from Soil Products Office, Ankara (Aksoylu Özbek & Günç Ergönül, 2020)	TMO-2 from Turkish Grain Board (Rahimi et al., 2011)	Ofis-95 from Turkish Grain Board (Rahimi et al., 2011)	Ofis-3 from Turkish Grain Board (Rahimi et al., 2011)
Myristic (C14:0)	0.05	-	-	0.05	0.04	0.06
Palmitic (C16:0)	8.48	8.67	9.03	10.19	7.96	9.45
Palmitoleic (C16:1)	0.25	0.17	0.21	0.25	0.13	0.16
Heptadecanoic (C17:0)	0.05	0.05	0.06	0.06	0.04	0.05
Heptadecenoic (C17:1)	0.03	0.03	0.04	0.03	0.02	0.02
Stearic (C18:0)	2.18	2.18	2.12	2.03	2.09	2.23
Oleic (C18:1)	14.13	16.43	16.99	17.79	14.84	13.96
Linoleic (C18:2)	72.72	71.83	70.78	68.76	74.15	73.24
Linolenic (C18:3)	0.55	0.53	0.67	0.72	0.58	0.68
Arachidic (C20:0)	0.1	0.10	0.11	0.08	0.09	0.10
Gadoleic (C20:1)	0.07	-	-	0.04	0.06	0.04
Eicosadienoic (C20:2)	0.002	-	-	-	-	-
Tricosanoic (C23:0)	0.34	-	-	-	-	-
Lignoseric (C24:0)	0.15	-	-	-	-	-

Because of the instability and flavor reversion associated with autoxidation, substantial levels of linolenic acid are often inappropriate for oil-food items (Singh et al., 1998). As a result of its low linolenic acid concentration and high linoleic acid content, poppy seed may be a good oil seed crop for the food industry (Singh et al., 1998). Since poppy seed oil contains more than 80% oleic and linoleic acid, it is a part of an oleic-linoleic fatty acid, like sunflower oil, sesame oil, olive oil, corn oil, safflower oil, and palm oil (Özbek and Ergönül, 2020). A PUFA/SFA ratio greater than 0.40 is advised for a balanced diet and improved cardiovascular health. All of the poppy seed oils investigated had rather high PUFA/SFA ratios. Blending poppy seed oil with other oils rich in -3 fatty acids yields oil with a balanced fatty acid distribution (Özbek and Ergönül, 2020).

Safflower seed

Safflower (*Carthamus tinctorius L.*) is a historic agricultural crop that is widely farmed globally. It is also a part of the Compositae family, which includes artichoke, chicory, and sunflower (Aydeniz & Guneser, 2014). The plant's parts can be used for a variety of purposes, including the preparation of food colors, flavorings, dyes, and medication; the manufacturing of vegetable oils and bird feed; and the feeding of cattle. While the majority of the world's cultivated safflower production is concentrated in the United States, Mexico, Kazakhstan, and India, wild safflower is widely located in northwest India, Turkey, Uzbekistan, Turkmenistan, Kazakhstan, Iran, and subtropical portions of western Iraq (Aydeniz & Guneser, 2014; Chakradhari et al., 2020). Because of its excellent tolerance and adaptability to any environment with minimal rainfall, safflower (Carthamus tinctorius L.) is a major oilseed crop in arid and semi-arid locations around the world (Akbari et al., 2020; Zanetti et al., 2013). But researchers disagree on the impact of drought stress on fatty acid composition of safflower seed oil. For palmitic acid, some observed a decrease (Ashrafi & Razmjoo, 2010), others an increase (Nouraei et al., 2016), and still others reported no change at all (Kim et al., 2006). (Akbari et al., 2020) reported that the stearic and palmitoleic acids levels were decreased by drought stress. They indicated also that drought stress increased MUFA only in 2018, with no change in 2017. According to (Nazari et al., 2017), the key reason for greater oleic under drought stress is earlier plant maturity (Gao et al., 2021). (Akbari et al., 2020) indicated that under drought stress, an increase in total PUFA levels of fatty acids is a possible defense mechanism against the negative effect of drought on the grass plant. Safflower is an excellent example of a plant with variable fatty acid composition in seed oil. When the temperature rises during seed maturity, linoleic acid content falls while oleic, palmitic, and stearic acid content rises (Samanci & Özkaynak, 2003). Safflower seeds include 11–22% fiber, 15–22% protein, and 38–48% oil. Since the hull accounts for 18–59% of the seed weight and the 1,000-seed weight spans from 14 to 105 g, there is a significant difference between the various types (Bowles et al., 2010).

Safflower is amongst the greatest examples of a crop with variable fatty acid composition in seed oil (Gecgel et al., 2007). Safflower oil has the highest linoleic acid content out of all commercial oils, with 6-8% palmitic, 2-3% stearic, 16-20% oleic, and 71-75% linoleic acids as its main constituents (Akbari et al., 2020; Gecgel et al., 2007; Velasco, L., & Fernandez-Martinez, 2001). So, safflower oil is high in omega-3 fatty acids, which are essential for good health (Akbari et al., 2020). Due to its reported capability to reduce blood cholesterol levels, high-linoleic safflower oil is used as a premium cooking oil (Gecgel et al., 2007).

The effects of sowing and harvest dates on fatty acid composition of two safflower varieties with high oleic and high linoleic genotypes grown in the Trakya region of Turkey were determined by (Gecgel et al., 2007). sowing and harvest dates effects were found significant for major fatty acids (palmitic, stearic, oleic and linoleic acids) , while the minor fatty acids (lauric , myristic, palmitoleic, linolenic and arachidic acids) were not affected. During seed growth, the level of palmitic acid declined. When the impacts of sowing dates were compared in both locations, high levels of C18:0 were related with low levels of C18:2 at maturity. In addition, for all varieties, the formation of C18:1 and C18:2 acids was inversely related. The lowest C18:1 content was discovered with the greatest C18:2 content (Gecgel et al., 2007).

Aydeniz et al. (2013) determined the fatty acid composition of cold pressed Dinçer variety safflower seed oil (Table 7). The fatty acid composition of the samples analyzed agrees extremely well with those published in the codex (FAO, 1999) and other publications (Chakradhari et al., 2020; Gibbins et al., 2012; Golkar et al., 2011; Lee et al., 2004). As can be seen from the Table 7, the fatty acid composition of safflower seed oil is significantly influenced by genotype, climatic conditions, particularly temperature during the growing season, development stages of seed, and sowing time where it is planted (Chehade et al., 2022). The fatty acid compositions of several safflower seed oils listed in the Table were similar to those reported by others (Carvalho et al., 2006; ÇamaŞ & Çırak, 2007; Sabzalian et al., 2008; Samanci & Özkaynak, 2003). Linoleic acid (55.32-66.67%), oleic acid (21.28-27.44%), and palmitic acid (9.45-13.87%) were found in the oils of the Yenice and Dinçer types, according to (Samanci & Özkaynak, 2003). (Guan et al., 2008) studied the fatty acids of 21 safflower germplasm from 12 different countries. Their findings revealed that palmitic acid ranged from 4.04% to 7.86%, stearic acid ranged from 1.5% to 2.75%, oleic acid ranged from 7.9% to 32.99%, and linoleic acid ranged from 62.7% to 83.74%.

Table 7. Fatty acid composition (%) of some safflower seed cultivars grown in different regions in Turkey

Fatty acid	Dinçer variety (Aydeniz et al., 2014)	Remzibey-05 variety from Field Crops Department at Agricultural Faculty of Ankara University (Coşge et al., 2007)	Yenice variety from Field Crops Department at Agricultural Faculty of Ankara University (Coşge et al., 2007)	Alakova (Çumra Şeker) variety (Matthaus & Özcan, 2015)	Linas variety from Trakya Agricultural Research Institute (Günç Ergönül & Aksoylu Özbek, 2018)	Balcı variety from Transitional Zone Agricultural Research Instıtute (Günç Ergönül & Aksoylu Özbek, 2018)
Myristic (C14:0)	0.25	0.11	0.11	-	0.15	0.13
Palmitic (C16:0)	6.76	6.19	5.70	6.81	6.63	7.05
Palmitoleic (C16:1)	-	0.12	0.10	0.03	0.09	0.09
Stearic (C18:0)	2.50	2.20	2.20	1.88	2.48	2.46
Oleic (C18:1)	12.31	32.11	10.53	12.6	14.06	14.18
Linoleic (C18:2)	76.92	58.73	80.86	75.2	75.59	75.05
Linolenic (C18:3)	-	0.07	0.08	0.13	0.78	0.80
Arachidic (C20:0)	0.35	0.33	0.25	-	0.10	0.10
Gadoleic (C20:1)	-	0.17	0.13	0.36	0.14	0.16
Behenic (C22:0)	0.25	-	-	-	-	-
Docosahexaenoic (C22:6)	0.26	-	-	-	-	-

(Arslan & Tarikahya Hacioğlu, 2018) analyzed the fatty acid composition of wild and cultivated safflower species. All of the safflower accessions studied were linoleic type. Less than 1% of the total fatty acid content was docosahexaenoic acid (C22:6), pentadecanoic acid (C15:0), arachidic acid (C20:0), linolenic acid (C18:3), nervonic acid (C24:1), lignoceric acid (C24:0), behenic acid (C22:0) and myristic acid (C14:0). Linoleic, oleic, palmitic, and stearic acid content ranged from 58.8% to 82.6%, 7.3% to 22.8%, 4.8%-8.8%, and 1.8%-4.9%, respectively. According to the results of the different studies, it could be said that the variety and genetics of the seed are important variables influencing fatty acid composition.

Sesame Seed

Sesame (*Sesasum indicum* L.) seed which belongs to Tubiflorae family and Pedaliaceae family is one of the most important oil source known in many countries and is known with its high nutritive value. India, China and Sudan are leading countries that are contributing 60% of global production (Carvalho et al., 2012). As reported by (Hossam S. El-Beltagi et al., 2022) the average yield of sesame seed is ranging among 256 to 1400 kg/ha according to Food and Agricultural Organization (FAO) Report and among the oilseed crops sesame ranks 8th in terms of global production. Sesame seed consumption was USD 6559.0 million in 2018 and it is predicted to be USD 7244.9 million in 2024 (Yeasmin, 2021).

Sesame family is known as a small family containing 16 genera and 60 species and 37 of these 60 species belong to Sesamum genus. *Sesamum indicum* L. (2n=26) is cultivated between these 37 species (Asghar & Majeed, 2013).

Sesame seed (*Sesamum indicum*) is cultivated worldwide for its oil and protein content. Sesame seed also contains approximately 25% protein (Asghar & Majeed, 2013). According to (Mahmood Biglar, 2012), sesame seed contains oil up to 40-60%. According to (Harfi et al., 2019), it contains high level of oil (44-58%), protein (18-25%) and is an important source of micro elements like Fe, Zn, Ca, Mg, Cu and Se, dietary fiber and several vitamins. On the other hand, according to (Gbadamosi et al., 2017), sesame has averagely 13.5% carbohydrate and 5% ash and sesame seed oil is odorless and so close in terms of quality when compared to olive oil. In same study it was reported that sesame seed oil was straw-like in color and had an excellent taste for using as salad-oil requiring a little or no winterization process. It is understood that it can be used directly as cooking oil for many purposes in both industry and at home.

Sesame (*Sesamum indicum* L.) plant is cultivated generally in tropical and subtropical regions for its oil. Sesame seeds are also used as a condiment in dishes and for patisserie products of different countries (Özdemır et al., 2018). Sesame oil is rich in UFAs and its effectiveness in reducing blood cholesterol is well-known (Carvalho et al., 2012). In this study also it was reported that sesame seed oil contains the natural antioxidants sesamol, sesamolin and gamma-tocopherol. Because of these compounds present in sesame oil, it has high oxidative stability. (Hossam S. El-Beltagi et al., 2022) reported that the plant sterols in sesame oil are associated with reducing the absorption of cholesterol from the diet leading to lower LDL cholesterol levels and risk of cardiovascular illness. Since sesame oil has important bioactive compounds in its composition it is also known for its potential for enhancing the shelf life of other oils. Because of its potential therapeutic and nutritional value and also oxidative resistance, sesame seed in widely known as the queen of oil seeds (Harfi et al., 2019). Because of high content of essential linoleic and linolenic acids sesame oil is known as an important and valuable food source (Hama, 2017).

(Kurt, 2018) reported that oleic and linoleic acids in sesame oil are the predominant fatty acids and constitute more than 80% of the total fatty acid content. On the other hand, high level of MUFA and PUFA content increases the oil quality for human diet. They also reduce blood cholesterol and play important role in preventing atherosclerosis (Kurt, 2018). Sesame oil contains about 47% oleic acid (C18:1), 39% linoleic acid (C18:2), 9.0% palmitic acid (C16:0), 4.1% stearic acid (C18:0), and 0.7% arachidic acid (C20:0). Fatty acid composition of sesame seed is affected by various ecological and cultural factors. Also genotypic factors play an important role in the process, resulting in the fact that each genotype shows different fatty acid composition (Uzun et al., 2002)

As seen from Table 8, average fatty acid composition of different types of sesame samples are given. (Baydar, 2005)determined the fatty acid composition of 6 different types of sesame samples (HB-01/BMB, TSP-933749, TR-3821512, TSP-932403, Baydar-2001 and Muganlı-57) in West Mediterranean Agricultural Research Institute in 2000 and 2002. Analysis results given in the Table 8 belonging to year 2002. Average palmitic, stearic, oleic, linoleic and linolenic acid contents of the samples were determined as 9.2%, 5.7%, 42.9% and 41.5% respectively.

(Özdemır et al., 2018) studied the fatty acid composition of 39 sesame seed samples cultivated in Muğla Province which were supplied from the Ula Directorate of Provincial Food, Agriculture, and Livestock. It was reported that sesame samples obtained from 7 different cultivars, namely Yerli (22 samples), Beyaz susam (4 samples), Fethiye Sarısı (3 samples), Ortaca Sarısı (3 samples), Tanas (3 samples), Kocasusam (2 samples), and Sarısu (2 samples) and all samples were from the 2016 crop season. According to analysis results, average myristic acid content of oil samples was 0.01%, whereas palmitic acid content was 9.57%. Palmitoleic and heptadecenoic acids content of the samples were 0.11% and 0.04%. The average stearic, linoleic and linolenic acid contents of the oil obtained from 39 different sesame seed samples were 4.99%, 42.05% and 42.04%.

Sesame seeds (Gökova/Altın Susam) from Ula, Gökova and Köyceğiz regions of Muğla were analyzed and their average fatty acid composition was reported (Özpolat et al., 2021). In this research sesame oil was extracted by cold-press technique. Average myristic acid, palmitic acid, palmitoleic acid, stearic acid, oleic acid, linoleic acid, linolenic acid and arachidic acid contents of the samples were reported as 0.015%, 9.45%, 0.13%, 4.96%, 40.46%, 42.57%, 0.31% and 0.52% respectively. (Yakar et al., 2020) reported average fatty acid compositions of 6 different types of sesame samples (Arslanbey, Hatipoğlu, Boydak, Sus-4, Sus-6, Sus-7, Sus-8, Sus-10, Sus-26 and Sus-27). All samples were from Agricultural Faculty of Siirt University in Kezer Campus. As results of the study, average palmitic and palmitoleic acid contents of the samples were 9.40% and 0.13% whereas stearic, oleic, linoleic and linolenic acid contents were found as 5.89%, 46.16%, 36.91% and 0.36% respectively.

Jasad (2020) determined fatty acid compositions of Özberk-82, Gölmarmara, Muganlı-57, Batem Aksu, Batem Uzun and Baydar-2001. As reported in the study, all samples were from West Mediterranean Agricultural Research Institute located in Antalya, Turkey and sesame oil was extracted by cold-press technique. Average palmitic, stearic, oleic, linoleic and linolenic acid contents of sesame oil from different sasame samples were determined as 9.56%, 5.33%, 44.09%, 39.45% and 0.34% respectively.

According to the results of the different studies, it could be said that the variety and genetics of the seed are important variables influencing fatty acid composition.

Table 8. Fatty acid composition (%) of some sesame seed cultivars grown in different regions in Turkey

Fatty acid	(Baydar, 2005)	(Özdemır et al., 2018)	(Özpolat et al., 2021)	(Yakar et al., 2020)	(Jasad, 2020)
Myristic (C14:0)	-	0.01	0.015	-	-
Palmitic (C16:0)	9.2	9.57	9.45	9.40	9.56
Palmitoleic (C16:1)	-	0.11	0.13	0.13	0.14
Stearic (C18:0)	-	0.04	-	-	-
Oleic (C18:1)	5.7	4.99	4.96	5.89	5.33
Linoleic (C18:2)	42.9	42.05	40.46	46.16	44.09
Linolenic (C18:3)	41.5	42.04	42.57	36.91	39.45
Arachidic (C20:0)	-	0.26	0.31	0.36	0.34
Eicosenoic (C20:1)	-	0.63	0.52	0.61	0.59
Eicosadienoic (C20:2)	-	0.15	-	0.21	-
Docosadienoic (C22:2)	-	0.1	-	0.12	-

Camelina seed

Camelina (*Camelina sativa*) is known as an annual summer oilseed and is a member of mustard family which also has winter-hardy types. Camelina is also recognized by the popular given names “false flax” and “gold of pleasure” and was widely grown in Eastern Europe and Russia among the years 1940 and 1950 (Crowley & Fröhlich, 1998). Today this crop originates from Eastern Europe to Western Asia and known as one of the most resistant plant to biotic and abiotic stresses from the family Barassicaceae (Popowska et al., 2021). Camelina sativa is an important and valuable member of Cruciferaea family and according to several reports and scientific researches, it has been cultivated and used for consumption of human for approximately 30 centuries (Katar et al., 2012).

According to (Katar et al., 2012), average oil content of Camelina sativa is about 42% for summer-habit types and 45% for winter-habit types. It has a potential to be used as oil seed by using less chemical fertilizers. When this advantage is taken into consideration this issue makes this crop a superior one when compared to other crops used for oil production (Katar, 2013)

(Crowley & Fröhlich, 1998) reported that Camelina sativa oil is a good source of omega-3 fatty acids (nearly the 38% of total fatty acid content) and this is found important in terms of offering a supply for the growing demand for higher quality edible oils. Camelina sativa also has a low amount of SFAs. Also (Karvonen et al., 2002) determined that camelina sativa oil is a good source of linoleic acid when compared to other edible oils. It was reported that 36% to 40% of its fatty acid content consists of α-linoleic acid, n-3 fatty acid of plant origin. According to (Kiralan et al., 2018), camelina oil is used for manufacturing biofuels, jet fuel, feed, several pharmaceuticals and cosmetic products. In the same study it is indicated that camelina oil is also used for manufacturing salad oil, cooking oil, margarines, sauces, and dressings. In the same study it was indicated that camelina oil is rich in α-linoleic acid (C18:3, 32.5%), linoleic acid (C18:2, 18.1%), gondoic acid (C20:1, 16.9%) and oleic acid (C18:1, 14.8%). Because of its high amount of α-linoleic acid, camelina oil was taken into consideration for its health-promoting characteristics (Kiralan et al., 2018).

Since camelina oil is rich in PUFAs (linolenic acid (ω-3) from 36 to 41%; linoleic acid (ω-6) from 16 to 20%) and the ratio of ω-3 and ω-6 is 2.5: 1, this oil is recommended for people having high blood cholesterol. Also erusic acid content of camelina oil is relatively low and this oil contains natural antioxidants in its composition (Ostrikov et al., 2021). (Zubr, 2009) studied the fatty acid composition of camelina oil and reported that average linoleic acid (n-6) was ranging among 12.4% and 15.3%, whereas the α-linoleic acid content of the total oil composition was 36.8%-40.8%. Altough the amount of α-linoleic acid in camelina oil was found less than the amount present in flax oil (50%-60%), camelina oil was reported as an α-lineloic acid rich oil among the others (Zubr, 2009).

Fatty acid compositions of camelina seed oil from different researches are given as Table 9. (Göre & Kurt, 2017) reported fatty acid composition of 12 different types of camelina seeds in their research. Types of camelina seeds were Ames 26665, Ames 26667, Ames 28372, Ames 26673, Ames 26676, Ames 26680, Ames 26686, CR-1674190, CR 476/65, PI 304269, Vniimk-17 and a local type. As results of the study, average amounts of palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, arachidic acid, eicosenoic and erusic acid contents of camelina seed oil was 6.66%, 2.60%, 16.05%, 18.11%, 37.75%, 1.65%, 16.65% and 0.51%. In this study it was determined that average erusic acid contents of the oil fraction of camelina seed samples were below the amount of 2%.

(Katar et al., 2012) reported that they used 11 different types of camelina seeds in their research which were Vinimik 17, PI 304269, CR 476/65, CR 1674/90, Ames 26665, Ames 26667, Ames 26673, Ames 26676, Ames 26680, Ames 26686 and Ames 28372. Research was carried out in research area of Central Research Institute for Field Crops in Turkey. According to analysis results, average palmitic and stearic acid contents of the samples were 6.36% and 2.63%, whereas average oleic, linoleic, linolenic acid contents of the samples were 16.03%, 20.16% and 30.98%, respectively. Also the amounts of arachidic, eicosenoic and erusic acid contents of the samples were given as 1.85%, 14.07% and 3.23%.

Similarly, (Çelik, 2017) reported the average palmitic acid content of camelina seed as 6.99%. In this research, average stearic acid, oleic acid, linoleic acid and linolenic acid contents of the samples were 3.46%, 16.29%, 16.71% and 28.81%. Average arachidic acid, eicosenoic acid and erusic acid contents of the samples were determined as 1.73%, 15.32% and 3.07% respectively. In both studies reported by (Katar et al., 2012) and (Çelik, 2017), erusic acid contents of the samples were over the limit of 2%.

(Kiralan et al., 2018) investigated the fatty acid compositions of oil extracted from camelina sativa seed samples from camelina sativa plants grown in Ankara region. In their research, two different extraction method was used. One of them was cold-pressing technique and the second one was hexane-extraction method. Average amounts of palmitic acid and stearic acid in oil fraction of cold pressed camelina seeds were reported as 5.12% and 2.66%, whereas these values were 5.24% and 2.70% for the oil sample obtained by solvent extraction technique. Oleic, linoleic, linolenic and arachidic acid contents of the oil samples extracted by using cold press technique were 14.90%, 17.11%, 34.56% and 1.54, whereas the eicosenoic, eicosatrienoic and erusic acid contents were found as 16.67%, 1.35% and 2.82%. As seen from the results, erusic acid contents of the oil fraction of camelina samples were over 2%.

According to (Kiralan et al., 2018), oleic, linoleic, linolenic and arachidic acid contents of the camelina seed oil which was obtained by using solvent (hexane) extraction technique were 14.92%, 17.66%, 33.92% and 1.58%. Eicosenoic, eicosatrienoic and erusic acid contents of the samples were determined as 16.53%, 1.33% and 2.80% respectively.

(Ratusz et al., 2018) investigated 29 samples of camelina seed purchased directly from producers and small local manufacturers. As seen from Table 9, average palmitic acid and stearic acid content of camelina seed oil samples were determined as 5.5% and 2.2%. Average oleic, linoleic and linolenic acid contents of these 29 different samples were reported as 17.0%, 17.4% and 36.0% respectively. Eicosenoic acid content of the samples was averagely 13.7%, whereas erusic acid was 1.8% which was found below the limit of 2.0%.

Table 9. Fatty acid composition (%) of some camelina seed cultivars grown in different regions in Turkey

Fatty acid	(Göre & Kurt, 2017)	(Çelik, 2017)	(Katar et al., 2012)	(Kiralan et al., 2018)		(Ratusz et al., 2018)
				Cold-press technique	Hexane-extraction technique	
Palmitic (C16:0)	6.66	6.99	6.36	5.12	5.24	5.5
Stearic (C18:0)	2.60	3.46	2.63	2.66	2.70	2.2
Oleic (C18:1)	16.05	16.29	16.03	14.90	14.92	17.0
Linoleic (C18:2)	18.11	16.71	20.16	17.11	17.66	17.4
Linolenic (C18:3)	37.75	28.81	30.98	34.56	33.92	36.0
Arachidic (C20:0)	1.65	1.73	1.85	1.54	1.58	0.9
Eicosenoic (C20:1)	16.65	15.32	14.07	16.67	16.53	13.7
Eicosatrienoic (C20:3)	-	2.05	-	1.35	1.33	-
Erusic (C22:1)	0.51	3.07	3.23	2.82	2.80	1.8

Flax seed (linseed)

Linseed oil is known as derived from the seeds of flaxseed (*Linum usitatissimum* L., the Linaceae family). Flaxseed is widely cultivated in Europe for its fiber and oil content for several industries like food and textile. Linseed has long been used in animal and human diets as a source of oil (El-Beltagi et al., 2007). Linseed today plays an important role in food industry in terms of manufacturing functional foods from the point of view of its nutrition value (Bayrak et al., 2010). Linseed oil can be used as cooking oil and as salad oil, but usage of this oil for edible purposes is limited because of its instability (Kanmaz, 2017).

Canada, Argentina, USA, India and China are the leading countries whereas also linseed production is present in several European countries. As it was reported, linseed contains approximately 40% oil and 30% dietary fiber (Bayrak et al., 2010; Ghosh et al., 2019; Lewinska et al., 2015; Rubilar et al., 2010).

Linseed is a popular oil source because of the high content of α -linolenic acid content of the oil fraction (Lewinska et al., 2015; Kanmaz, 2017; Rubilar et al., 2010). α -linolenic acid content of linseed oil is nearly 55% of total oil. According to (Bayrak et al., 2010) this percentage is 5.5 times more than the sources containing the highest α-linolenic acid. In their study, (El-Beltagi et al., 2007) indicated that linseed oil is the richest source of omega-6 and omega-3 polyunsaturated fatty acids which are essential for human being since human organism cannot synthesize these valuable fatty acids. From that point of view, linseed oil has an important compositional difference when compared to other oils like olive oil, rapeseed oil, soybean oil and sunflower oil. According to (El-Beltagi et al., 2007), linseed oil consists of oleic acid (16-24%), linoleic acid (18-24%) and linolenic acid (36-50%).

(Ghosh et al., 2019) and (Goyal et al., 2014) reported that around 73% of the fatty acids in linseed oil are PUFAs and approximately 50% of the total fatty acid composition consist of α-linolenic acid. Since its high amount of α-linolenic acid, linseed oil is thought to be useful for rheumatoid arthritis and other inflammatory diseases, several types of cancer, neurological and hormonal disorders. According to (Nabey et al., 2013), α -linolenic acid suppresses peripheral blood mononuclear lymphocytes proliferation and and α

-linolenic acid lignans in linseed modulate the immune response and may play a beneficial role in the clinical management of autoimmune disease.

According to (Goyal et al., 2014) linseed oil is low in SFAs at level of approximately 9% and it provides excellent omega-6/omega-3 fatty acid ratio of approximately 0.3:1. In the same study it is indicated that the bioavailability of α-linolenic acid depends on the type of linseed used. It is known that α-linolenic acid has higher bioavailability in oil than in milled seed. Bioavailability of α-linolenic acid in whole seed is lower than the bioavailability in oil or milled seed.

Linseed has two different colors; brown and yellow. According to (Moknatjou et al., 2015), brown linseed is rich in α-linolenic acid. One type of yellow linseed which was developed in USA named Omega is also rich in α-linolenic acid like brown linseed. The second type is named as Solin but its α-linolenic acid is lower. (Moknatjou et al., 2015) reported that linseed has an oil content of 38-45% and fatty acid composition of oil composition depends parameters like location, environmental conditions, climate and cultivation.

(Gutte et al., 2015) investigated that linseed oil is poor for SFAs (9%) and moderate in MUFAs (18%), very rich in PUFAs (73%) and α -linolenic acid can be metabolized in the body into docosahexaenoic acid (DHA, omega-3) and eicosapentaenoic acid (EPA, omega-3) by several kinds of enzyme in metabolism. These fatty acids are known with their positive health effects on diseases like hypertension, diabetes, several types of cancer, osteoporosis and arthritis.

Data related to fatty acid composition of linseed oil present in different researches is given as Table 10. (Bayrak et al., 2010) investigated the fatty acid compositions of 81 different genotypes of linseed originated from Turkey, Austria, Czech Republic, Slovak Republic, Hungary, Germany, Bulgaria, Russia and Sweden and which were grown in the experimental area of the Department of Field Crops Faculty of Agriculture, Ankara University. As seen from the Table 10, palmitic and stearic acid contents of linseed oil samples were 5.07% and 4.78%, whereas the average amount of unsaturated fatty acids oleic, linoleic and linolenic were found as 22.30%, 13.98% and 53.46% respectively.

Five different linseed cultivars (Sakha 1, Sakha 2, Giza 8 (Egypt), Lithuania (Lithuania) and Aryana (France) were investigated by (El-Beltagi et al., 2007) in order to determine their fatty acid compositions. According to the results obtained, it can be seen that average palmitic and stearic acid contents of the linseed oil samples were 7.1% and 3.7%. Oleic, linoleic and linolenic acid contents of samples were found as 22%, 18.3% and 48.2% in the same study.

An oil-type brown flaxseed (TR 77705) cultivar (*Linum usitatissimum* L.) was investigated by Kanmaz (2017) and cultivar was supplied from National Gene Bank of Aegean Agricultural Research Institute in İzmir, Turkey. Palmitic, stearic, oleic, linoleic and linolenic acid contents of the oil fraction of linseed samples were detected as 4.67%, 3.61%, 17.60%, 14.86% and 58.28% respectively. On the other hand, by conduction a different study, (Danish & Nizami, 2019) reported that average palmitic and stearic acid content of linseed samples were 5.69% and 5.58%., whereas oleic, linoleic and linolenic acid contents of the samples were 20.59%, 15.80% and 51.38% respectively. As reported by (Lewinska et al., 2015), the fatty acid profiles of two commercially available linseed oils from local markets were investigated. According to results of the analysis, palmitic, stearic, oleic, linoleic and linolenic acid contents of the samples were 5.2%, 4.7%, 17.9%, 17.15% and 54.5%.

In another study, in which quite different findings were obtained, four genotypes of *Linum usitatissimum* L. - A900013 - var. elatummulticaule, A900015 and A900017 - var. usitatissimum and A900018 - var. caesium were cultivated in a trial field of the IPGR Sadovo - Southern Bulgaria (Teneva et al., 2014). Fatty acid compositions of oil fraction of these four different types of linseed were determined. According to analysis results, palmitic, stearic, oleic, linoleic and linolenic acid contents of the samples were reported as 8.88%, 5.0%, 28.9%, 16.53% and 39.95%. As seen from the results, average palmitic acid content of these four different genotypes is rather higher than the palmitic acid content of samples investigated in different studies. Also average linolenic acid content of the samples is lower when compared to other studies conducted in different countries.

Table 10. Fatty acid composition (%) of some flax seed varieties

Fatty acid	(Bayrak et al., 2010)	(El-Beltagi et al., 2007)	(Danish & Nizami, 2019)	(Kanmaz, 2017)	(Lewinska et al., 2015)	(Teneva et al., 2014)
Myristic (C14:0)	-	0.7	0.05	-	-	0.2
Palmitic (C16:0)	5.07	7.1	5.69	4.67	5.2	8.88
Palmitoleic (C16:1)	-	-	0.1	-	-	0.2
Stearic (C18:0)	4.78	3.7	5.58	3.61	4.7	5.0
Oleic (C18:1)	22.30	22	20.59	17.60	17.9	28.9
Linoleic (C18:2)	13.98	18.3	15.80	14.86	17.15	16.53
Linolenic (C18:3)	53.46	48.2	51.38	58.28	54.5	39.95

CONCLUSION

The fatty acid composition of oil plants is not always constant; under the control of genetic, ecological, morphological, physiological and cultural practices. The distribution of fatty acids shows significant differences in ecological regions located at different latitudes. Among the environmental factors, especially the effect of temperature on fatty acid synthesis is evident. Fatty acid composition is also affected by soil properties. Fatty acid compositions of oil plants are affected by genotype, apart from ecological and many other factors. In addition, fatty acids are constantly changing during the positions of the seeds in the plant and during the periods from the formation of the seed to its maturation. There may be differences in fatty acid composition between seeds to be harvested at different maturation periods; For this reason, when determining the fatty acid composition of seeds, ripening periods should also be taken into account. As a result, the fatty acid composition shows characteristic differences specific to plant species. In addition, the specific fatty acid composition of each oil plant is not constant, but is constantly changing depending on many factors. Therefore, it is important for oil quality to know under which conditions a change will occur in the fatty acid composition of oil plants.

3. REFERENCES

Abdel-Nabey, A., Abu–Tor, E., & Abou-Gharbia, H. (2013). CHEMICAL AND TECHNOLOGICAL STUDIES ON FLAXSEED (Linum usitatissimum) AND ITS APPLICATION IN SOME FUNCTIONAL FOODS. *Journal of Food and Dairy Sciences*, *4*(5), 193–216. https://doi.org/10.21608/jfds.2013.71828

Acids, M. F., & Disease, C. (2009). AHA Science Advisory. *Progress in Cardiovascular Nursing*, *24*(1), 19–26. https://doi.org/10.1111/j.1751-7117.2009.00028.x

Adeleke, B. S., & Babalola, O. O. (2020). Oilseed crop sunflower (Helianthus annuus) as a source of food: Nutritional and health benefits. *Food Science and Nutrition*, *8*(9), 4666–4684. https://doi.org/10.1002/fsn3.1783

Akbari, G. A., Heshmati, S., Soltani, E., & Amini Dehaghi, M. (2020). Influence of Seed Priming on Seed Yield, Oil Content and Fatty Acid Composition of Safflower (Carthamus tinctorius L.) Grown Under Water Deficit. *International Journal of Plant Production*, *14*(2), 245–258. https://doi.org/10.1007/s42106-019-00081-5

Akkaya, M. R. (2018). Fatty acid compositions of sunflowers (helianthus annuus L.) grown in east mediterranean region. *Rivista Italiana Delle Sostanze Grasse*, *95*(4), 239–247.

Aksoylu Özbek, Z., & Günç Ergönül, P. (2020). Determination of Physicochemical Properties, Fatty Acid, Tocopherol, Sterol, and Phenolic Profiles of Expeller–Pressed Poppy Seed Oils from Turkey. *JAOCS, Journal of the American Oil Chemists' Society*, *97*(6), 591–602. https://doi.org/10.1002/aocs.12337

Aljuhaimi, F., & Özcan, M. M. (2018). Influence of oven and microwave roasting on bioproperties, phenolic compounds, fatty acid composition, and mineral contents of nongerminated peanut and germinated peanut kernel and oils. *Journal of Food Processing and Preservation*, *42*(2). https://doi.org/10.1111/jfpp.13462

Altıntop, M., & Gıdık, B. (2019). Development of Sunflower, Soybean Safflower and Rapeseed Production in Turkey. *Bayburt Üniversitesi Fen Bilimleri Dergisi* , *2*(2), 307–315.

Aly, A. A., Zaky, E. A., Elhabeby, B. S., Alessa, H., Hameed, A. M., Aljohani, M., Nassan, M. A., Kadasah, S., Mohamed, E. S., & Alghamdi, A. A. A. (2021). Effect of Thyme Addition on some Chemical and Biological Properties of Sunflower Oil. *Arabian Journal of Chemistry*, *14*(11), 103411. https://doi.org/10.1016/j.arabjc.2021.103411

Arslan, Y., & Tarikahya Hacioğlu, B. (2018). Seed fatty acid compositions and chemotaxonomy of wild safflower (Carthamus L., asteraceae) species in

Turkey. *Turkish Journal of Agriculture and Forestry*, *42*(1), 45–54. https://doi.org/10.3906/tar-1708-68

Asghar, A., & Majeed, M. N. (2013). Chemical characterization and fatty acid profile of different sesame verities in Pakistan. *American Sournal of Scientific and Industrial Research*, *4*(6), 540–545. https://doi.org/10.5251/ajsir.2013.4.6.540.545

Ashrafi, E., & Razmjoo, K. (2010). Effect of irrigation regimes on oil content and composition of safflower (carthamus tinctorius l.) cultivars. *JAOCS, Journal of the American Oil Chemists' Society*, *87*(5), 499–506. https://doi.org/10.1007/s11746-009-1527-8

ASİL, H., & BOZDOĞAN KONUŞKAN, D. (2021). Farklı yağlı tohumlardan soğuk pres yöntemiyle elde edilen sabit yağların yağ asidi kompozisyonlarının araştırılması. *Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi*, *26*(3), 670–678. https://doi.org/10.37908/mkutbd.959699

Aşkın, B. (2018). Determination of Chemical and Physical Properties for Seeds and Oils of Some Different Oleic and Linoleic Sunflower Types. *Selcuk Journal of Agricultural and Food Sciences*, *32*(1), 73–80. https://doi.org/10.15316/sjafs.2018.67

Azcan, N., Ozturk Kalender, B., & Kara, M. (2004). Investigation of Turkish poppy seeds and seed oils. *Chemistry of Natural Compounds*, *40*(4), 370–372. https://doi.org/10.1023/B:CONC.0000048250.81843.0a

Bajpai, S., Prajapati, S., Luthra, R., Sharma, S., Naqvi, A., & Kumar, S. (1999). Variation in the seed and oil yields and oil quality in the Indian germplasm of opium poppy Papaver somniferum. *Genetic Resources and Crop Evolution*, *46*(5), 435–439. https://doi.org/10.1023/A:1008753604907

Bakal, H., Gulluoglu, L., Onat, B., & Arioglu, H. (2017). The effect of growing seasons on some agronomic and quality characteristics of Soybean varieties in mediterranean region in Turkey. *Turkish Journal of Field Crops*, *22*(2), 187–196. https://doi.org/10.17557/tjfc.356213

Batley, A., & Vecchies, A. (2003). A study of genetic diversity among Brassica napus and Brassica juncea germplasm collections using Simple Sequence Repeat (SSR) Molecular Markers. 13th Australian Research Assembly on Brassicas – Conference Proceeding shttp://www.australianoilseeds.com/__data/assets/pdf_file/0020/4547/Genetic_diversity_among_Brassica_napus_and_Brassica_juncea.pdf

Baydar, H. (2005). Isparta Koşullarında Kanola (Brassica napus L .) Çeşitlerinin Verim ve Kalite Özellikleri. *Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü Dergisi*, *9*(3), 1–6.

Baydar, Hasan, & Erbaş, S. (2005). Influence of seed development and seed position on oil, fatty acids and total tocopherol contents in sunflower (Helianthus annuus L.). *Turkish Journal of Agriculture and Forestry*, *29*(3), 179–186. https://doi.org/10.3906/tar-0406-3

Bayrak, A., Kiralan, M., Ipek, A., Arslan, N., Cosge, B., & Khawar, K. M. (2010). Fatty acid compositions of linseed (Linum Usitatissimum L.) genotypes of different origin cultivated in Turkey. *Biotechnology and Biotechnological Equipment*, *24*(2), 1836–1842. https://doi.org/10.2478/V10133-010-0034-2

Biglar, M. (2012). Profiling of major fatty acids in different raw and roasted sesame seeds cultivars. *African Journal of Biotechnology*, *11*(24), 6619–6623. https://doi.org/10.5897/ajb11.1966

Bonku, R., & Yu, J. (2020). Health aspects of peanuts as an outcome of its chemical composition. *Food Science and Human Wellness*, *9*(1), 21–30. https://doi.org/10.1016/j.fshw.2019.12.005

Bowles, V. G., Mayerhofer, R., Davis, C., Good, A. G., & Hall, J. C. (2010). A phylogenetic investigation of Carthamus combining sequence and microsatellite data. *Plant Systematics and Evolution*, *287*(1), 85–97. https://doi.org/10.1007/s00606-010-0292-3

Boydak, E., Alpaslan, M., Hayta, M., Gerçek, S., & Simsek, M. (2002). Seed composition of soybeans grown in the Harran Region of Turkey as affected by row spacing and irrigation. *Journal of Agricultural and Food Chemistry*, *50*(16), 4718–4720. https://doi.org/10.1021/jf0255331

Bozan, B., & Temelli, F. (2008). Chemical composition and oxidative stability of flax, safflower and poppy seed and seed oils. *Bioresource Technology*, *99*(14), 6354–6359. https://doi.org/10.1016/j.biortech.2007.12.009

Buket Aydeniz , Onur Guneser, E. Y. (2014). *J Americ Oil Chem Soc - 2013 - Aydeniz - Physico-chemical Sensory and Aromatic Properties of Cold Press Produced Safflower.pdf*.

CamposMondragón, M. G., Calderón de la Barca, A. M., Durán Prado, A., Campos Reyes, L. C., Oliart Ros, R. M., Ortega García, J., Medina Juárez, L. a., & Angulo, O. (2009). Composición nutricional de maní nuevo (Arachis hypogaea L. *Grasas y Aceites*, *60*(2), 161–167. http://grasasyaceites.revistas.csic.es/index.php/grasasyaceites/article/view/562/576

Carvalho, I. S., Miranda, I., & Pereira, H. (2006). Evaluation of oil composition of some crops suitable for human nutrition. *Industrial Crops and Products*, *24*(1), 75–78. https://doi.org/10.1016/j.indcrop.2006.03.005

Carvalho, R. H. R., Galvão, E. L., Barros, J. A. C., Conceição, M. M., & Sousa, E. M. B. D. (2012). Extraction, fatty acid profile and antioxidant activity of sesame extract: (Sesamum Indicum L.). *Brazilian Journal of Chemical Engineering*, *29*(2), 409–420. https://doi.org/10.1590/S0104-66322012000200020

Chakradhari, S., Perkons, I., Mišina, I., Sipeniece, E., Radziejewska-Kubzdela, E., Grygier, A., Rudzińska, M., Patel, K. S., Radzimirska-Graczyk, M., & Górnaś, P. (2020). Profiling of the bioactive components of safflower seeds and seed oil: cultivated (Carthamus tinctorius L.) vs. wild (Carthamus oxyacantha M. Bieb.). *European Food Research and Technology*, *246*(3), 449–459. https://doi.org/10.1007/s00217-019-03414-w

Chehade, L. A., Angelini, L. G., & Tavarini, S. (2022). Genotype and Seasonal Variation Affect Yield and Oil Quality of Safflower (Carthamus tinctorius L.) under Mediterranean Conditions. *Agronomy*, *12*(1). https://doi.org/10.3390/agronomy12010122

Coşge, B., Gürbüz, B., & Kiralan, M. (2007). Oil Content and Fatty Acid Composition of Some Safflower (Carthamus tinctorius L.) Varieties Sown in Spring and Winter. *International Journal of Natural and Engineering Sciences*, *1*(3), 11–15. https://www.researchgate.net/publication/242606175%0Ahttps://www.researchgate.net/publication/242606175_Oil_Content_and_Fatty_Acid_Composition_of_Some_Safflower_Carthamus_tinctorius_L_Varieties_Sown_in_Spring_and_Winter

Crowley, J.G., Fröhlich, A. (1998). Factors Affecting the Composition and Use of Camelina. *End of Project Reports, Teagasc*, *September*, 1–23.

Çelik, Z.G. (2017). *Sağlıklı Beslenmede Kullanılan Bazı Tohumların Sabit Yağlarının Mukayeseli Fitokimyasal Analizi*. Bezmialem Vakıf Üniversitesi Sağlık Bilimleri Enstitüsü.

Dąbrowski, G., Czaplicki, S., & Konopka, I. (2020). Composition and quality of poppy (Papaver somniferum L.) seed oil depending on the extraction method. *Lwt*, *134*(August). https://doi.org/10.1016/j.lwt.2020.110167

Danish, M., & Nizami, M. (2019). Complete fatty acid analysis data of flaxseed oil using GC-FID method. *Data in Brief*, *23*, 103845. https://doi.org/10.1016/j.dib.2019.103845

Davis, J. P., Price, K., Dean, L. L., Sweigart, D. S., Cottonaro, J., & Sanders, T. H. (2016). Peanut Oil Stability and Physical Properties Across a Range of Industrially Relevant Oleic Acid/Linoleic Acid Ratios. *Peanut Science*, 1–11. https://doi.org/10.3146/ps14-17.1

El-Beltagi, H.S., Salama, Z., & El-Hariri, D. M. (2007). Evaluation of Fatty Acids Profile and the Content of Some Secondary Metabolites in Seeds of Different Flax Cultivars (Linum Usitatissimum L .). *Gen. Appl. Plant Physiology*, *33*(4), 187–202. http://www.bio21.bas.bg/ipp/gapbfiles/v-33/07_3-4_187-202.pdf

El-Beltagi, Hossam S., Maraei, R. W., El-Ansary, A. E., Rezk, A. A., Mansour, A. T., & Aly, A. A. (2022). Characterizing the Bioactive Ingredients in Sesame Oil Affected by Multiple Roasting Methods. *Foods*, *11*(15), 1–21. https://doi.org/10.3390/foods11152261

Eren, A. ; Kocatürk, M. ; Hos˜gün, E. Z. ; Azcan, N. (2012). Determination of seed yield, protein, oil content and fatty acid compositions and relationships of some soybean lines/cultivars. *Ziraat Fakültesi Dergisi - Süleyman Demirel Üniversitesi*, *7*(1), 1–9.

Ergun, Z.; Zarifikhosroshani, M. (2020). A comparative analysis of oil content and fatty acid in different varieties of Arachis hypogaea L. from turkey. *International Journal of Agriculture, Forestry and Life Sciences*, *4*(1), 42–47. https://dergipark.org.tr/en/pub/ijafls/issue/51802/691351

Erinç, H., Tekin, A., & Özcan, M. M. (2009). Determination of fatty acid, tocopherol and phytosterol contents of the oils of various poppy (Papaver somniferum L.) seeds. *Grasas y Aceites*, *60*(4), 375–381. https://doi.org/10.3989/gya.129508

FAO. (1999). *Joint FAO/WHO food standards programme: Codex standard for named vegetable oils. Rome, CX-Stan 210*.

Fayyaz-Ul-Hassan, & Ahmed, M. (2012). Oil and fatty acid composition of peanut cultivars grown in Pakistan. *Pakistan Journal of Botany*, *44*(2), 627–630.

Galão, O. F., Carrão-Panizzi, M. C., Gontijo Mandarino, J. M., Santos Júnior, O. O., Maruyama, S. A., Figueiredo, L. C., Bonafe, E. G., & Visentainer, J. V. (2014). Differences of fatty acid composition in Brazilian genetic and conventional soybeans (Glycine max (L.) Merrill) grown in different regions. *Food Research International*, *62*, 589–594. https://doi.org/10.1016/j.foodres.2014.04.025

Gao, J., Li, X., Zhang, G., Sadiq, F. A., Simal-Gandara, J., Xiao, J., & Sang, Y. (2021). Probiotics in the dairy industry—Advances and opportunities. *Comprehensive Reviews in Food Science and Food Safety*, *20*(4), 3937–3982. https://doi.org/10.1111/1541-4337.12755

Gecgel, U., Demirci, M., Esendal, E., & Tasan, M. (2007). Fatty acid composition of the oil from developing seeds of different varieties of safflower (Carthamus tinctorius L.). *JAOCS, Journal of the American Oil Chemists' Society*, *84*(1), 47–54. https://doi.org/10.1007/s11746-006-1007-3

Gergin, R. E., Peker, I., Baki, B., Tuzkaya, U. R., & Tanyas, M. (2022). Oilseed warehouse location selection with an integrated approach: a case of Turkey. *Kybernetes*. https://doi.org/10.1108/K-10-2021-1072

Ghafoor, K., Özcan, M. M., AL-Juhaimi, F., Babiker, E. E., & Fadimu, G. J. (2019). Changes in quality, bioactive compounds, fatty acids, tocopherols, and phenolic compositioninoven- and microwave-roastedpoppy seeds and oil. *Lwt*, *99*(October 2018), 490–496. https://doi.org/10.1016/j.lwt.2018.10.017

Ghosh, S., Bhattacharyya, D. K., & Ghosh, M. (2019). Comparative study of chemical characteristics, phytochemical contents and antioxidant activity of polar and non-polar solvent extracted flaxseed oil. *Acta Pharmaceutica Sciencia*, *57*(3), 65–74. https://doi.org/10.23893/1307-2080.APS.05718

Gibbins, R. D., Aksoy, H. A., & Ustun, G. (2012). Enzyme-assisted aqueous extraction of safflower oil: Optimisation by response surface methodology. *International Journal of Food Science and Technology*, *47*(5), 1055–1062. https://doi.org/10.1111/j.1365-2621.2012.02940.x

Golkar, P., Arzani, A., & Rezaei, A. M. (2011). Genetic analysis of oil content and fatty acid composition in safflower (Carthamus tinctorius L.). *JAOCS, Journal of the American Oil Chemists' Society*, *88*(7), 975–982. https://doi.org/10.1007/s11746-011-1758-3

Gölükcü, M., Tokgöz, H., & Kocatürk, M. (2019). Bazı soya (Glycine max) çeşit ve hatlarının yağ içeriği ile yağ asitleri bileşimlerinin araştırılması. *Akademik Ziraat Dergisi*, *8*(2), 283–290. https://doi.org/10.29278/azd.538613

Göre, M., & Kurt, O. (2017). Farklı Ketencik [Camelina sativa (L.) Crantz.] Genotiplerinin Ham Yağ Oranları ve Yağ Asidi Kompozisyonlarının Belirlenmesi. *Kahramanmaraş Sütçü İmam Üniversitesi Doğa Bilimleri Dergisi*, *January 2018*, 201–205. https://doi.org/10.18016/ksudobil.349198

Goyal, A., Sharma, V., Upadhyay, N., Gill, S., & Sihag, M. (2014). Flax and flaxseed oil: an ancient medicine & modern functional food. *Journal of Food Science and Technology*, *51*(9), 1633–1653. https://doi.org/10.1007/s13197-013-1247-9

Grosso, N. R., Lucini, E. I., López, A. G., & Guzmán, C. A. (1999). Chemical composition of aboriginal peanut (Arachis hypogaea L.) seeds from Uruguay. *Grasas y Aceites*, *50*(3), 203–207. https://doi.org/10.3989/gya.1999.v50.i3.657

Guan, L. L., Wu, W., & Zheng, Y. L. (2008). Seed oil and fatty acids of different safflower genotypes and their cor-relations with agronomic traits and photosynthetic parameters. *Philippine Agricultural Scientist*, *91*(4), 383–388.

Gulluoglu, L., Bakal, H., Onat, B., Sabagh, A. EL, & Arioglu, H. (2016). Characterization of peanut (Arachis hypogaea L.) seed oil and fatty acids composition under different growing season under mediterranean environment. *Journal of Experimental Biology and Agricultural Sciences*, *4*(5S), 564–571. https://doi.org/10.18006/2016.4(5s).564.571

Günç Ergönül, P., & Aksoylu Özbek, Z. (2018). Identification of bioactive compounds and total phenol contents of cold pressed oils from safflower and camelina seeds. *Journal of Food Measurement and Characterization*, *12*(4), 2313–2323.

https://doi.org/10.1007/s11694-018-9848-7

Gürsoy, M. (2019). Importance of Some Oil Crops in Human Nutrition Turkish Journal of Agriculture - Food Science and Technology Importance of Some Oil Crops in Human Nutrition. *Turkish Journal of Agriculture - Food Science and Technology*, *7*(December), 2154–2158. https://doi.org/10.24925/turjaf.v7i12.2154-2158.2916

Gutte, K. B., Sahoo, A. K., & Ranveer, R. C. (2015). Effect of ultrasonic treatment on extraction and fatty acid profile of flaxseed oil. *OCL - Oilseeds and Fats*, *22*(6). https://doi.org/10.1051/ocl/2015038

Hama, J. R. (2017). Comparison of fatty acid profile changes between unroasted and roasted brown sesame (Sesamum indicum L.) seeds oil. *International Journal of Food Properties*, *20*(5), 957–967. https://doi.org/10.1080/10942912.2016.1190744

Harfi, M. El, Nabloussi, A., Rizki, H., Ennahli, S., & Hanine, H. (2019). Proximate Composition and Fatty Acid Composition , Phytochemical Content of Sesame (Sesamum indicum L.) Seeds Landrace from Morocco. *Advances in Crop Science and Technology*, *7*(3).

He, M., Qin, C. X., Wang, X., & Ding, N. Z. (2020). Plant Unsaturated Fatty Acids: Biosynthesis and Regulation. *Frontiers in Plant Science*, *11*(April), 1–13. https://doi.org/10.3389/fpls.2020.00390

Hlinková, A., Havrlentová, M., Šupová, J., & Bednárová, A. (2012). *of Cultivation on Variability in Its Lipid Composition*. *1*, 908–922.

Isaac, I. O., & Ekpa, O. D. (2013). Fatty Acid Composition of Cottonseed Oil and its Application in Production and Evaluation of Biopolymers. *American Journal of Polymer Science*, *2013*(2), 13–22. https://doi.org/10.5923/j.ajps.20130302.02

Jasad, H. (2020). *Farkli Susam Tohumu Çeğğtlerġnden Soğuk Pres Yöntemġyle Elde Edġlen Yağlarin Karakterġzasyonu Ve Oksġdatġf Stabġlġtelerġnġn Belġrlenmesġ*.

Juan-Polo, A., Sanahuja, A. B., Prats Moya, M. S., Monedero Prieto, M., Sanchez Reig, C., & Maestre Pérez, S. E. (2022). Optimization and validation of a simplified methodology for simultaneous extraction of fatty acids and tocopherol homologues in peanuts. *Journal of Food Composition and Analysis*, *106*(November 2021). https://doi.org/10.1016/j.jfca.2021.104287

Kabutey, A., Herák, D., & Mizera, Č. (2022). Determination of Maximum Oil Yield, Quality Indicators and Absorbance Spectra of Hulled Sunflower Seeds Oil Extraction under Axial Loading. *Foods*, *11*(18). https://doi.org/10.3390/foods11182866

Kamdar, J. H., Jasani, M. D., & Georrge, J. J. (2020). Development of Peanut Breeding

Lines With High Oleic Acid Content. *SSRN Electronic Journal*, 388–391. https://doi.org/10.2139/ssrn.3573337

Karaca, E., & Aytac, S. (2007). The factors affecting on fatty acid composition of oil crops. *Anadolu Journal of Agricultural Sciences*, *22*(1), 123–131. http://agris.fao.org/agris-search/search/display.do?f=2010/TR/TR1007.xml;TR2010001365

Karvonen, H. M., Aro, A., Tapola, N. S., Salminen, I., Uusitupa, M. I. J., & Sarkkinen, E. S. (2002). Effect of α-linolenic acid-rich Camelina sativa oil on serum fatty acid composition and serum lipids in hypercholesterolemic subjects. *Metabolism: Clinical and Experimental*, *51*(10), 1253–1260. https://doi.org/10.1053/meta.2002.35183

Katar, D. (2013). Determination of fatty acid composition on different false flax (Camelina sativa (L.) Crantz) genotypes under Ankara ecological conditions. *Turkish Journal of Field Crops*, *18*(1), 66–72.

Katar, D., Arslan, Y., & Subaşi, I. (2012). Genotypic variations on yield, yield components and oil quality in some camelina (Camelina sativa (L.) Crantz) genotypes. *Turkish Journal of Field Crops*, *17*(2), 105–110.

Kaya, A. R. (2020). Ana Ürün Olarak Yetiştirilen Bazı Soya Fasulyesi (Glycine max. (L.) Merrill) Çeşitlerinin Önemli Kalite Özelliklerinin Belirlenmesi. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, *3*(4), 1012–1020. https://doi.org/10.18016/ksutarimdoga.vi.691990

Kazemian-Bazkiaee, F., Ebrahimi, A., Hosseini, S. M., Shojaee-Aliabadi, S., Farhoodi, M., Rahmatzadeh, B., & Sheikhi, Z. (2020). Evaluating the protective effect of edible coatings on lipid oxidation, fatty acid composition, aflatoxins levels of roasted peanut kernels. *Journal of Food Measurement and Characterization*, *14*(2), 1025–1038. https://doi.org/10.1007/s11694-019-00352-9

Khalatbari, A., Shirani Rad, A., Valadabady, S. A., Sayfzadeh, S., & Zakerin, H. (2022). Yield Components and Fatty Acids Variation of Canola Cultivars Under Different Irrigation Regimes and Planting Dates. *Gesunde Pflanzen*, *74*(1), 17–27. https://doi.org/10.1007/s10343-021-00585-z

Kim, K.-S., Ryu, S.-N., & Chung, H.-G. (2006). Influence of Drought Stress on Chemical Composition of Sesame Seed. In *Korean Journal of Crop Science* (Vol. 51, Issue 1, pp. 73–80).

Kiralan, M., Kiralan, S. S., Subaşi, I., Aslan, Y., & Ramadan, M. F. (2018). Fatty acids profile and stability of camelina (Camelina sativa) seed oil as affected by extraction method and thermal oxidation. *Rivista Italiana Delle Sostanze Grasse*, *95*(4), 223–228.

Kirbaşlar, F. G., Türker, G., Özsoy-Güneş, Z., Ünal, M., Dülger, B., Ertaş, E., &

Kizilkaya, B. (2012). Evaluation of Fatty Acid Composition, Antioxidant and Antimicrobial Activity, Mineral Composition and Calorie Values of Some Nuts and Seeds from Turkey. *Records of Natural Products*, *6*(4), 339–349.

Kolláthová, R., Varga, B., Ivanišová, E., Gálik, B., Bíro, D., Rolinec, M., Juráček, M., Šimko, M., Hanušovský, O., & Zábranský, Ľ. (2019). The content of nutrients and fatty acids profile in different oilseeds. *Journal of Central European Agriculture*, *20*(4), 1063–1068. https://doi.org/10.5513/JCEA01/20.4.2320

Konuskan, D. B., Arslan, M., & Oksuz, A. (2019). Physicochemical properties of cold pressed sunflower, peanut, rapeseed, mustard and olive oils grown in the Eastern Mediterranean region. *Saudi Journal of Biological Sciences*, *26*(2), 340–344. https://doi.org/10.1016/j.sjbs.2018.04.005

Konuşkana, D. B., Yılmaztekinb, M., Mertc, M., & Oktay Gençerd. (2017). Physico-Chemical Characteristic and Fatty Acids Compositions of Cottonseed Oils. *Journal of Agricultural Sciences*, *23*, 253–259.

Kurt, C. (2018). Variation in oil content and fatty acid composition of sesame accessions from different origins. *Grasas y Aceites*, *69*(1), 1–9. https://doi.org/10.3989/gya.0997171

Lančaričová, A., Havrlentová, M., Muchová, D., & Bednárová, A. (2016). Oil content and fatty acids composition of poppy seeds cultivated in two localities of Slovakia. *Agriculture*, *62*(1), 19–27. https://doi.org/10.1515/agri-2016-0003

Lee, Y. C., Oh, S. W., Chang, J., & Kim, I. H. (2004). Chemical composition and oxidative stability of safflower oil prepared from safflower seed roasted with different temperatures. *Food Chemistry*, *84*(1), 1–6. https://doi.org/10.1016/S0308-8146(03)00158-4

Lewinska, A., Zebrowski, J., Duda, M., Gorka, A., & Wnuk, M. (2015). Fatty acid profile and biological activities of linseed and rapeseed oils. *Molecules*, *20*(12), 22872–22880. https://doi.org/10.3390/molecules201219887

Matthaus, B., & Özcan, M. M. (2015). Fatty acid composition, tocopherol, and sterol contents of sumac (Rhus coriaria L.) fruit oils. *European Journal of Lipid Science and Technology*, *117*(8), 1301–1302. https://doi.org/10.1002/ejlt.201400547

Mehmet Firat Baran*‡, Mehmet Recai Durgut**, T. A., & Poyraz Ulger**, B. K. (2016). Determination of Some Physical Properties of Rapeseed. *INTERNATIONAL JOURNAL of ENGINEERING TECHNOLOGIES*, *2*(2), 49–55.

Menderes, A. A., Akkaya, N., & Dan, T. (2019). *Farkli çeşitlerden elde edilen pamuk yağlarinin trigliserit ve sterol bileşimlerinin belirlenmesi*.

Mihai, A. L., Negoiţă, M., & Horneţ, G.-A. (2020). Nutritional Potential of Some Cold

Pressed Vegetable Oils in Terms of Fatty Acids. *Current Trends in Natural Sciences*, *9*(17), 104–116. https://doi.org/10.47068/ctns.2020.v9i17.012

Moknatjou, R., Hajimahmoodi, M., Toliyat, T., Moghaddam, G., Sadeghpour, O., Monsef-Esfahani, H., & Shams-Ardekani, M. R. (2015). Effect of roasting on fatty acid profile of brown and yellow varieties of flaxseed (Linum usitatissimum L). *Tropical Journal of Pharmaceutical Research*, *14*(1), 117–123. https://doi.org/10.4314/tjpr.v14i1.17

Mora-Escobedo, R., Hernández-Luna, P., Joaquín-Torres, I. C., Ortiz-Moreno, A., & Robles-Ramirez, M. D. C. (2015). Physicochemical properties and fatty acid profile of eight peanut varieties grown in Mexico. *CYTA - Journal of Food*, *13*(2), 300–304. https://doi.org/10.1080/19476337.2014.971345

Moreno, J. J., & Mitjavila, M. T. (2003). The degree of unsaturation of dietary fatty acids and the development of atherosclerosis (Review). *Journal of Nutritional Biochemistry*, *14*(4), 182–195. https://doi.org/10.1016/S0955-2863(02)00294-2

Muhammad, A., Akhtar, A., Aslam, S., Khan, R. S., Ahmed, Z., & Khalid, N. (2021). Review on physicochemical, medicinal and nutraceutical properties of poppy seeds: a potential functional food ingredient. *Functional Foods in Health and Disease*, *11*(10), 522–547. https://doi.org/10.31989/ffhd.v11i10.836

Musa Özcan, M., & Atalay, Ç. (2006). Determination of seed and oil properties of some poppy (Papaver somniferum L.) varieties. *Grasas y Aceites*, *57*(2), 169–174. https://doi.org/10.3989/gya.2006.v57.i2.33

Nasiri, A., Sam-Daliri, M., Shirani-Rad, A. H., Mousavi, A. A., & Jabbari, H. (2021). The Response of Growth and Yield of Canola Genotypes to Humic Acid Application in Different Plant Densities. *Gesunde Pflanzen*, *73*(1), 17–27. https://doi.org/10.1007/s10343-020-00524-4

Naveed, M., Sajid, H., Mustafa, A., Niamat, B., Ahmad, Z., Yaseen, M., Kamran, M., Rafique, M., Ahmar, S., & Chen, J. T. (2020). Alleviation of salinity-induced oxidative stress, improvement in growth, physiology and mineral nutrition of canola (Brassica napus L.) through calcium-fortified composted animal manure. *Sustainability (Switzerland)*, *12*(3), 1–17. https://doi.org/10.3390/su12030846

Nazari, M., Mirlohi, A., & Majidi, M. M. (2017). Effects of Drought Stress on Oil Characteristics of Carthamus Species. *JAOCS, Journal of the American Oil Chemists' Society*, *94*(2), 247–256. https://doi.org/10.1007/s11746-016-2938-y

Necdet ÇamaŞ, CÜNEYT ÇIRAk, E. E. (2007). *Seed yield, oil content and fatty acids composition of safflower (*. *22*(1), 98–104.

Nergiz, C., Yalçin, H., & Yildiz, H. (1997). Some analytical characters of cottonseed varieties grown in Turkey. *Grasas y Aceites*, *48*(6), 411–414. https://doi.org/10.3989/gya.1997.v48.i6.813

Nouraei, S., Rahimmalek, M., Saeidi, G., & Bahreininejad, B. (2016). Variation in Seed Oil Content and Fatty Acid Composition of Globe Artichoke Under Different Irrigation Regimes. *JAOCS, Journal of the American Oil Chemists' Society*, *93*(7), 953–962. https://doi.org/10.1007/s11746-016-2852-3

Olasunkanmi Gbadamosi, S., Saka Olasunkanmi, G., Temitope Omolayo, F., & Taiwo Olusegun, O. (2017). FATTY ACID PROFILE, PHYSICO-CHEMICAL AND FUNCTIONAL PROPERTIES OF OIL AND PROTEIN ISOLATE SIMULTANEOUSLY EXTRACTED FROM SESAME (Sesamum indicum) SEED Effect of Processing Parameters on Simultaneous Recovery of Oil and Protein from Sesame Seed View project. *Annals. Food Science and Technology*, *18*(1), 1–10. https://www.researchgate.net/publication/316035947

Orsavova, J., Misurcova, L., Vavra Ambrozova, J., Vicha, R., & Mlcek, J. (2015). Fatty acids composition of vegetable oils and its contribution to dietary energy intake and dependence of cardiovascular mortality on dietary intake of fatty acids. *International Journal of Molecular Sciences*, *16*(6), 12871–12890. https://doi.org/10.3390/ijms160612871

Ostrikov, A. N., Kleimenova, N. L., Kopylov, M. V., & Bolgova, I. N. (2021). The study of the fatty acid composition of camelina oil obtained by cold pressing. *IOP Conference Series: Earth and Environmental Science*, *640*(4). https://doi.org/10.1088/1755-1315/640/4/042009

Özcan, M., & Seven, S. (2003). Análisis físico-químicas y composición de ácidos grasos del aceite de maní maní y mantequilla de maní. *Grasas*, *54*(1), 12–18.

Özdemır, İ. S., Karaoğlu, Ö., Dağ, Ç., & Bekıroğlu, S. (2018). Assessment of sesame oil fatty acid and sterol composition with FT-NIR spectroscopy and chemometrics. *Turkish Journal of Agriculture and Forestry*, *42*(6), 444–452. https://doi.org/10.3906/tar-1802-130

Özkaynak Kanmaz, E. (2017). the Effect of Roasting Process on Fatty Acid Composition and Phenolic Content of Whole Flaxseed, Flaxseed Flour and Flaxseed Meal Flour. *Gida / the Journal of Food*, *42*(4), 382–391. https://doi.org/10.15237/gida.gd16081

ÖZPOLAT, M., AKKAYA, M. R., & BAKAÇHAN, Y. (2021). Altın (Gökova) Susamın (Sesamum indicum L.) Bazı Tohum ve Yağ Özellikleri. *Akademik Gıda*, *19*(3), 300–308. https://doi.org/10.24323/akademik-gida.1011226

Öztürk, Ö. (2022). *Comparison of bioactive compounds , antioxidant activity , fatty acid composition and phenolic compounds of three rapeseed varieties*. *XCIX*.

Qu, C., Li, Z., Yang, Q., Wang, X., & Wang, D. (2022). Effect of Drying Methods on Peanut Quality during Storage. *Journal of Oleo Science*, *71*(1), 57–66. https://doi.org/10.5650/JOS.ESS21146

Rahimi, A., Kıralan, M., Arslan, N., Bayrak, A., & Doğramacı, S. (2011). Variation in fatty acid composition of registered poppy (Papaver sumniferum L .) seed in Turkey. *Academic Food Journal*, *9*(3), 22–25.

Rai, K., Bagati, G., Kumar S., Rai, P., & Rai, S.K. (2018). Fatty Acid Profiling in Rapeseed Mustard (Brassica species). *International Journal of Current Microbiology and Applied Sciences*, *7*(05), 148–157. https://doi.org/10.20546/ijcmas.2018.705.019.

Ratusz, K., Symoniuk, E., Wroniak, M., & Rudzińska, M. (2018). Bioactive compounds, nutritional quality and oxidative stability of cold-pressed camelina (Camelina sativa L.) oils. *Applied Sciences (Switzerland)*, *8*(12), 1–17. https://doi.org/10.3390/app8122606

Rosa, P. M., Antoniassi, R., Freitas, S. C., Bizzo, H. R., Zanotto, D. L., Oliveira, M. F., & Castiglioni, V. B. R. (2009). Chemical composition of brazilian sunflower varieties. *Helia*, *32*(50), 145–156. https://doi.org/10.2298/HEL0950145R

Rubilar, M., Gutiérrez, C., Verdugo, M., Shene, C., & Sineiro, J. (2010). Flaxseed as a source of functional ingredients. *Journal of Soil Science and Plant Nutrition*, *10*(3), 373–377. https://doi.org/10.4067/S0718-95162010000100010

Sabzalian, M. R., Saeidi, G., & Mirlohi, A. (2008). Oil content and fatty acid composition in seeds of three safflower species. *JAOCS, Journal of the American Oil Chemists' Society*, *85*(8), 717–721. https://doi.org/10.1007/s11746-008-1254-6

Samanci, B., & Özkaynak, E. (2003). Effect of Planting Date on Seed Yield, Oil Content and Fatty Acid Composition of Safflower (Carthamus tinctorius) Cultivars Grown in the Mediterranean Region of Turkey. *Journal of Agronomy and Crop Science*, *189*(5), 359–360. https://doi.org/10.1046/j.1439-037X.2003.00053.x

Shad, M. A., Pervez, H., Zafar, Z. I., Nawaz, H., & Khan, H. (2012). Physicochemical properties, fatty acid profile and antioxidant activity of Peanut Oil. *Pakistan Journal of Botany*, *44*(1), 435–440.

Shah, S. N. (2017). FTIR characterization and physicochemical evaluation of cottonseed oil. *Pakistan Journal of Analytical & Environmental Chemistry*, *18*(1), 46–53. https://doi.org/10.21743/pjaec/2017.06.04

Sharif, I., Farooq, J., Chohan, S. M., Saleem, S., Kainth, R. A., Mahmood, A., & Sarwar, G. (2019). Strategies to enhance cottonseed oil contents and reshape fatty acid profile employing different breeding and genetic engineering approaches. *Journal of Integrative Agriculture*, *18*(10), 2205–2218. https://doi.org/10.1016/S2095-3119(18)62139-2

Shokri, Z., Ashouri, M., Doroudian, H. R., Roshan, N. M., & Sadeghi, S. M. (2022).

Evaluating the Yield, Fatty Acid Composition, and the Seed Micronutrients Content in Peanut Cultivars under the Influence of Various Rates of Sulfur and Zinc Application. *Journal of Nuts*, *13*(3), 183–197. https://doi.org/10.22034/jon.2022.1955111.1160

Silva, M. P., Martinez, M. J., Casini, C., & Grosso, N. R. (2010). Tocopherol content, peroxide value and sensory attributes in roasted peanuts during storage. *International Journal of Food Science and Technology*, *45*(7), 1499–1504. https://doi.org/10.1111/j.1365-2621.2010.02293.x

Singh, S. P., Shukla, S., Khanna, K. R., Dixit, B. S., & Banerji, R. (1998). Variation of major fatty acids in F8 generation of opium poppy (Papaver somniferum x Papaver setigerum) genotypes. *Journal of the Science of Food and Agriculture*, *76*(2), 168–172. https://doi.org/10.1002/(sici)1097-0010(199802)76:2<168::aid-jsfa919>3.0.co;2-x

Szydłowska-Czerniak, A., Tułodziecka, A., Momot, M., & Stawicka, B. (2019). Physicochemical, Antioxidative, and Sensory Properties of Refined Rapeseed Oils. *JAOCS, Journal of the American Oil Chemists' Society*, *96*(4), 405–419. https://doi.org/10.1002/aocs.12199

Tan, A. S., & İş, M. E. M. (2017). *Menemen , İ zmir Ekolojik Ko ş ullar ı nda Verim , Verim Komponentleri ve Kalite Özelliklerinin Belirlenmesi*. *24*(2), 29–50.

Teneva, O. T., Zlatanov, M. D., Antova, G. A., Angelova-Romova, M. Y., & Marcheva, M. P. (2014). Lipid composition of flaxseeds. *Bulgarian Chemical Communications*, *46*(3), 465–472.

USDA. (2022). *Oilseeds: World Markets and Trade (May 2022). May*. https://apps.fas.usda.gov/psdonline/circulars/oilseeds.pdf (Stand: 12.05.2022, 12:54)

Uzun, B., Ülger, S., & Çağirgan, M. I. (2002). Comparison of determinate and indeterminate types of sesame for oil content and fatty acid composition. *Turkish Journal of Agriculture and Forestry*, *26*(5), 269–274. https://doi.org/10. 3906/tar-0201-5

Velasco, L., & Fernandez-Martinez, L. (2001). Breeding for oil quality in safflower. *In J. W. Bergman & H. H. Mundel (Eds.), Proceed- Ings of the 5th International Safflower Conference, North Dakota and Sidney, (Pp. 133–137), Montana, USA*.

Wang, D., Meng, Y., Zhao, X., Fan, W., Yi, T., & Wang, X. (2019). Sunflower oil flavored by essential oil from Punica granatum cv. Heyinshiliu peels improved its oxidative stability and sensory properties. *Lwt*, *111*(January), 55–61. https://doi.org/10.1016/j.lwt.2019.05.005

Wei, L., Wang, D., Sun, J., Wang, X., Shen, Y., & Di, H. (2022). Determination of Ten

Long-Chain Fatty Acids in Poppy-Seed Oil Using Electro-Enhanced Solid-Phase Microextraction-GC/MS. *Food Analytical Methods*, *15*(9), 2462–2469. https://doi.org/10.1007/s12161-022-02301-7

Woodfield, H. K., & Harwood, J. L. (2016). Oilseed Crops: Linseed, Rapeseed, Soybean, and Sunflower. In *Encyclopedia of Applied Plant Sciences* (Second Edi, Vol. 3). Elsevier. https://doi.org/10.1016/B978-0-12-394807-6.00212-4

Xiao, Y., Liu, H., Du, P., Liang, X., Li, H., Lu, Q., Li, S., Liu, H., Hong, Y., Varshney, R. K., & Chen, X. (2022). Impact of different cooking methods on the chemical profile of high-oleic acid peanut seeds. *Food Chemistry*, *379*(December 2021), 131970. https://doi.org/10.1016/j.foodchem.2021.131970

YAKAR, Y., ARSLAN, H., & BİLMEZ ÖZÇINAR, A. (2020). Siirt Ekolojik Şartlarında İkinci Ürün Olarak Yetiştirilen Bazı Susam (Sesamum Indicum, L.) Genotiplerinin Yağ Asidi Kompozisyonlarının Belirlenmesi. *Gümüşhane Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *January*. https://doi.org/10.17714/gumusfenbil.731944

Yang, A., Qi, M., Wang, X., Wang, S., Sun, L., Qi, D., Zhu, L., Duan, Y., Gao, X., Ali Rajput, S., & Zhang, N. (2019). Refined cottonseed oil as a replacement for soybean oil in broiler diet. *Food Science and Nutrition*, *7*(3), 1027–1034. https://doi.org/10.1002/fsn3.933

Yeasmin, S. (2021). "Characteristics of Sesame (Sesamum Indicum l.) Seed Meal Grown in the Northern Region of Bangladesh." *Biomedical Journal of Scientific & Technical Research*, *38*(1), 29944–29949. https://doi.org/10.26717 /bjstr.2021.38.006083

Yılmaz, A., Yılmaz, H., Arslan, Y., Çiftçi, V., & Baloch, F. (2021). Ülkemizde Alternatif Yağ Bitkilerinin Durumu. *European Journal of Science and Technology*, *22*, 93–100. https://doi.org/10.31590/ejosat.843220

Vanak, Z.P. (2020). Chapter 38 - Cold pressed colza oil. In *Cold Pressed Oils Green Technology, Bioactive Compounds, Functionality, and Applications* (pp. 429–437).

Zanetti, F., Monti, A., & Berti, M. T. (2013). Challenges and opportunities for new industrial oilseed crops in EU-27: A review. *Industrial Crops and Products*, *50*, 580–595. https://doi.org/10.1016/j.indcrop.2013.08.030

Zhang, D., Guo, X., Wang, Q., Zhao, L., Sun, Q., Duan, X., Cao, Y., & Sun, H. (2022). Investigation on lipid profile of peanut oil and changes during roasting by lipidomic approach. *Lwt*, *154*, 112594. https://doi.org/10.1016/j.lwt. 2021.112594

Zhang, D., Li, X., Cao, Y., Wang, C., & Xue, Y. (2020). Effect of roasting on the chemical components of peanut oil. *Lwt*, *125*(November 2019), 109249.

https://doi.org/10.1016/j.lwt.2020.109249

Zubr, J. (2009). Camelina oil in human nutrition. *Agro Food Industry Hi-Tech*, *20*(4 SUPPL), 22–28.

CHAPTER 9

SAFFLOWER (*Carthamus tinctorius* L.) AGRICULTURE

Zeynep DUMANOĞLU[1]*

[1] Department of Biosystem Engineering, Faculty of Agriculture, Bingol University, Bingol, Turkey Orcid No: 0000-0002-7889-9015
*Corresponding author: zdumanoglu@bingol.edu.tr

INTRODUCTION

Safflower (*Carthamus tinctorius* L.), which belongs to the *Asteraceae* family, is one of the economically valuable oil plants in an annual herbaceous structure that has been cultivated for about 3000 years (Koç et al., 2017; Culpan & Arslan, 2018; Baydar & Erbaş, 2020; Koç & Güneş,2021; Kammili & Yadav, 2022). It is estimated that there are about 25 species in this genus of safflower, which is related to the genus Carthamus. It is reported by researchers that it was cultivated in the fertile land between the Fırat and Dicle in Mesopotamia before Christ and spread to China and Japan from India after Christ. With the expansion of the Ottoman Empire towards Spain, this plant spread to different geographies.

Such as Mexico, India, USA, Ethiopia, Argentina and Australia are among the most important safflower producers in the world, and approximately 90% or more of their production is met by these countries (Uysal, et al.2006). It is cultivated in a few provinces in Turkey such as Balıkesir, Eskişehir and Isparta. In addition, wild safflower species can be found in the natural flora of the Eastern Anatolia Region. Although safflower is a plant grown in summer, it is cultivated in a way that is not affected by winter frosts, taking into account the climatic characteristics of the place where it is cultivated (Geçit et al., 2018).

In Turkey, as in the world, agricultural lands have decreased over the years. As a result, there has been a decrease in safflower production, as in other products. While 58 000 tons of product was obtained from safflower planted on 395 710 decares of land in 2016, this value decreased to 21 325 tons in 151 150 decares of land in 2020 (Table 1). Safflower production value has decreased by approximately 50%. On the other hand, the yield per decare did not decrease much. Despite the decrease in agricultural lands and production, the yield value was not very high.

Tablo 1. Safflower production in Turkey over the years (TÜİK, 2021)

Years	Safflower sown area (da)	Safflower Production (ton)	Safflower Yield (kg/da)
2016	395 710	58 000	147
2017	273 762	50 000	183
2018	246 932	35 000	142
2019	158 601	21 883	138
2020	151 150	21 325	141

Figure 1. Safflower (*Carthamus tinctorius* L.)
(https://hsb.wikipedia.org/wiki/Sw%C4%9Btlica)

SAFFLOWER AGRICULTURE

Safflower is an industrial plant with many positive features such as adaptability to different climatic conditions and resistance to salinity (Uysal et al., 2006). In order to be evaluated economically, there is a demand for precipitation of approximately 600 mm. Of course, soil moisture is also important here. If the soil moisture is adequate for seed awakening before planting, the plant needs less water. Since safflower has a pile root structure, its roots can extend from 1-1.5 m to 2-3 m deep. Thanks to its strong root structure, negative situations such as overturning and tilting are not encountered in the plant. In all these cases, the soil structure is quite effective. In general, it does not have a very selective structure in soil and its cultivation possibilities increase thanks to its salt-resistant structure. However, in highly acidic soils, the desired yield may not be obtained when sufficient plant nutrients cannot be obtained. On the other hand, it can be easily cultivated on lands with good drainage, sandy, clayey-loam soil structure and pH of 5-8. Safflower seeds can start to germinate when the soil temperature is about 4-5 °C.

Safflower seeds can be left to the seed bed by using scattering or sowing machines with the help of mechanization. It can be planted with a mineral fertilizer spreader as a spreader, or it can be planted in rows with 30-60 cm between rows and 5-10 cm above rows. Although the need for seeds in my spreading hand is slightly higher (2-3 kg) as in other plants, it can be achieved more economically with less seeds (1-1.5 kg) in row planting. Seeds are left at a planting depth of about 3-5 cm. Depending on the conditions under which safflower is grown, crop rotation can also be applied with plants (such as wheat, chickpeas, lentils).

Figure 2. safflower agriculture (https://commons.wikimedia.org/)

For harvesting and threshing, it is expected that safflower seeds will contain approximately 10% moisture. During the summer months (July-August), the harvest of the plant begins. It can be harvested with simple agricultural tools such as sickles, as well as harvesters used for grain. Residues remaining on the field surface can be utilized by mixing them back into the soil. Depending on the climatic conditions in which the safflower plant is grown, approximately 100-200 kg of seeds can be obtained per decare. Safflower seeds generally have a hard and thick structure with bright white, cream, gray-white, brown or red stripes. Thousand grain weights of safflower vary between 30-45 g.

EVALUATION OF THE SAFFLOWER PLANT

Safflower, which was previously grown for its flowers, was evaluated as a dye because of the yellow or reddish-yellow color of its petals, and it is even known as false saffron. Y It has found a place for itself in many fields, including in the labor, in the coloring of fabrics, in the production of medicines. Over time, oil properties were also noticed and it was started to be grown as an oil plant. In addition, the pulp of the safflower plant, which is left after the oil is taken, and the types without thorns can be used as animal feed as green-dried grass (Dajue & Mündel, 1996; Johnston et al., 2002; Geçit et al., 2018; Yılmaz & Tunçtürk, 2018; Koç & Güneş, 2021; Koutrobas et al., 2021). Due to the attractiveness of its flowers, it is among the plants evaluated in landscape areas (Uysal et al., 2006). In addition, it is used as a raw material in the production of varnish, varnish and dyestuffs (Yıldırım et al., 2005).

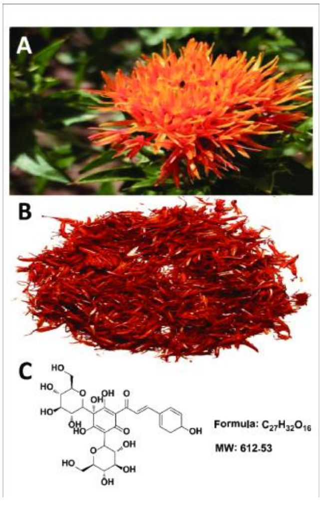


Figure 3. Safflower flower (*Carthamus tinctorius* L.) (Bai et al., 2020)

According to the researches, it has been determined that depending on the region where the safflower plant is grown and the climatic conditions, it generally contains about 32-40% oil, 32-34% carbohydrates, 14-15% protein, 5-8% moisture and 2-7% ash (Weiss, 2000; Çoşge et al., 2007; Kalafat et al., 2009; Kurt et al., 2017). Safflower oil contains more linoleic acid (Omega-3) than other vegetable oils. For this reason, consumption of safflower oil is recommended to prevent cardiovascular diseases and due to its anticholesterol effect (Uysal et al., 2006).

CONCLUSION

As a result, it is thought that the safflower plant, which has an important place in the industrial sense in Turkey and the world, will increase according to the current situation. This plant, which is strong and durable, is considered as raw material by many sectors. For this reason, it is foreseen that researches will be diversified in order to determine the wild species in the natural flora, to carry out breeding studies to develop new varieties, to increase planting opportunities with the help of mechanization and to allow the producer to gain economic gain.

REFERENCES

Bai, Xue., Wang, Wen-Xiao., Fu, Rui-Jia., Yue, Shi-Jun., Gao, Huan., Chen, Yan-Yan & Tang, Yu-Ping. Therapeutic potential of hydroxysafflor yellow a on cardio-cerebrovascular diseases. Frontiers in Pharmacology. 11:01265. (DOI:10.3389/fphar.2020.01265)

Baydar, H. & Erbaş, S. (2020). Our native and national safflower varieties:olein, zirkon and safir. Journal of the Faculty of Agriculture. Turkey 13th National 1st International Field Crops Congress (özel sayı): 233-237.

Culpan,E. & Arslan, B. (2018). Effects of applications salicylic acid on seed yield and some quality traits of safflower cultivars (*Carthamus tinctorius* L.). Academic Journal of Agriculture 7(2):173-178.

Dajue, L. & Mündel, H.H. (1996). Safflower *Carthamus tinctorius* L. Promoting the cnservation and Use of Underutilized and Neglected Crops. 7. Institute of Plant Genetics and Crop Plant Research.

Geçit, H.H., Çiftçi, C.Y., Emeklier, H.Y., İkincikarakaya, S.Ü., Adak, M.S., Kolsarıcı, Ö., Ekiz, H., Altınok, S., Sancak, C., Sevimay C.S. & Kendir H. (2018). Field Crops. Ankara University Faculty of Agriculture Publications. Publication No: 1643, Ankara.

Johnston, A.M., Tanaka, D.I., Miller, P.R., Brandt, S.A., Nielsen, D.C., Lafond, G.P. & Riveland, N.R. (2002). Oilseed crops for semiarid cropping systems in te Northern Great Plais. Agron J. 94, 231-240.

Kalafat, S., Karakaya, A., Kaya, M.D. & Bayramin, S. (2009). A preliminary study on the reactions of safflower genotypes to rüşt disease. Plant Protection Bulletin. 49(4): 183-187.

Kammili, A. & Yadav, P. (2022). Enhancing oleic acid and oil content in low oil and oleic type Indian safflower (*Carthamus tinctorius* L.). Industrial Crops & Products 175. 114254.

Koç, H., Güneş, A. & Aydoğan, S. (2017). Evaluation of Yield and Yield Components of Safflower Lines Developed by Selection in Konya Conditions. KSU J Nat. Sci. (Özel Sayı): 181-185.

Koç, H. & Güneş, A. (2021). Determining the Relationships between Flower Yield and Some Morphological Traits in Safflower Genotypes. Turkısh journal of Nature and Science. 10(1): 90-95.

Koutroubas D.S., Damalas, A.C.& Fotiadis, S. (2021). Safflower assimilate remobilization, yield, and oil contet i response to nitrojen avability, sowing time and genotype. Field Crops Research. 274: 108313.

Kurt, O., Çelik, N., Göre, M., Hacikamiloğlu, M.S., Özyılmaz, T. & Şenel, A.A. (2017). Determination of oil and fatty acid composition of some safflower (*Carthamus tinctorius L.)* cultivars. KSU J. Nat. Sci. (Special ıssue): 206-210.

TÜİK. (2021). Türkiye İstatistik Kurumu/Yağlı Tohumlar (erişim: Temmuz 2021)

Uysal, N., Baydar, H. & Erbaş, S. (2006). Determination of Agricultural and Technological Properties of Safflower (*Carthamus tinctorus* L.) Lines Developed from Isparta Population. Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi 1(1):52-63.

Weiss E.A. (2000). Safflower. In: Oilseed Crops, Blackwell Sci. Ltd., Victoria, Australia, pp 93-129.

Yıldırım, B., Tunçtürk, M., Dede, Ö. & Okut, N. (2005). Effect of Different Doses of Nitrogen and Phosphorus on the Yield and Quality of Safflower (*Carthamus tinctorius* L.). J. Agric. Sci. 15(2):113-117.

Yılmaz, S. & Tunçtürk, M. (2018). Determination of Yield and Yield Components of Some Safflower Cultivars in Soil with and without Tillage under Muş Ecological Conditions. Journal of the Instıtute of Natural & Applied Sciences 23 (1):69-78.

CHAPTER 10

HEMP (CANNABIS)

Dr. Hatice Eda TOKUL[1]

[1] Manisa Celal Bayar University, School of Tobacco Technology, Manisa, Turkiye
ORCHID:0000-0002-6545-8219

1. DEFINITION

Hemp, belongs to the order Urticales, belongs to the family *Cannabaceae*. The genus name is Cannabis. There are 2 species belonging to this genus, one is called *sativa* and the other is called *indica*. Cannabis sativa and Cannabis indica should not be considered as separate species. Appropriate expression is *C. sativa subsp. sativa* and *C. sativa subsp. indica*. The vernacular taxonomy of "*Sativa*" and "*Indica*." There is also wild cannabis and called *Cannabis sativa ssp. ruderalis* (Mc Partland, 2018). There is another subspecies called giant cannabis: *C. sativa var. gigantica* (Ulaş, 2019). It is known by names such as “kenevir, hemp, çedene, kinap” in Turkey. English name is "hemp".

Linnaeus knew that *C. sativa* was a species cultivated in Europe. He reported him origin as the region called the Indian Oriental, which includes India, southeast Asia, and the Malay Islands, and Malabaria, Japan. Lamarck, on the other hand, defined two species as *C. sativa* and *C. indica*. He stated that *C. sativa* originated in Iran and Europe and *C. indica* originated in India (Mc Partland, 2018).

Cannabis indica is a seed type cannabis. Therefore, their fiber yields are low. Vegetation period is short (3 months). The stem is woody and short. They can reach 50-60 cm in length. They also take the name of Turkish Indian hemp. Also called seed type cannabis or medicinal cannabis.

Cannabis sativa is the fiber type hemp. It is cultivated in Europe. Vegetation period is 6 months. It has a fibrous and long stem. They can grow up to 5-6 m in length. Depending on ecological conditions and agricultural practices, 25 tons/ha dry matter yield can be obtained from fiber hemp. Fiber performance is affected by the onset of flowering and seed development (Struik et all, 1999).

Lamarck’s description of *C. indica* differed from his description of *C. sativa* by eight ‘‘very distinct’’ morphological characters in stalks, branching habitus, leaflets, and flowers. Lamarck also described chemotaxonomic differences: *C. indica* produced a strong odor, and was psychoactive, ‘‘The principal effect of this plant consists of going to the head, disrupting the brain, where it produces a sort of drunkenness that makes one forget one’s sorrows, and produces a strong gaiety.’’ (Mc Partland, 2018).

2. MORPHOLOGY

The number of chromosomes is 2n=20. It is an annual, dioecious plant. However, in seed type (*C. indica*) there are monoic ones. This gender status is not observed in cannabis in the primary period. It can be distinguished in the secondary period. The male plant shows weak and slow development in the secondary period, dies early. Despite, female plants have fast growth, green body, good fiber content in terms of quantity. It is pile rooted up to 2 m in length (Başbağ and Ekinci 2020). The female plants have got many branches. Its stem is hard and woody. It is also gnarled, and leaves emerge from these nodes. Branching occurs from the top. When the plant is fully mature, its height is 50 cm (*C.ruderalis*) - 6m. (*C. sativa*) (Anonymous, 2021). Males of the Cannabis sativa species have a long and knotty stem. Fiber is obtained from these plants. The length of the internodes is the length of the fiber to be obtained. Primary fibers are suitable for textile use and these fibers are found in the shell part and consist of lasting tissue. During the growth process of the plant, the number of fibers does not change, but the fibers stretch out. Hemp fibers consist of fiber bundles and each fiber cell is 20-35 microns. The bright hemp fibers are yellow-brown and the cross-section of the fiber is polygonal (Gedik, 2012). Its leaves are in the form of compound leaves, consisting of 3-11 pieces (less than *C. indica*, usually 7). The middle leaflet is always larger than the others. The margins of all leaflets are toothed. The leaves are arranged oppositely on the stem. The technique shows an alternating arrangement from the end of the stem. Small leaves and rich fluff are observed in the flowering parts of the plant. On male plants, sparse inflorescences of yellowish-green male flowers; In female plants, dense flower bunches consisting of green-looking female flowers were located in the leaf axils. On the male plant, the flowers are joined to the panicle stem with short petioles. Male cannabis plants end with a rich inflorescence. In male flowers, the outermost 3 bract leaves, including 5 perianth remnants; They also have thin filaments, white round heads (anthers) and 5 male organs (stamens).

Stamens hang out of flower between perianth leaves. The heads are also covered with very small warts. The pollen, which is white or yellow, is easily carried by the wind. The female flowers are arranged in pairs, sessile, dense, spike-like, opposite each other on the female plants, on the axis of the inflorescence. In each pair, often only one flower bears fruit; the other is barren. The female cannabis plant ends with a dense, rich, spike-like flower collection with abundant leaves. In female flowers, the bract leaves are combined and clearly envelop the flower over the perianth. Perianth leaves merged to form a cup-shaped, uninterrupted sheath around the ovary. The female organ, which has a single-chambered ovary and forms a single seed in it, has two large stigmas (stigmas) extending upwards between the protective (bracte) leaves. The stigmas are hairy and red in color, suitable for open fertilization. Although its seeds are generally used as bird food in Turkey, it has started to be preferred more in the kitchen in recent years with the understanding of its health benefits. Cannabis seeds are egg-shaped, hard and brownish-greenish in color (achene). The seed in the walnut is endospermic and the embryo is curled up in the fruit. Because it contains a single seed and its shell is hard and unbreakable, walnut is used as a seed in the cultivation of cannabis and is practically called cannabis seed. Depending on the variety, the length of the seeds is 4.0-6.0 mm; 1000 grain weight of cannabis seeds with a width between 3.0-3.5 mm varies between 9-27 g. (Anonymous, 2022).

3. CHEMICAL COMPOSITION

There is a very complex phytochemical content in hemp. These phytochemicals are composed of different chemical classes, and a total of more than 700 compounds have been identified in this way (ElSohly ve Slade 2005; Sharma ve Kumar, 2019). Some of these compounds are unique to cannabis. While amino acids, fatty acids, and steroids represent primary metabolism, cannabinoids (cannabigerol (CBG), cannabicromen (CBC), cannabidiol (CBD), cannabisiccosol (CBL), cannabielsoin (CBE), cannabinol (CBN), cannabinodial (CBND), cannabitriol (CBT)), flavonoids, stilbenoids, terpenoids, lignans and alkaloids represent secondary metabolites. The composition of the fiber includes cellulose, hemicellulose, lignin and pectin. It is also a source of Δ-9- tetrahydrocannabinol (THC), which is the main active chemical compound in oil and its structure (Kriese et all., 2004). The main activity of this compound is to cause acute transient psychotic reaction in healthy individuals when applied as a pure compound. Psychoactive activities are also evident. Such as antinociceptive, antiepileptic, cardiovascular, immunosuppressive (Ameri, 1999), antiemetic, appetite stimulating effect (Mechoulam and Shabat, 1999), anti-inflammatory (Formukong et all, 1988), neuroprotective antioxidants 1998) has positive effects in in vivo and in vitro clinical studies. The nomenclature was made taking into account the amount of the main active substance. *Cannabis sativa subsp. indica* is the strain that contains relatively high amounts of THC. it contains low amounts of THC, *Cannabis sativa subsp. sativa* named (Doğan and Doğan, 2021). Concentrations of compounds present depend on plant tissue, age, genotype, growing conditions, harvest time and storage conditions (Kushima et all, 1980; De Roos et all., 1996; Keller et. all, 2001; Flores-Sanchez and Verpoorte, 2008). The synthesis of cannabinoids increases when plants are under stress (Pate, 1999). Hemp seeds generally contain about 25-35% lipid and 20-25% crude protein by weight (Vonapartis et all, 2015).

The data presented in Table 1 were obtained by Callaway (2004) from cold oil pressing of "Finola" cannabis variety seed at 45°C followed by analysis of the ground flour of the seed meal.

Table 1. Nutritional content of hemp (Callaway, 2004)

	Seed	**Seed Meal**
Oil (%)	35.5	11.1
Protein (%)	24.8	33.5
Carbohydrates (%)	27.6	42.6
Moisture(%)	6.5	5.6
Ash (%)	5.6	7.2
Energy (kJ / 100g)	2200	1700
Total dietary fiber (%)	27.6	42.6
Digestible fiber (%)	5.4	16.4
Indigestible fiber (%)	22.2	26.2

Besides the medicinal potential of beneficial cannabinoids in the leaves and flowers of the cannabis plant itself (Zlas et.all, 1993), both ripe hemp seeds and seed meal have excellent properties in terms of dietary fat, fiber and protein sources (Table 1). Hemp is an invaluable source for animal feed, especially due to its high oil (35.5% seed and 11.1% seed meal), protein (24.8% seed and 33.5% seed meal) and carbohydrate (27.6% seed and 42.6% seed meal) content.

As an industrial plant food source, both hemp and hemp products are rich sources of protein and polyunsaturated fat, as well as significant amounts of vitamins and beneficial minerals (Table 2).

Table 2. Nutrition Facts of Hemp in terms of Vitamins and Minerals (mg/100g) (Callaway, 2004)

Vitamin E	90
Thiamine (B1)	0.4
Riboflavin (B2)	0.1
Phosphorus (P)	1160
Potassium (K)	859
Magnesium (Mg)	483
Calcium (Ca)	145
Ferrous(Fe)	14
Sodium (Na)	12
Manganese (Mn)	7
Zinc(Zn)	7
Cuprous (Cu)	2

As seen in Table 2, hemp is also very rich in terms of phosphorus (1160 mg P/100g), potassium (859 mg K/100g), magnesium (483 mg P/100g) and calcium (145 mg Ca/100g).

4. USUAGE

Cannabis is an industrial plant with a very high usefulness. The whole plant is used. Therefore, it has a high economic value. It is used in many industries (textile, food, construction, energy, medicine, composite materials, cellulose, cosmetics).

Hemp has been cultivated for its fiber for centuries. It is the most widely used fiber source in Central Asia and Anatolia. It has been reported that its history in Anatolia dates back to the 1500s (Gizlenci et all., 2019).

The fiber is very strong. It is used in making sacks and this use can be made over and over again. It is also used in rope making and weaving.

Hemp is a textile fiber used for building applications mixed with polyester fiber and fire retardants. An innovative material created by mixing hemp gravel, binder and water developed and studied by Glé, P. et al. (2011). It is a good mix of heat conduction, sound absorption capacity and used in the construction industry.

In the Ottoman Empire, before the ball was poured, a clay mortar mixed with flax and hemp fibers was plastered on the mold to form the outer surface of the ball. Thanks to the durability of the fibers, the outer surface of the ball would also be made of a solid material (Yılmaz, 2014).

When cellulose-based plant fibers obtained from hemp are added to polymer composites, more positive results were obtained than synthetic fibers. We can express some of the positive aspects of cellulose fibers as follows: Cellulose fibers are non-toxic, biodegradable and recyclable materials. It is known that when they are used at high rates, they enable the production of low-density composites and give high strength and hardness performance. Moreover, natural fibers are flexible and, thanks to this feature, they are more resistant to breaking during the process (Santos et all., 2008; Spoljaric et all., 2009). For this reason, lignocellulosic fibers including banana, hemp and coconut fibers attract the attention of many researchers in terms of their benefits as polymer additives in industrial areas. Such fibers also have many advantages compared to glass fibers, such as low density and low price (Joseph et all., 2002;

Mothé et all., 2009; Merlini et all., 2011). In recent years, natural fibers such as flax, hemp, jute, kenaf have been added to thermoset and thermoplastic composites and are widely used in transportation (automobile, railway, boat, etc.), construction and packaging industries (Mohanty et all., 2000; Puglia et all., 2005). Automotive companies in the USA use thermoplastic and thermoset composites reinforced with natural fibers such as hemp, hemp and linen in approximately 1.5 million of the vehicles produced (Faruk, 2009). In 2008, composites reinforced with hemp were used in the spoiler and some parts of the Lotus company's ECO Elise concept vehicle (Dönmez Çavdar and Boran, 2016). Besides Ford, most automobile manufacturers (General Motors, Daimler, Toyota, Fiat, Volkswagen and BMW) use cellulose-based fibers such as wheat straw, banana, coconut, flax, hemp, hemp, sisal, manila hemp in plastic composites. These fibers are used in automobile interior parts (Ashori, 2008; Hill et all., 2012; Dönmez Çavdar and Boran, 2016).

In places where there is a shortage of wood and coal, the woody parts of which the fibers have been removed are also used as fuel for fiber production. At the end of the physical and chemical analyzes, it was determined that it is possible to pellet the hemp stalk without using any additives. The ash content of the pellet obtained from the hemp stalk ranges from 3.76% to 11.72%. In terms of its calorific value, it is seen that the hemp stalk has a very high value between 4309 and 4588 kcal/kg. Considering that the heating value of 90% of the lignite coal mined in Turkey is below 3000 kcal/kg (Anonymous, 2012), it can be said that hemp straw is a quality fuel source. The amount of stem (biomass) remaining after the hemp fiber is taken is around 900 kg/da in some varieties. For this reason, it can be said that the pellet can create a good side income for the producer. It has been determined that the fuel pellet obtained from hemp plant residues has the potential as an environmentally friendly, sustainable and renewable solid biofuel source and can be an alternative fuel to fossil fuels (Dok et all, 2021).

Hemp fiber is seen as an alternative fiber in every sector where petroleum and its derivatives are used (Demirbek and Bulut, 2021).

Oil is obtained from the seed. Its seed is roasted and eaten as a snack in some regions of Turkey and its name is called “çetene”. The seed shape is round. Thousand grain weight is 14-22 gr. It is used in feeding because it encourages cage birds to sing.

5. CULTIVATING

In 1937, hemp cultivation was banned in the USA with the law called "Marijuana Tax Law". After this ban, it started to be implemented in some countries in Europe and Turkey. Cannabis production has decreased significantly all over the world due to the widespread use of synthetic fibers, the acquisition of cannabis as a narcotic substance, and its substitution with other plant fibers (jute, sisal…).

As a result of the evaluations made by the Ministry of Agriculture and Forestry, it was decided to release industrial hemp cultivation in 19 provinces as of 2019. Today, hemp production regions in Turkey are given in Figure 1. As seen in Figure 1, these are the Central Black Sea Region from Zonguldak to Ordu in the north, Çorum, Amasya, Tokat, Yozgat, Kayseri and Malatya provinces to the south, and Central Anatolia where hemp cultivation is intense. Apart from this, Rize, Burdur, Antalya, Kütahya, Uşak and İzmir are also seen as other breeding provinces.

Figure 1: Cannabis Cultivation Areas in Turkey (Ceyhan et all., 2022).

Today, the farmers who will plant hemp in Turkey still have to obtain legal permission from the provincial or district directorates of the Ministry of Agriculture and Forestry and have to constantly control the production process. The cannabis plant grown without permission is destroyed in accordance with the provisions of the law, regardless of its purpose, and criminal proceedings and legal prosecution are carried out against the grower. Permitted cannabis planted areas are regularly checked by the technical staff of the provincial and district directorates from planting to harvest (Aksoy et all, 2019).

The situation of hemp farming in Turkey until its release in some provinces in 2019 and the situation in 2019 are compared in Table 3 and Table 4. In Table 3, the cultivation area and production amount of seed type cannabis, which was quite limited in the period until its release (2009-2018), increased in 2019.

Table 3. Turkey's cannabis seed sowing area, yield and production by years (TUIK, 2020)

	Cultivation area (ha)	Production amount (tons)	Yield (kg/ha)
2009	0,066	3	450
2010	0,221	7	320
2011	0,140	8	570
2012	0,064	4	630
2013	0,007	1	1430
2014	0,01	1	10
2015	0,01	1	10
2016	0,025	1	50
2017	0,024	1	420
2018	0,059	3	510
2019	0,536	20	420

When Table 4 is examined, the relatively higher cultivation areas (0.221,0.157 ha) of fiber hemp in 2010-2011 decreased in the following years and increased again in 2019 when legal permission was granted.

It can be concluded from Table 3 and Table 4 that legal regulations are an important factor affecting the future of hemp. It is hoped that after these permits, its cultivation will increase every year. Here we will also touch on the cultivation of cannabis.

Table 4. Hemp fiber cultivation area, production and yield of Turkey by years (TUIK, 2020)

	Cultivation area (ha)	Production amount (tons)	Yield (kg/ha)
2009	0,066	4	610
2010	0,221	10	450
2011	0,157	16	1020
2012	0,063	6	950
2013	0,012	1	830
2014	0,01	1	10
2015	0,01	1	10
2016	0,045	7	1560
2017	0,046	7	1520
2018	0,055	7	1270
2019	0,16	19	1260

Climate requests

Although cannabis is a plant that can show high adaptability to climatic conditions in general, it is sensitive to cold. It grows best at 14-27^{o}C. In order to give the best yield, there are also different and special climate requirements according to the species (*C.sativa*, *C.indica*). Since *C.sativa* species is grown for fiber production, it gives the best fiber yield in regions with high relative humidity. The higher the moisture content, the higher the fiber yield. It can be grown without irrigation in regions with at least 700 mm of rainfall. The need for irrigation arises in regions that do not receive enough rainfall. It requires precipitation or irrigation, especially before planting. This need for water continues in the early stages of its development. If a good irrigation is done during this period, it completes its development well. Although it is relatively resistant to light frosts in spring, extreme and sudden drops in temperatures (less than -5/-6^{o}C) damage the plant (Basbag and Ekinci 2020). Therefore, hemp is grown in the summer and harvested in the fall. Regular irrigation or precipitation, which will keep the soil moist until it passes the first developmental stage, is the most ideal for the plant. Drought in the later stages provides the best seed yield and quality, especially for seed type cannabis (*C. indica*).

Soil requirements

Hemp is not very picky in terms of soil requirements. Although it grows best in deep plowed and alluvial soils rich in organic matter, it cannot develop ideally and yield cannot be obtained in clayey, heavy soils and extremely sandy soils with low water holding capacity. Sandy-loam soils are ideal soils (Anderson, 2018). Some researchers have reported that the ideal soil pH for cannabis cultivation is between 6-7.5 (Gizlenci et all., 2019).

Soil preparation and planting

Soil preparation is started by making deep plowing in autumn to prepare the soil for winter. Thus, both the reproductive organs of the weeds in the depths of the soil are damaged, and the soil becomes airy and provides the highest level of benefit from the winter precipitation. When the soil pan comes in the spring, a more superficial plow is made, a disc harrow is pulled and the soil is made suitable for seed emergence.

Fiber cannabis cultivation is done by sowing the seed directly into the field. Sowing in the field can be done either by hand spreading or by machine. However, sowing with seeder should be preferred as it is more advantageous than manual sowing. Thus, the seed is not wasted by using sufficient amount of seeds, and the output is homogeneous as the planting depth will be constant. Row spacing varies depending on fiber and seed type. In planting with seeder, the row spacing should be set as 20 cm for fiber type cannabis and 40 cm for seed type hemp. It would be ideal to set the on-row distance around 6 cm. Seed type cannabis is widely grown in the greenhouse environment in the world. Plants to be grown in the greenhouse environment are propagated by cuttings or tissue culture. In addition, it can be grown with hydroponic culture. It is stated that the hydroponic method is more efficient in greenhouse cultivation, but requires very meticulous care (Basbag and Ekinci 2020).

Maintenance

One of the most important maintenance processes is irrigation. Cannabis can be grown without irrigation if it receives at least 700 mm of precipitation in a place where temperature and humidity requirements are met. Especially in the first development period, if there is no precipitation, irrigation should be done at regular intervals and the soil should be kept moist. Although this is the condition of the soil being tempered and is also a necessity in the later stages of the plant for fiber hemp, the amount of irrigation should not be overdone in the advanced development period for seed yield, quality and ideal harvest time for seed type cannabis (Gizlenci, 2019).

During the autumn plowing for soil preparation, farmyard manure is given to the soil. In the spring, soil analysis should be done and mineral fertilizers should be given as needed. Hemp removes a lot of nutrients from the soil (Gizlenci, 2019). Fertilizers containing 80-120 kg/ha of pure nitrogen and superphosphate fertilizers containing 60-80 kg/ha of pure phosphorus are recommended.

Hoeing is done in the field when the length of the hemp is 5-10 cm. With this hoeing, it is aimed to break the cream layer formed by irrigation in the soil, to remove weeds and to create a healthier environment for the plant by airing the soil. If an effective hoeing is done, it does not need to be done a second time and a single hoeing is sufficient.

Harvest

In fiber-type hemp, the harvest time of the plant is the time when the fiber quality is highest. Although this period varies according to ecological conditions and the applied maintenance procedures, it is around 4-6 months from planting. In early harvest, all plants are harvested together. Sometimes, male and female cannabis are harvested at different times as they mature at different times. In this case, the harvest time of the male plant is earlier. About a week after the flowers of the male individuals bloom, the leaves fall and the stem turns yellow, indicating that the plant is harvesting time. The female plants are harvested 4-5 weeks after the male plant harvest. Because at the same time, the seeds mature during this time (Gizlenci, 2019). Harvesting can be done by machine or by hand. After harvest, the stems of the plant are pooled to obtain fiber. The harvested leaves are dried until they gain a crisp and brittle structure, that is, until the moisture content drops from 80% to 5-10%. It is stored under suitable storage conditions.

6. CONCLUSION

In this study, it is aimed to mention once again the importance of the cannabis plant, which has served humanity for centuries with its wide range of uses and is still used as a raw material and additive in dozens of sectors all over the world. In order to benefit more from both fiber and seed type cannabis, we think that efforts to increase their production should be given importance.

7. REFERENCES

Aksoy, D., Aytaç S. & Paslı, R. (2019). Endüstriyel kenevir gerçeği, 2.Uluslararası 19 Mayıs Yenilikçi Bilimsel Yaklaşımlar Kongresi, M. Abdullayev, (Eds), 2019. Samsun, Türkiye, İktisadi Kalkınma ve Sosyal Araştırmalar Enstitüsü, pp.850-858.

Ameri A. (1999). The effects of cannabinoids on the brain. *Prog Neurobiol*. 58(4):315-48. doi: 10.1016/s0301-0082(98)00087-2. PMID: 10368032.

Anonymous, (2012). Türkiye Kömür İşletmeleri Kurumu. Kömür Sektör Raporu (Linyit) 2011. Stratejik Planlama Koordinasyon Birimi, Ankara.

Anonymous, (2021). Kenevir, Cannabis. Doğal Tarım Merkezi. https://dogal-tarim.org/index.php/2021/02/17/kenevir-cannabis/ (Erişim Tarihi: 30.10.2022).

Anonymous, (2022). Kenevir, http://biokenevir.com/kenevir.html (Erişim Tarihi:30.10.2022).

Anderson, R.D., (2018). Effects of nitrogen fertilizer rate, timing, and herbicide use on industrial hemp (*Cannabis Sativa*) [Masters Theses & Specialist, Projects University of Western Kentucy]. Paper 2100. htps://digitalcommons.wku.edu/theses/2100

Ashori, A. (2008).Wood–plastic composites as promising green-composites for automotive ındustries. Bioresource Technology, 99(11), 4661-4667.

Başbağ, S., Ekinci, R. (2020). Kenevir Tarımı. A. Onay, H. Yıldırım ve R. Ekinci (Eds), Kenevir (*Cannabis sativa* L.) (p.61-84). Palme Yayınevi.

Callaway, J. C. (2004). Hempseed as a Nutritional Resource: An Overview. *Euphytica*, 140, 65-72.

Ceyhan V., Türkten, H., Yıldırım, Ç., Canan S., (2022). Economic viability of industrial hemp production in Turkey, Industrial Crops and Products, 176, 114354, ISSN: 0926-6690, https://doi.org/10.1016/j.indcrop.2021.114354.

De Roos, A. D., Van Zoelen, E. J. & Theuvenet, A. P. (1996). Determination of gap junctional intercellular communication by capacitance measurements. *Pflugers Arch,* 431, 556-563.

Demirbek, D. M., Bulut, M.O., (2021). Kenevir liflerinin eldesi, özellikleri ve kompozit uygulama alanları. *Bartın University International Journal of Natural and Applied Sciences* JONAS, 4(2): 176-191.

Doğan, N., Doğan, C. (2021). Mucizevi Bitki Kenevir (*Cannabis sativa* L.)'in gıda endüstrisinde kullanımı. Bozok *Vet Sci*. 2(2):47-56.

Dok, M., Acar, M., Gizlenci, Ş., (2021). Kenevir (Cannabis sativa L.) Sapının Katı Yakıt Pelet Özelliklerinin Belirlenmesi. *Anadolu, J. of AARI.* 31 (2): 161-169. doi: 10.18615/anadolu.1029901.

Dönmez Çavdar, A., Boran, S. (2016). Doğal Liflerin Ototmotiv Sanayiinde Kullanımı. *Kastamonu Uni., Orman Fakültesi Dergisi, 2016, 16 (1): 253-263*

Elsohly, M. & Slade, D. (2005). Chemical constiutents of marijuana: The complex mixture of natural cannabinods. *Life Sci*, 78(5), 539-548. doi: https://doi.org/10.1016/j.lfs.2005.09.011

Faruk, O. (2009). Cars from Jute and Other Bio-Fibers. http://biggani.com/files_of_biggani/ … (Erişim tarihi: 27.10.2022).

Flores-Sanchez, I. J. & Verpoorte, R. (2008). Secondary metabolism in cannabis. *Phytochem Rev*, 7(3), 615-639.

Formukong EA, Evans AT, Evans FJ. (1988). Analgesic and antiinflammatory activity of constituents of Cannabis sativa L. Inflammation. 12(4):361-71. doi: 10.1007/BF00915771. PMID: 3169967.

Gedik, G. (2012). Kenevir Liflerinden Üretilen Kumaşların Optimum Ağartma Koşullarının ve Yöntemlerinin Belirlenmesi. (Publication No.376234)[Master dissertation. Pamukkale Universty]. Ulusal Tez Merkezi.

Gizlenci Ş., Acar, M., Yiğen Ç., Aytaç S., (2019) Kenevir Tarımı: T.C. Tarım ve Orman Bakanlığı TAGEM Karadeniz Araştırma Enstitüsü Müdürlüğü.

Glé, P., Gourdon, E., & Arnaud, L. (2011). Acoustical properties of materials made of vegetable particles with several scales of porosity. *Applied Acoustics*, *72*(5), 249-259.

Hampson AJ, Grimaldi M, Axelrod J, Wink D. (1998). Cannabidiol and (-)Delta9-tetrahydrocannabinol are neuroprotective antioxidants. Proc Natl Acad Sci U S A. 7;95(14):8268-73. doi: 10.1073/pnas.95.14.8268. PMID: 9653176; PMCID: PMC20965.

Hill, K., Swiecki, B., Cregger, J. (2012). The Bio-Based Materials Automotive Value Chain, Washington, DC 20585, Center for Automotive Research.

Joseph, S., Sreekala, J.M.S., Oommen, Z., Koshyc, P., Thomas, S. 2002. A comparison of the mechanical properties of phenol formaldehyde composites reinforced with banana fibres and glass fibres. Composite Science and Technology, 62(14), 1857–1868.

Keller, A., Leupin, M., Mediavilla, V., & Wintermantel, E. (2001). Influence of the growth stage of industrial hemp on chemical and physical properties of the fibres. *Industrial crops and products*, *13*(1), 35-48.

Krıese, U., Schumann, E., Weber, W.E., Beyer, M., Bruhl, L. & Matthaus, B. (2004). Oil content, tocopherol composition and fatty acid patterns of the seeds of 51 *Cannabis sativa* L. genotypes. *Euphytica*, 137(3), 339-351. doi: 10.1023/B:EUPH.0000040473.23941.76

Kushıma, H., Shoyama, Y. & Nıshıoka, I. (1980). *Cannabis* XII: variations of cannabinoid contents in several strains of *Cannabis sativa* L. with leaf-age, season and sex. *Chem Pharm Bull,* 28(2), 594-598.

Mc Partland, J.M. (2018). Cannabis Systematics at the Levels of Family, Genus, and Species. *Cannabis and Cannabinoids Research*. 3(1):213-217. doi:10.1089/can.2018.0039

Mechoulam R, Ben-Shabat S., (1999). From gan-zi-gun-nu to anandamide and 2-rachidonoylglycerol: the ongoing story of cannabis. Nat Prod Rep.16(2):131-43. doi: 10.1039/a703973e. PMID: 10331283.

Merlini, C., Soldi, V., Barra, G.M.O. 2011. Influence of fiber surface treatment and length on physico-chemical properties of short random banana fiber-reinforced castor oil polyurethane composites. Polymer Testing, 30(8), 833-840.

Mohanty, A.K., Misra, M., Hinrichsen, G. 2000. Biofibers, biodegradable polymers and biocomposites: An overview.Macromolecular Materials and Engineering, 276/277(1), 1-24.

Mothé, C.G., Araújo, C.R., Wang, S.H. 2009. Thermal and mechanicals characteristics of polyurethane/curaua fiber composites. Journal of Thermal Analysis and Calorimetry, 95(1), 181–185.

Pate, D.W. (1999). The phytochemistry of Cannabis: its ecological and evolutionary implications. In: Ranalli P (Eds) Advances in hemp research (p. 21-42) Haworth Press, NY.

Puglia, D., Biagiotti, J., Kenny, J.M. 2005. A review on natural fibre-based composites-Part II: Application of natural reinforcements in composite materials for automotive industry.Journal of Natural Fibers,1(2),23-65.

Santos, P.A., Giriolli, J.C., Amarasekera, J., Moraes, G. 2008. Natural fibers plastic composites in automotive applications. SPE Automotive Composites Conference & Exhibition Troy, MI, USA, p. 1-9.

Sharma, V. & Kumar, R. (2019). FTIR and NIRS in Forensic Chemical Sensing. T. R. L. C. Paixao, O.S. Maiara and W. K T Coltro (Eds) Forensic Analytical Methods (p. 164-197). Royal Society of Chemistry Publishing. https://doi.org/10.1039/9781788016117-00164

Spoljaric, S., Genovese, A., Shanks, R.A. 2009. Polypropylene-microcrystalline cellulose composites with enhanced compatibility and properties. Composite Part A:Applied Science and Manufacturing, 40(6-7), 791-799.

Struik, P.C., Amaducci S., Bullard M.J., Stutterheim N.C., Venturi G., Cromack, H.T.H. (1999). Agronomy of Fibre Hemp. *Industrial Crops and Products*. 11 (2000) 107–118. doi: https://doi.org/10.1016/S0926-6690(99)00048-5

TÜİK, (2020). Türkiye İstatistik Kurumu, Bitkisel Üretim İstatistikleri. http://www.tuik.gov.tr/Start.do (Erişim tarihi: 29.09.2022.

Ulaş, E. (2019). *Mucize Bitki Kenevir, Gerçek Köye Dönüş Projesi.* İstanbul: Hiperlink Eğitim İletişim Yayıncılık San. Paz. ve Tic. Ltd. Şti.

Vonapartıs, E., Aubın, M., Seguın, P., Mustafa, A. F. & Charron, J. B. (2015). Seed composition of ten industrial hemp cultivars approved for production in Canada. *J. Food Compost. Anal.* 39, 8-12

Yılmaz, F., (2014). Fatih Sultan Mehmet Dönemi Topları ve Değişen Üretim Paradigması. FSM Scholarly Studies *Journal of Humanities and Social Sci.4:219-236.*

Zlas, J., Stark, H., Selıgman, J., Levy, R., Werker, E., Breuer, A. & Mechoulam, R. (1993). Early medical use of cannabis. *Nature,* 363(6426), 215-215.

CHAPTER 11

USE OF INDUSTRIAL PLANTS AS DAIRY ALTERNATIVES

Assoc. Prof. Dr. Aslı AKPINAR[1]

Assoc. Prof. Dr. Oktay YERLIKAYA[2]

[1] Manisa Celal Bayar University, Faculty of Engineering, Department of Food Engineering, Manisa-Turkey, ID: 0000-0002-0037-8295, asli.akpinar@cbu.edu.tr
[2] Ege University, Faculty of Agriculture, Department of Dairy Techonology, İzmir-Turkey, ID: 0000-0002-1532-4687, oktay.yerlikaya@ege.edu.tr

1.INTRODUCTION

In the last decade, new research has been carried out on the concepts of sustainable food and nutrition, as well as the use of alternative sources to meet changing needs and ensure that healthy foods reach consumers. With increasing urbanization and the increasing demand of western lifestyle consumers for these products, the speed of development of new products has increased. Nutrition is the continuation of human life, increasing the quality of life, taking the nutrients necessary and sufficient in the body for the renewal of cells. In order for the cells that make up our body to function regularly, it is necessary to take nutrients such as carbohydrates, proteins, fats, vitamins and mineral substances with various foods in our daily diet.

Milk is one of the most consumed foodstuffs by the human population since ancient times due to its nutritional value. Milk and dairy products have a very important share in the food pyramid, which includes the food groups that must be taken in order for a person to have a daily balanced diet. Milk and dairy products contain sufficient nutrients that a living thing needs for its survival, growth and development. Milk is a vital essential food that, due to the wide variety of nutrients it contains, is able to meet the needs of the organism in all mammals. Milk, which is the basic food in the nutrition of babies, is also used as an important raw material in the food industry, as a nutritional material in raising animals and as a raw material in pharmacology and other industrial branches. The nutrients necessary for an adequate diet are found in varying proportions in various plant and animal foods. Due to the essential aminoacids, fat, lactose, important mineral substances and vitamins it contains, milk is a valuable food in the human diet (Lindmark-Mansson and Akesson, 2000; Miller et al., 2000; Text, 2005). Especially milk, which has a great importance in terms of bone health; there are many studies on its positive effect against many chronic diseases such as cancer, hypertension and obesity (Onurlubaş and Çakırlar, 2016). Milk and dairy products are a rich source of some important minerals (especially phosphorus and calcium), protein, vitamins of group B. Therefore, it is important for public health. Proteins found in milk; it is known to have positive effects on calcium absorption and immune functions, reduce cancer and blood pressure, and have a protective effect in the treatment of obesity and against tooth decay (Pereira, 2014). In addition to growth and development; immunoglobulins, enzymes, enzyme inhibitors, growth hormones, other hormones, growth factors, antibacterial agents, such as protein and peptide structured elements and fatty acids, vitamins and minerals, which are physiologically important in its structure, have many important features in the life cycle (Erk et al., 2019).

However, current consumption of milk has raised concerns among health awareness and at-risk populations, as clinical studies have shown that certain milk components are associated with harmful health effects such as cow's milk allergy, lactose intolerance, anemia and coronary heart disease. (Bode and Gudmand-Hoyer, 1988; Swagerty and Walling, 2002; Kneepkens, 2009).

The growing demand for a Western-style diet is putting pressure on the global food supply. The high consumption of animal products, especially meat and dairy, is one of the main reasons contributing to the negative impact of the modern diet on global and individual health. Therefore, there is great interest in shifting to a more plant-based diet when it comes to environmentally friendly or balanced nutrition to support personal, community, national, regional, global and world health at all levels of society (Pointke et al., 2022). Among the reasons why consumers prefer plant-based milk alternatives to cow's milk, whether vegan or not; reducing environmental pollution caused by animal production, increasing sensitivity to animal rights, high calorie intake, lactose intolerance and milk-induced allergic reactions in plant sources (Pointke et al., 2022). The diet of people who adopt a vegan diet consists of fruits, vegetables, legumes, nuts, seeds, oils and whole grains (Karabudak, 2012).

Beverages (plant-based beverages, plant-based alternative milks, vegan beverages) in which industrial plants are used are, by definition, not and cannot be dairy; rather, they are products obtained by mixing extracts from non-animal products, i.e. vegetable products, with water to bring them to a milk-like appearance, palate, aroma and consistency. The European Commission has banned milk-like products derived from plant sources, with the exception of milk from animals, from being called 'milk' (Council Regulation 1234/2007).

2. VEGANISM AND DAIRY ALTERNATIVE PLANTS

Vegan and vegetarian diets have become a very popular diet in recent years. Although popular in recent years, the concept of vegetarianism dates back to Ancient Greece, while the concept of veganism is a more recent philosophy (Mann, 2014). The first written source found belongs to the Orfeci, who did not consume meat in Ancient Greece. In Ancient Greece, it is thought that there was a relationship between Pythagoras' proposition of reincarnation in the 500s BC and vegetarian diet. Pythagoras stated that vegetarianism should be based on ethical grounds, and he himself pioneered this. These justifications have changed over the years. Around the same time, Buddha is also known to have advocated a vegetarian diet and spread it to many audiences. Hinduism and Jainism advocate vegetarianism, arguing that humans do not have the right to use animals. After the Ancient Greek era, until the 16th century, there was not enough information about vegetarianism. It is known that many scientists such as Leonardo da Vinci during the Renaissance and Tryon, Rousseau, Voltaire in the Age of Enlightenment were fed as vegetarians (Leitzmann, 2014; Kınıkoğlu, 2015; Turkmen, 2015; Tunçay-Son, 2016).

The movement called "Straight Edge", which is an important step for veganism, emerged in the 90s. This movement rejects all forms of drugs and free relations, including alcohol and cigarettes. So much so that after a while, vegetarianism began to be known as vegetarianism, and those who were aware that being a vegetarian was to continue to slaughter animals took the movement further and created the "Vegan Straight Edge" movement. The Vegan Straight Edge movement defends and believes in the view that animals exist for their autonomy, not for humans. These principles are a commitment to the promise that people give themselves that will continue to be valid for life (Larsson et al., 2003).

Vegetarianism is a diet that mostly involves the consumption of plant-based food products instead of animal-based foods (Karabudak, 2012). The International Vegetarian Union (IVU, 2016) defined vegetarianism as "the consumption of food containing only animal products such as dairy products, eggs and honey, or from plants." Based on this definition, vegetarians consume grains, legumes, fruits, vegetables, seeds, dairy products and eggs in their diets; they do not consume meat from any animal, including red meat, chicken and seafood. Vegans, on the other hand, do not consume any animal-based products and consume only plant-based foods. They do not even consume eggs because they are provided from chicken, honey because they are provided from bees, chocolate because they contain milk, but they do not even use any clothes and jewelry produced from animals (Karabudak, 2012; Petti et al., 2017).

Today, an increasing number of researches are published on the effects of saturated fats and cholesterol molecules contained in animal foods on our body. These researches are generally carried out on large masses of people who consume animal food intensively and point to the health problems caused by the consumption of animal foods by these masses (Bode and Gudmand-Hoyer, 1988; Swagerty and Walling, 2002; Kneepkens, 2009). Lactose is the essential carbohydrate found in all mammalian milks. Its sources other than mammals are quite rare. Whole cow's milk contains about 4.8% lactose and meets about 30% of the calorie content of its milk. Dietary lactose is digested by the enzyme lactase, which is located at the brushy edges of the cells of the small intestine and released, is converted and absorbed into glucose and galactose, which are monosaccharides. These components then pass into the blood and meet the energy requirement in humans. Lactose intolerance is the inability to digest lactose, which is a carbohydrate found in milk or dairy products, as a result of deficiency of the necessary lactase enzyme in digestion or insufficiency in enzyme activity. All mammals lose most of the lactase activity in the intestine after delectation. Low lactase activity is seen in approximately 75% of adult people. This low activity causes lactose to be digestible and leads to gastrointestinal disorders. Milk intolerance is especially common in Asian European breeds. It is estimated that one out of every 10 people living on Earth cannot digest milk (Akın et al., 2012; Yıldırım and Özen, 2017). The biggest factor in preferring drinks obtained from plants in people who are not vegan or vegetarian but cannot digest the lactose in milk is that they do not experience discomfort with plant based drinks. Formulas and beverages that are plant-based do not contain components such as cholesterol, saturated fatty acids, antigens and lactose found in animal milks, while they are rich in non-allergic protein, essential fatty acids and minerals (Verduci et al., 2019).

Due to lactose intolerance, health reasons, sensitivity to animal rights and environmental factors, plant-based alternatives of animal-based foods have started to be produced in order to meet people's food habits. Milk-like beverages prepared by resembling to cow's milk and produced industrially are available in the market as plant-based drinks or alternatives. For this purpose, many researches are carried out today on plant-based drinks produced using industrial plants such as soy, peanuts, sunflower seeds, hemp, sesame. Soy takes the highest share among the industrially produced beverages. Plant based drinks produced as milk alternatives are defined in the literature as "legumes, oilseeds, or water extracts of cereals that resemble the appearance of cow's milk." With the developing technology in recent years, legumes, oilseeds, hard-shelled fruits, cereals are used in the production of vegetable milk alternatives. Plant-based milk alternatives are beverages obtained from the breakdown (size reduction) of plant material (cereals, pseudo-grain, legumes oilseeds, nuts) extracted in water, the particle size is brought into the range of 5-20 μm by further homogenizing the appearance and consistency of such drinks to resemble cow's milk (Sethi et al., 2016; Jeske et al.., 2018; Röös et al., 2018; Yılmaz-Ersan and Topçuoğlu, 2019). Although there is no defined and classified of these plant-based milk alternatives as specified in the literature, a general classification of plant-based/vegetable milk alternatives into five categories can be made. a) Cereal based: Oat milk, Rice milk, Corn milk, Spelt milk. b) Legume based: Soy milk, Peanut milk, Lupin milk, Cowpea milk. c) Nut based: Almond milk, Coconut milk, Hazelnut milk, Pistachio milk, Walnut milk. d) Seed based: Sesame milk, Flax milk, Hemp milk, Sunflower milk. e) Pseudo-cereal based: Quinoa milk, Teff milk, Amaranth milk (Sethi et al., 2016).

Especially today, we can say that these alternatives have a serious share in the food industry. However, the nutritional deficiency of people who consume vegetable drinks instead of animal milks and the processes such as bleaching, hot grinding and ultra-high temperature treatment that plant-based beverages are exposed to while obtaining them cause nutrient loss, especially vitamins and minerals. For this reason, plant-based beverages are often supplemented with protein, essential vitamins and minerals to have a nutrient content equivalent to cow's milk and to recover nutrients that are inevitably lost during processing. As an example, calcium carbonate and tricalcium phosphate as sources of calcium; Vitamins A, D, E and B_{12} are added as sources of vitamins (Sethi et al., 2016). A growing number of studies comparing the nutritional content of plant drinks among themselves or with animal milks is increasing (Sethi et al., 2016; Jeske et al., 2017; Silva et al., 2020).

Also, in recent years, plant sources (cereals and legumes) are considered functional food and nutraceuticals due to the presence of health-promoting components such as dietary fibers, minerals, vitamins and antioxidants. In this regard, very few legumes and oilseeds have been used for the preparation of healthy, affordable and nutritious plant-based milk alternatives that are not animal milk. In the past, much attention has been paid to soy milk as it is a nutritious and healthy alternative to cow's milk. But recently it has tended to explore the use of cereals, oilseeds, nuts for new food uses, on the basis of their functional properties, which reveal the physical properties and interactions of food components (Sethi et al., 2016). Individuals with cow's milk allergy, lactose intolerance and hypocholesterolemia prefer these drinks. Despite the lack of added sugar and total protein content, phenolic compounds, unsaturated fatty acids, antioxidant activity, and bioactive compounds such as phytosterols and isoflavones make plant-based milk alternatives substitutes an excellent choice (Aydar et al., 2020). Vegan diets are rich in polyunsaturated fatty acids, dietary fiber, vitamins C and E, folate, magnesium, iron and copper. In the diet of vegetarians, vitamins B_2, B_{12} and D, iodine and calcium have the lowest doses. Vegetarian and especially vegan diets, based on their high fiber content and favorable composition of fatty acids, have been noted to be the most protective against cardiometabolic diseases (Sobiecki et al., 2016). Be conscious when following vegetarian and vegan diets and types; protein, vitamin B12, calcium, iron, zinc, iodine and vitamin D should be taken as external supplements (Erk et al., 2019).

While vegetarian diets do not include meat, poultry, or fish, vegan diets additionally exclude dairy products and eggs from their diets. In the research, it is stated that the number of people adopting vegan and vegetarian diets has increased by 500% in the last 6 years (Joyce et al., 2012). Although vegetarian diets are usually rich in carbohydrates, n-6 fatty acids, dietary fiber, carotenoids, folic acid, vitamin C, vitamin E and Mg in terms of nutrients; it is relatively weak in protein, saturated fat, omega-3 fatty acids. Vegan diets are insufficient in terms of vitamin B_{12} and Ca. In studies with vegetarians and vegans, it has been observed that people who choose this diet have, on average, a low body mass index and low plasma cholesterol concentration (Le and Sabate, 2014).

3. MILK ALTERNATIVE INDUSTRIAL PLANTS

Soy

"Soy", one of the oldest agricultural plants in the world, has been used as a foodstuff for many years in the Far East (East Asia such as China, Manchuria, Vietnam and Korea). Developed western countries (Europe and America), which met with soy about 120-130 years ago, used soy as animal feed until the 1950s and started to include it in diets as human food after the 1950s. Thanks to improved techniques, soy has become a widely used raw material in pasta, biscuits, pastry, bread industry today. The soybean plant entered our country for the first time in the 1930s and its agriculture is mainly done in the Çukurova Region for today. Although it has not yet had the chance to spread in the field of consumption in our country, it is confronted with special use areas such as soy meat, minced meat, milk, cheese (tofu) (Gürsoy et al., 1999; Tekgezer, 2004; Nazlıcan, 2006; Karaçıl and Acar-Tek, 2013).

Due to the fact that the positive effects of soybeans on health have been revealed by scientific studies in recent years, there are increasing tendencies in developing functional new products to be added to traditional foods in whole or in part. Within these food products, soy drink has also become a common product as a healthy type of beverage (Godfrey, 2002; Prabhakaran and Perera, 2006; Özcan et al., 2015).

Due to the fact that it is very similar in the protein structure of animal foods and is the only plant with a similar proportion of protein, soybeans (Glysine max L. merrill) is called "boneless meat". Soybeans have become widespread to be processed as soy beverages and used as a source of protein in human nutrition. Soy drink is obtained by water extraction from soybeans and then by heat treatment to stop the activities of anti-nutrients (trypsin etc.) and to ensure food safety (Chen, 1987; Gürsoy et al., 1999,2000; Şahingöz and Arlı, 2022).

Generally, soy drink contains 8-10% total solids, depending on the water/bean ratio. 3.6% of this solid consists of protein, 2.9% of carbohydrates, 2.0% of fat and 0.5% of ash. Soy drink content compared to the content of cow's milk and breast milk, while it contains higher protein, iron, 16 unsaturated fatty acids and niacin; fat, carbohydrate and calcium amounts are lower. The fact that it does not contain cholesterol and lactose and contains 0.25 mg/g total isoflavones (over age weight) makes it an alternative to cow's and human milk (Liu, 1999,2004).

Soy drink is rich in isoflavones. Each glass of soy drink contains about 20 mg of isoflavones (mostly genistein and daidzein). There are no isoflavones in cow's milk. Isoflavones have many healthy effects, such as reducing cholesterol, relieving menopausal symptoms, preventing osteoporosis, and reducing the risk of certain cancers (prostate cancer and breast cancer). In countries with high consumption of soy products, including soy drinks, these cases of cancer are very low. Isoflavones are also antioxidants that protect our cells and DNA against oxidation (Kant and Brodway, 2015).

Soy protein is a complete protein. It contains all the essential amino acids that the body needs in the right proportion and amount to meet the growth, care and repair needs of cells. Soy protein is the only complete plant-based protein available to vegetarian and vegan lifestyle adopters and whose protein quality is equal to milk, meat, and egg proteins. According to WHO/FAO/UNU, the use of soy protein as a protein source in the daily diet maintains nitrogen balance in both children and adults by supporting normal muscle formation (Kant and Brodway, 2015). Glisinin (11S globulin) and β- konglisinin (7S globulin) are the most important soybean proteins. In some studies, the essential amino acid amounts of cow's milk and soy drink were compared. As a result, they found that soy milk had the amino acids necessary for the ideal standard protein, except for lysine and methionine+cystine amino acids (Hegazi et al., 1976). Soy drink contains most linoleic, oleic and palmitic fatty acids in its structure. Soy drink; It has a carbohydrate structure consisting of oligosaccharides such as sucrose, raffinose, stachyose from soybeans and hemicellulose such as araban and arabinogalacone (Gürsoy et al., 1999; Huang et al., 2008). Soy drink, which is prepared by extracting soy with water, offers a promising performance as a carrier of probiotics. It is also enriched in nutrients such as proteins, unsaturated fatty acids, lecithin, isoflavones, mineral substances, free amino acids and polypeptides, while it contains only a small amount of saturated fatty acids and does not contain cholesterol or lactose. Therefore, soy drink and fermented soy drink products are considered the most affordable substitute for cow's milk and an ideal nutritional supplement for the lactose intolerant population (Abou-Dobara, et al., 2016).

Soy drink is seen to be a very suitable raw material choice for the production of vegan cheese-like products with its properties such as not containing lactose, not causing allergic reactions such as cow's milk, high nutritional nature, not containing cholesterol and even reducing serum cholesterol levels.

Peanuts

Peanuts (Arachis hypogaea) are an important product worldwide that is in the legume family and is also called American nuts (Bonku and Yu, 2020). It is a rich source of essential fatty acids and antioxidants such as protein, fat, mineral, linoleic and oleic acid (Bansal et al., 2006; Arya et al., 2016; Bonku and Yu, 2020). It is stated that 100 grams of peanuts contain an average of 25.8 g of protein, 49.24 g of fat, 16.13 g of carbohydrates and 8.5 g of dietary fiber. Peanuts have a desirable lipid profile due to the fact that they are rich in unsaturated fatty acids, do not contain trans fatty acids and cholesterol by nature. It also has positive biological effects due to its high oleic acid content (Chenault et al., 2008; Suchoszek-Lukaniuk et al., 2011). In addition, it is also called functional food because it contains various functional components (Sim et al., 2012; Arya et al., 2016). Vitamin E in oil or chlorogenic acid, caffeic acid, coumaric acid, ferulic acid, flavonoids and stilbene (resveratrol) content are therefore antioxidant (Arya et al., 2016; Chenault et al., 2008; Akram et al., 2018). It is noted that peanuts contain resveratrol and resveratrol exert a prebiotic-like effect on the development of beneficial microflora such as *Lactobacillus* spp. when it reaches the large intestine (Peng et al., 2015). Recently, the use of peanuts as a source of cheap protein in people's diets has attracted attention. In addition to its traditional consumption as peanut butter or roasted peanuts, it is successfully evaluated as an ingredient in foods such as bakery products, soups and desserts, or in meat product formulations. In addition, after the fat extraction process, peanut powder is produced from the protein-rich (47-55%) by-product. In addition to its high protein content, peanut powder can be added to many foods due to its light taste and light color (Bansal and Kochhar, 2014). Peanuts, which are among the oilseeds, are used in the preparation of plant-based milk alternatives, but similar to soy drinks, the presence of bean flavor limits its use. Peanut drink is widely used in developing countries by the low-income group, malnourished children, vegetarians, and people who are allergic to cow's milk (Sethi et al., 2016). In the studies carried out, it is aimed to produce the best quality beverages by making different combinations and applications in milk alternative drinks prepared with peanuts. In order to have the best quality peanut drink, degreasing, roasting, alkaline soaking, steaming is applied. For an acceptable stability, various applications can be carried out, such as heating, homogenizing, adding stabilizers and adding emulsifiers. It has been observed that the stability of the product is greatly improved by heating at high temperature during homogenization (Sethi et al., 2016).

Hemp Seed

Hemp; Cannabis indica belonging to the family of *Cannabaceae*, *Cannabis sativa* and *Cannabis ruderalis* species called *Cannabis sativa* L. is a plant used as food, textile fiber and medicine for a long time. While the varieties *Cannabis sativa* and *Cannabis indica* are more economical and common, *Cannabis ruderalis* is considered a rarer variety characterized by a sparse, wild growth that grows in the Northern Himalayas region of the former Soviet Union and the southern states of the former Soviet Union (ElSohly et al., 2017). Developing new products by processing hemp seeds and conducting studies on the developed products are important for the spread of hemp seed products. On average, hemp seed consists of 35.5% oil, 24.8% protein, 27.6% dietary fiber, of which 5.4% is digestible and 22.2% is indigestible dietary fiber. It also contains 6.5% moisture and 5.6% ash. It is characterized by its high content of vitamins (A, C, E, B_1, B_2), minerals (phosphorus, magnesium, potassium, calcium, iron, sodium) and β-carotene content (Callaway, 2004). Hemp oil, hemp flour, hemp protein powder and hemp beverage produced from hemp seeds have healthy fatty acids composition, high protein content, amino acid profile and rich vitamin-mineral combination, as well as high sensory properties. In this context, the trend of using it as food and/or evaluating it in food processes has been on the rise (Doğan and Doğan, 2021).

In addition to these nutritional properties, hemp seeds are also rich in natural antioxidants, bioactive peptides, phenolic compounds, tocopherols, carotenoids and phytosterols. In addition to these beneficial components, hemp seeds also contain some antinutrient compounds that can negatively affect their nutritional value. Antinutrient components are biological compounds that reduce the bioavailability of nutrients in human or animal foods, reduce food intake, or lead to the release of toxic products in metabolism, thereby contributing to the deterioration of gastrointestinal and metabolic performance. In general, compounds such as saponins, phytic acid, alkaloids, certain oligosaccharides, protease inhibitors, cyanogenic glycosides, glucosinolates and tannins are conventionally included in this group. Antinutrient components reported in hemp seeds are phytic acid, trypsin inhibitors, concentrated tannins, cyanogenic glycosides and saponins (Farinon et al., 2020).

Sesame

The seeds of the sesame plant contain 50-60% fat and 25% protein. Its oil is a quality cooking oil with a high content of unsaturated fatty acids (47% Oleic + 39% Linoleic). Sesame, which has an important place in vegetable oil production in the world, has been limited as a cooking oil due to the fact that it is not economical in our country. Sesame produced in Asian countries where sesame production is intensively produced is widely considered as edible vegetable oil. In Turkey, it is widely used in the production of tahini and tahini halva and in the production of bakery products (Ümmetoğlu and Taşkın, 2015). Due to the antioxidant sesamol contained in the composition of sesame oil, sesame oil is stable and therefore has a long shelf life (Öztürk and Ova, 2010). Sesamol is due to compounds such as sesaminol that exert a strong antioxidant effect specific only to this oil. In addition, sesame lignans and tocopherols are the most important antioxidant compounds found in sesame oil. The most important characteristic feature of sesame oil is its resistance to oxidative degradation (Ünal, 2006).

When the nutritional values of sesame peel, which is an oilseed, were examined, it was determined that the fattiest acids contained were 43% oleic, 35% linoleic, 11% palmitic, 7% stearic acids while determining the composition of 10.2% protein, 12.2% fat, 23.4% ash, as well as the composition of these acids constituted 96% of the total fatty acids. It was concluded that sesame peel contains a high percentage of minerals with a calcium content of 10.5%, followed by potassium, magnesium and phosphorus. The total amount of dietary fiber in sesame peel was found to be 42%. The high amount of bioactive components and dietary fiber content of oilseed has accelerated the studies on their use in various food formulations in recent years (Öztürk and

Ova, 2010). Due to its nutritional, functional and health properties, there is great interest in developing new products from peeled sesame seeds. In this context, studies are carried out on the production of milk alternative beverages using sesame seeds and the quality of this drink (Quasem et al., 2009). The importance of seed source and pre-treatments applied to these seeds is quite high on the quality of drinks produced using sesame seeds. In the studies carried out, it has been reported that the stability and sensory properties of the milk alternative drink obtained from sesame are good, but it is still open to development. In particular, the effect of the amount of water used and the yield of the product on sensory characteristics is important (Afaneh et al., 2011a,b).

Research in sesame drink production has shown that steaming and alkaline soaking significantly improve the yield of total solids, and pasteurization increases dispersion stability. Roasting and alkaline soaking have been observed in sesame milk, which improves overall acceptability and flavor by reducing bitterness. Milk alternative sesame drink is commercially available under brands such as Ecomil (Spain), Vegemil (South Korea), etc. (Sethi et al., 2016).

Sunflower seed

Sunflower is an important oil plant in terms of vegetable crude oil production due to the high percentage of fat (22-55%) it contains (Arıoğlu et al., 2010). The crude protein content of whole and unshelled seeds ranges from 15 to 20%. The protein and fat content of the unshelled samples is higher than that of all seeds, since the fraction of the stems ranges from 16 to 45% of the seed weight and is mainly made of cellulose and lignine with low levels of fat and protein (Grompone, 2005). In unshelled samples in the range of 10.28 to 11.25%, a small reduction in crude fiber content and fiber is likely due to an incomplete peeling (Idriss, 2013). Sunflower seeds are the richest natural food source of vitamin E (31-35mg). A regular intake of sunflower will promote protection from aging, free radicals, and skin cell damage, as vitamin E is a powerful antioxidant. Also sunflower seeds are a good source of saturated fat (5g) and a good trace of omega-3 in the form of monounsaturated (9.5g) and polyunsaturated (33g), mainly omega-6, (30g). The protein content of sunflower seeds is complete in all essential amino acids and provides 23% protein and is the 10th best protein food with 58% utilization protein (NPU). As the minerals, especially magnesium (354 mg), with its copper value (1.8 mg), it is very good and vital for blood development, skin healing, nerve fiber protection and cartilage repair. For a great natural increase in vitamin B_1, sunflower seeds provide 2.3 mg plus B_2 (0.3 mg) and B_3 (4.5 mg). Anisimova et al., (2002), reported that sunflower is a rich source of soluble protein. An important advantage of sunflower protein products is that to date, no toxic components have been reported. Sunflower protein products do not contain lysine and isoleucine. However, they are rich in other essential amino acids, especially methionine and cystine (Idriss, 2013). Sunflower has a cream color and a relatively soft, walnut flavor under certain conditions. However, chlorogenic acid has become a fundamental barrier to its use in human foods, as this phenolic acid contributes to a gray color to cooked products and develops a green color under alkaline conditions (Fleming and Sosulski, 1977). For this reason, it is not possible to use it as a direct drink. However, due to their content, sunflower protein concentrates are considered as protein sources for mixtures in the production of milk alternative beverages. In a study, quality characteristics were determined by producing milk alternative beverages using hazelnuts, sunflower seeds and pumpkin seeds. Sunflower seeds have been shown to have an effect on the total phenolic content and DPPH activity of plant-based milk (Kuru and Sedimentary, 2020).

4. USE OF INDUSTRIAL PLANTS AS MILK ALTERNATIVES

Soy Beverage and Products

Despite the high nutritional value of soybean beverage, its bean-like taste and odor, which is not appreciated by our society, has been one of the most important problems affecting the commercial value of the product. In order to alleviate this problem to some extent, $NaHCO_3$ is added at a certain rate during the soy milk production stage or soy milk is mixed with cow's milk in certain proportions. It is reported that processes such as hot shredding, boiling, using defatted soy flour and protein isolate in soy beverage production, vacuum deodorization, using flavoring agents, soaking in low-concentration alkaline solutions, peeling, and high-temperature heat treatment of the obtained soy milk are reported to be the most effective methods (Kınık, 1992; Temiz and Hurşit, 2005). Soy drink can be used wherever cow's milk is used. It can be a refreshing drink with its plain or flavored variety. It is also used as a cholesterol-free and low-fat cream sauce and for making all kinds of dairy desserts. In countries where animal nutrition is difficult, soy drinks can be used instead of milk (Kesenkaş et al., 2013).

Al and Gr (2008) compared soy milk and beverages obtained from 75% soybean and 25% corn in their study. The obtained beverage samples were analyzed in terms of protein, moisture, ash, fiber and fat contents, microbiologically and sensory properties. Supplementation of soybean drink with corn drink did not cause any significant changes in microbial counts and profiles of soy-corn drinks. However, the addition of maize to soybeans for soy-corn beverage production significantly improved its taste, aroma, consistency and overall acceptability compared to soy beverage.

Astolf et al. (2020) compared cow, goat, donkey milk and plant-based milk alternatives in terms of major and minor elements. Soy, rice, oat, spelt, almond, coconut, hazelnut, walnut, cashew, hemp and quinoa beverages obtained from markets in Italy were used as plant-based milk alternatives. As a result of the analysis, 41 elements were determined in 43 different milk samples and their compositions were compared. According to the results obtained, it was observed that the levels of toxic trace elements such as As, Cd, Hg and Pb in animal and plant-based milk alternatives were very low in all samples analyzed and did not pose any threat to consumers. Only cow and goat milks were found to be important sources for the main minerals such as Ca, K, Mg, Na and P, while soy and coconut milks were found to be good sources of Mg. Hazelnut milk contains a significant amount of Na, while hemp milk has the highest Mo content. It has been observed that soy milk stands out as the closest vegetable milk alternative to cow or goat milk. Chalupa-Krebzdak et al. (2018) compared commercially available plant-based milk alternatives and cow's milk in terms of nutritional value. The protein content of plant-based milk alternatives varies considerably due to formulation differences between brands, even if they are produced from the same plant. The rice-based milk alternative had the lowest protein content with 0.28 g/100 mL, while the soy drink had the highest protein content with protein values ranging from 2.50 to 3.16 g/100 mL. The hemp-based milk alternative was found to have a protein content of 0.83 g/100 mL. In general, plant-based milk alternatives have been found to be low in protein. They may have beneficial fat content compared to bovine milk.

In a study using four different *Lactobacillus* species (*Lb. plantarum*, *Lb. brevis*, *Lb. johnsonii* and *Lb. delbrueckii* subsp. *bulgaricus*) to produce a symbiotic product based on soy beverages, lactic acid fermentation was used to produce a product with increased consumer acceptability. Inulin was used as a prebiotic component. Inulin concentrations ranging from 1% to 9% have been tested as probiotic bacteria promoters. The addition of inulin has proven to have a positive effect on the growth of lactic acid bacterial cultures in amounts up to 5% concentration. Fermented symbiotic inulin-fortified soy milk can be considered as a valuable product produced due to the cumulative effect of individual properties of inulin, soy beverage and probiotic bacteria. In addition, the fermented product was found to exhibit sensory qualities and rheological behavior similar to yogurt. However, the goal of obtaining a product with high sensory acceptability was not achieved. It has been noted that there still remains a challenge in the attempt to make the milk of soy drinks a valuable product in terms of sensory properties. In future research on fermented soy beverage, it has been suggested to use other natural raw materials such as muesli or fruit that may mask the unpleasant soy flavor (Iancu et al., 2010).

In recent years, researchs have focused on the elimination of off-taste and protein recovery in soy products. Although the bitter taste and bean-like odor of soybeans are acceptable to those living in Asia, many people cannot embrace this aroma (Scalabrini et al., 1998). The reason is that low molecular weight aldehydes formed during processing are tasteless. Removing these off-flavors from the product is imperative for the production of delicious product (Bordignon et al., 2004). Soybean beverage is used as drinking milk, but it can also be used in the production of some fermented and non-fermented dairy products. Soy yogurt comes first among these products. There are very few studies on the enzyme transglutaminase, which is used to prevent structure, texture and consistency defects seen in yoghurts produced with soy drink (Gürsoy et al., 1999).

Soy yogurt comes to mind at the beginning of the products produced by fermenting soy drinks with some lactic acid bacteria. However, difficulties are experienced in the production of traditional yoghurt due to the components consisting of sucrose, raffinose and stachiose, as well as the components of arabin and arabinogalact in the soy beverage. Therefore, structure, consistency and aroma defects are observed in yoghurts obtained from soy drinks. In order to eliminate these defects, it is tried to increase the acceptability of the products by conducting research on the types of bacteria used in fermentation, the mixing of other animal milks with certain proportions of soybean drink, the use of enzymes, the use of fruit extracts and aromas (Gürsoy et al. 1999). In a study examining the fermentation of soybean drink with *Bifidobacterium longum* and *Bifidobacterium bifidum* cultures, reconstituted fat milk containing 12% dry matter was mixed with 20, 40, 60, 80 and 100 percent soy milk and soy yoghurt was produced. It has been reported that yoghurts containing 20% soy drink have the closest values to the control among the samples produced. The amount of acetaldehyde in the mentioned sample was found to be 1.6 times higher than the control, and it was determined that this situation plays an important role in masking the soy flavour (Kamaly, 1997). Many researchers such as Özbey et al., 2007; Kwok et al., 1998; Chou and Hou (2000), Valdez and Giori (1993) Kamaly (1997) have worked on probiotic yogurt produced using soy beverages. A study examining the developmental differences of *L. acidophilus* in soy milk and cow's milk was carried out by Valdez and Giori (1993). Milk alternatives were fermented using *S. thermophilus*, *L. acidophilus* and *L. casei*. While the presence of *L. casei* had no effect on *L. acidophilus*, it was found to have an inhibitory effect on the growth of *S. thermophilus*. In addition, it was determined that *L. acidophilus* showed better growth in soy milk at the end of the fermentation and 21-day storage period. For this reason, it has been reported that soy drinks can be used in the production of probiotic yogurt.

Tofu which is one of the products produced from soy drinks; It is a white creamy colored, soft and smooth cheese obtained by precipitating the soy drink prepared by water extraction from soybeans with coagulants such as calcium sulfate, magnesium sulfate and glucano delta lactone and filtering this precipitate in bags. Consumption of tofu as a popular food is common, especially in Far East countries such as India, China, and Japan (Wang, 1986a; Kınık and Akbulut, 1994; Ötleş; 1998). The heat treatment applied to the soy beverage to be used in the production of tofu is necessary not only for protein denaturation and clot formation, but also to improve its nutritional value and reduce undesirable aroma. Besides this cheese, there are many cheeses and cheese-like products produced by using soy drink (or by creating different combinations with cow's milk).

Peanut Beverage and Products

Although food allergy can be seen in all kinds of food in general, some foods in particular constitute approximately 90% of allergic reactions. Various techniques such as physical (heat, radiation and high pressure applications), chemical (glycosylation, magnetic bead adsorption and acid application) and biological methods (microbial fermentation, enzyme catalysis and genetic engineering) can be applied to reduce the allergenicity of peanuts. These applied techniques should create the necessary infrastructure and transfer them to the food industry, which works with foods containing allergens. In addition, allergen warnings must be made in the production, sales and mass consumption of allergen-containing foods such as peanuts, and allergen-sensitive individuals are encouraged to carefully examine the allergen warnings in the product label information (Kesenkaş et al., 2013; Ötleş and Çağındı, 2003).

Since the early 1950s, various ways have been developed by researchers to produce peanut drink products and derivatives (Diarra et al., 2005). In 1950, a way to produce stable hazelnut emulsions was developed as a finely obtained mixture of peanut flour and water. However, the stability of the emulsions could not be maintained for a long time, the part called milk collapsed and they tried to develop it with edible emulsifiers (Jasper 1973). Peanut drink can be obtained by mixing raw peanuts and water as yellow mud for 30 minutes. Researchers followed the same path for peanut drink production over time, but always led to improving the peanut drink production process for peanut drink production. Dora Armstrong made the peanut drink similarly, but then the deodorization was followed by a bubbling stream through it (Lee and Beuchat 1992). According to this study, the following steps are followed; Dry-blank peanut kernels and soak in 0.5% sodium bicarbonate for 18 hours, drain and rinse with tap water, add 2:1 water (water: peanut), heat treat at 100°C for 10 minutes, add 5:1 water (water: peanuts) and grinding in a colloid mill. Straining, homogenization and heat treatment with three layers of cloth. Until now, peanut drink, which is a cheap and nutritional supplement, has been transformed into fermented products such as buttermilk, yogurt and cheese (Lee and Beuchat 1992).

Fermentation of peanut drink has several advantages; Fermented products have better chemical and sensory properties than unfermented products. In addition, hexanal, the compound responsible for the undesirable bean flavor and significant production of acetaldehyde in the peanut beverage, is destroyed by fermentation. Also, fermentation significantly reduces sulfur. As a result of fermentation, the bitter taste of beans decreases and the sour, creamy taste increases (Lee and Beuchat 1992). In this regard, fermentation can increase peanut consumption and thus improve protein availability (Sunny-Roberts et al., 2004).

Yogurt obtained from peanut drink was also prepared by Isanga and Zhang (2009) and developed a method of preparing peanut drink yogurt. Briefly, the following steps are followed in the method; The shells of the peanuts were removed by soaking in 0.5 g/100 mL $NaHCO_3$ for 12 hours. After washing with water, the kernels were mixed with water at a ratio of 1:5 [peanuts (g) : water (mL)] and mixed for 5 minutes. The slurry was filtered through three-layer cheesecloth to obtain peanut drink. 4 g/100 mL skimmed milk powder was added to peanut drink and mixed, and the beverage was heated at 43°C. 7 g/100 mL of sucrose was added to the beverage as a sweetener. Then homogenization and pasteurization were done. It was cooled to 43◦C and inoculated with 3 mL/100 mL starter cultures (L. bulgaricus and *S. thermophilus*; 1:1) and incubated at 43 ◦C for 4-5 hours. The main conclusion of the researchers was that adding glucose (2%) to pasteurized peanut beverage before fermentation with *Lactobacillus bulgaricus* NRRL B1909 and suggested that it should be supplemented with powdered milk because it improves its properties (Diarra, Nong, and Jie 2005).

In the production of kefir using peanut drink; 60% peanut drink and 40% diluted skim milk powder were mixed at 12% and 3% (w/v) sucrose was added. Homogenisation, pasteurization and inoculation with culture at approximately 25°C followed by fermentation at 24°C for 18 hours (Isanga and Zhang, 2009; Bensmira and Jiang, 2011).

Hemp seed beverage and products

As an industrial plant food source, both hemp and hemp products are rich sources of protein and polyunsaturated fat, as well as significant amounts of vitamins and beneficial minerals. One of the most important of these, α-tocopherol, is the only form of vitamin E that meets human requirements (Leizer et al., 2000). Hemp is also a very important source of Phosphorus, Potassium, Magnesium and Calcium. Hemp seed drink is made by homogenizing ground seeds in water (1:5 w/v) and the filtered beverage is often heat treated for long shelf life (Mitchell and Shammet, 2008; Wang et al., 2018). Studies on hemp seed drinks are very limited and insufficient considering the studies on similar plant milk alternatives. The production of commercially stable hemp seed drink is challenging as hemp seed drink as an oil-in-water (O/W) emulsion is unstable and prone to agglomeration, coalescence and cream formation. This will result in a low quality product with a shorter shelf life and lower consumer acceptance (Wang et al., 2018). With the increasing interest in hemp, hemp products are also being researched. As a plant-based milk alternative, hemp beverage represents a stand-alone food, as well as being used as a basic raw material in the production of many foods (coffee, tea, smoothies, ice cream, confectionery, confectionery) and is also included in other types of products (yogurt, cheese, butter, cakes, sweets) may have more purchase potential than Comparing the nutritional composition is not easy, as plant-based drinks are enriched with different ingredients.

The hemp seed drink contains 0.4 g/100 mL of alpha linoleic acid, an omega-3 fatty acid. However, the hemp drink does not contain other essential omega-3 fatty acids such as EPA and DHA. Plant-based milk alternatives in general, lower protein and calcium content, higher glycemic index values, and presence of potential non-nutritional compounds make plant-based milk alternatives nutritionally inferior to cow's milk (Chalupa-Krebzdak et al., 2018).

The low allergenicity and high nutritional value of hemp seed milk make it a good alternative to milk, soy, peanut and milk substitutes. In addition, being a rich source of polyunsaturated fatty acids increases its importance in terms of health. The hemp beverage is an oil-in-water emulsion, which is a major problem in the industry as such emulsions are highly unstable and tend to clump and coalesce, resulting in loss of quality and shelf life. To resist this situation, emulsifiers or stabilizers are generally used. To overcome this problem, high pressure homogenization method is applied. The homogenization pressure determines the mechanical energy applied to separate the oil droplets and form new interfaces (Paul et al., 2019; Wang et al., 2018). Wang et al. (2018), pH change and homogenization processes were applied to hemp drink containing 4% protein and 5% oil, and increasing the homogenization pressure (up to 60 MPa) caused a more homogeneous distribution of emulsion droplets. Hemp drink produced by applying combined pH shift and HPH (60 MPa) was found to be quite stable, showing negligible phase separation within 3 days of storage at 4 °C. On the other hand, a significant reduction in microbial population was observed in cannabis beverages prepared with pH shift along with HPH. The results show that the combination process of pH change and HPH can potentially be used for the production of hemp drink without heat treatment.

Hemp seed drink is one of the important seed-based milk alternatives and is produced from industrial hemp. As mentioned earlier, the demand for plant-based milk is increasing day by day, but demand for hemp seed milk is insufficient and limited due to a lack of information and a generally negative attitude towards distinguishing between hemp and other cannabis strains. Prejudice against hemp products has been eliminated by studies in which THC (tetra-hydrocannabinol) analyzes cannabis products available in the market. The main purpose of this study is to have an overview of the nutritional components and nutritional qualities of hemp seed milk, to compare the properties of hemp seed drink with other plant-based milk alternatives and cow's milk, and also to discuss the methods and techniques used in hemp drink.

Zparaga et al. (2019) investigated whether cannabis beverage is a suitable food matrix for probiotic bacteria. It was determined that the fermentation process with *Lactobacillus casei* subsp. *rhamnosus* (at 37°C for 6 hours) continued. Bartkiene et al. (2019) produced cannabis beverages by fermenting hemp seed paste emulsion with different microorganisms (*Pediococcus acidilactici* LUHS29, *P. pentosaceus* LUHS183, *Lactobacillus casei* LUHS210 and *L. uvarum* LUHS245 strains) and also applying ultrasonication. They suggested that hemp seed drinks with more stable emulsion and the highest overall acceptability (9.6 points) could be obtained using the *L. uvum* LUHS245 strain and the ultrasonication process. Nissen et al. (2020) produced innovative prebiotic and probiotic plant-based beverages based on hemp seeds and the fermentation process. In this study, new formulations of commercial cannabis seed derived beverage to be fermented with probiotics (*Lactobacillus fermentum*, *Lb. plantarum* and *B. bifidum*) were created. To meet the demand for alternative and possibly healthier new matrices, they mixed hemp seed milk with some other plant-based milks (soy and rice milk). Chichowska et al. (2002) showed that hemp seed milk led to a significant reduction in triglycerides and cholesterol blood content of intragastric treated rats.

Sunflower and sesame beverage and products

There are very limited studies on milk alternatives produced using sunflower and sesame. Fleming and Soluski (1977) evaluated their potential use in milk-like beverages using sunflower protein concentrates (SFC) produced by aqueous diffusion of crushed seeds. Sunflower protein concentrates were used as protein sources for milk alternatives mixes. Mixing SFC with cow's milk also improved N solubility. An equal mix of SFC with milk had a low color and flavor profile and was equivalent in chemical score to a soy milk mix. Kuru and Tontul (2020) aimed to optimize a blended plant-based milk formulation produced using hazelnut, sunflower seeds and pumpkin seeds through blend design. The highest DPPH radical scavenging activity was determined in the plant-based milk sample produced using 100% sunflower seeds, but negative color and sensory properties were detected in the samples due to sunflower.

According to Quasem et al. (2009) conducted a study on the effect of pretreatment of sesame seeds and the effect of sesame seed source on the quality of the produced beverage in a study in which a basic procedure for the production of sesame drink was proposed. Sesame drink had acceptable dispersion stability and sensory properties, but stressed that the quality of sesame drink should be further improved. Several studies have reported the importance of controlling the ratio of vegetables to water in order to optimize yield and sensory acceptability. Afeneh et al. (2011a) proved that the initial sesame seed concentration and heat treatment of sesame beverage had a significant effect on sesame drink yield and sensory properties. The results showed that the best sesame seed concentration was 12% and the best heat treatment norm was 5 minutes at 85°C. Sesame seed concentration and heat treatment of sesame drink had a significant effect on the dispersion stability and sensory properties of sesame milk. On the other hand, Afeneh et al. (2011b) examined the possibility of producing yoghurt using sesame milk. Sesame milk did not have the gelling ability necessary for gel formation. The addition of dairy products (especially NFDM and dried whey) was necessary to stimulate acid and flavor production during fermentation of sesame milk with yogurt culture. Fermentation time played a role in determining the acceptability of the produced yoghurt and further studies are needed to evaluate the protein quality of the produced products and to investigate the effect of different processing conditions on it, and to determine the factors affecting the gelation of sesame drink proteins and to evaluate the effect of using different starter cultures on the quality of the product.

5. CONCLUSION AND FUTURE PERSPECTIVES

Among the beverages, milk is considered a healthy food, providing balanced proportions of macro (fat, proteins, and carbohydrates) and micronutrients (calcium, selenium, riboflavin, vitamin B_{12} and pantothenic acid, vitamin B_5). In some parts of the world, access to milk, therefore some minerals (iron), vitamins (folate), and other biomolecules (amino acids) in milk is limited. Non-dairy beverage consumption has increased due to health concerns such as the low level of some components in milk, the desire to limit animal foods, milk allergy, lactose intolerance and hypercholesterolemia. The market for plant-based milk alternatives is currently soybean, peanut, oat, coconut, hemp, cocoa, multigrain plant milk alternative, etc. predominates and most of them are produced by controlled fermentation due to their functional bioactive composition. THowever, it has also been tried in new food matrices such as meat, baby food, ice creams, juices, and cereals. In this sense, plant beverages will have great market potential due to the increasing awareness of cow's milk allergy and intolerance and the demand for healthy non-dairy products. In addition, it is aimed to preserve the number of probiotic microorganisms in the final product, thanks to the prebiotics added to the herbal milk alternatives.

6. REFRENCES

Abou-Dobara, M.I., Ismail, M.M., Refaat, N.M. (2016). Chemical composition, sensory evaluation and starter activity in cow, soy, peanut and rice milk. *J Nutr Health Food Eng* 5(3):634–640.

Afaneh, I.A., Abu-Alruz, K., Quasem, J.M., Sundookah, A., Abbadi, J., Alloussi, S., Sawalha, S. (2011a). Effect of critical processing variables on sesame milk quality. *American Journal of Agricultural and Biological Sciences*, 6(4): 517-520.

Afaneh, I.A., Abu-Alruz, K., Quasem, J.M., Sundookah, A., Abbadi, J., Alloussi, Z. Ayyad, S. (2011b). Fundamental elements to produce sesame yoghurt from sesame milk. *American Journal of Applied Sciences* 8(11): 1086-109

Akbulut, N., Kınık, Ö. (1991). Soya Sütünün Dondurma Üretiminde Kullanım Olanakları Üzerine Bir Araştırma. *Ege Üniversitesi Mühendislik Fakültesi Dergisi Seri: B Gıda Müh* 9(2): 1-13.

Akın N., Gündüz, A., Konak Ç. (2012). Teknolojik Açıdan Süt Ürünlerinde Laktoz Dönüşümleri ve İntoleransı. *Akademik Gıda* 10(4): 77-84.

Akram, N. A., Shafiq, F., Ashraf, M. (2018). Peanut (Arachis hypogaea L.): A Prospective Legume Crop to Offer Multiple Health Benefits Under Changing Climate. *Comprehensive Reviews in Food Science and Food Safety*, 17(5): 1325–1338.

Al, K., Oladimeji, G.R. (2008). Production and quality evaluation of soy-corn milk. *Journal of Applied Biosciences 1*(2): 40-45.

Arıoğlu, H.H., Kolsarıcı, Ö., Göksu, A.T., Güllüoğlu, L., Arslan, M., Çalışkan, S., Söğüt, T., Kurt, C., Arslanoğlu, F. (2010). Yağ bitkileri üretiminin artırılması olanakları. Türkiye Ziraat Müh. Bir. VII. Teknik Kong. Bildiri Kitabı I.: 361-377. Ankara.

Arya, S. S., Salve, A. R., Chauhan, S. (2016). Peanuts as functional food: a review. *Journal of Food Science and Technology*, 53(1): 31–41.

Astolfi, M.L., Marconi, E., Protano, C., Canepari, S. (2020). Comparative elemental analysis of dairy milk and plant-based milk alternatives. *Food Control* 116: 107327.

Aydar, E.F., Tutuncu, S., Özcelik, B. (2020). Plant-based milk substitutes: Bioactive compounds, conventional and novel processes, bioavailability studies, and health effects. *Journal of Functional Foods* 70:103975.

Bansal, P., Kochhar, A. (2014). Sensory and nutritional evaluation of value added products using potato flour for nutritional and health benefits. *International Journal of Agriculture Innovations and Research*, *3*(1): 1–6.

Bansal, S., Mangal, M., Sharma, S. K., Yadav, D. N., Gupta, R. K. (2016). Optimization of process conditions for developing yoghurt like probiotic product from peanut. *LWT - Food Science and Technology* 73: 6–12.

Bartkiene, E., Zokaityte, E., Lele, V., Sakiene, V., Zavistanaviciute, P., Klupsaite, D., Bendoraitiene, J., Navikaite-Snipaitiene, V., Ruzauskas, M. (2019). Technology and characterisation of whole hemp seed beverages prepared from ultrasonicated and fermented whole seed paste. *International Journal of Food Science & Technolog*y 55(1): 406-19.

Bensmira, M., Jiang, B. (2011). Organic Acids Formation during the Production of a Novel Peanut-Milk Kefir Beverage. *British Journal of Dairy Sciences* 2(1): 18–22.

Bode, S., Gudmand-Hoyer, E. (1988). Incidence and Clinical Significance of Lactose Malabsorption in Adult Celiac Disease. *Scand J Gastroenterol*. 23:484-488.

Bonku, R., Yu, J. (2020). Health aspects of peanuts as an outcome of its chemical composition. *Food Science and Human Wellness* 9(1): 21–30.

Bordignon. J.R., Kazuhiko N., Tadashi Y., Sayuki N. (2004). Hydrolysis of isoflavone and consumption oligosaccharides during lactic acid fermentation of soybean, Food and Technology Division, Japan International Research Center for Agricuture Sciences (JIRCAS), Tsukuba, Ibaraki 305-8686, Japan

Callaway, J. (2004). Hempseed as a nutritional resource: An overview. *Euphytica*, 1401, 65-72.

Chalupa-Krebzdak, S., Long, C. J., Bohrer, B.M. (2018). Nutrient density and nutritional value of milk and plant-based milk alternatives. *International Dairy Journal* 87: 84– 92.

Chen, S. (1987). Soymilk Without Beany Flavor. *Food Manufacture* 3(2):31-32.

Chenault, K. D., Ozias-Akins, P., Gallo, M., Srivastava, P. (2008). Peanut. In C. Kole & T. C. Hall (Eds.), Compendium of Transgenic Crop Plants: Transgenic Oilseed Crops (pp. 169–198). Blackwell Publishing Ltd.

Chichowska, J., Kliber, A., Kozowska, J., Biskupski, M., Grygorowicz, Z. (2002). Thyroid hormone and metabolic changes after treated rats with hemp milk. http://www.hempreport.com/pdf/HempMilkStudy%5B1%5D.pdf

Chou, C.C., Hou, J.W. (2000). Growth of bifidobacteria in soymilk and their survival in the fermented soymilk drink during storage. *International Journal of Food Microbiology* 56(2-3): 113-21.

Diarra, K., Guo Nong, Z., Jie, C. (2005). Peanut Milk and Peanut Milk Based Products Production: A Review. *Critical Reviews in Food Science and Nutrition* 45(5): 405–23.

Dogan, N., Dogan, C. (2021). Mucizevi Bitki Kenevir'in (Cannabis sativa L.) Gıda Endüstrisinde Kullanımı. *Bozok Veterinary Sciences*, 2(2), 47-56.

ElSohly, M.A., Radwan, M.M., Gul, W., Chandra, S., Galal, A. (2017). Phytochemistry of Cannabis sativa L. *Progress in the Chemistry of Organic Natural Products* 103: 1–36.

Erk, G., Seven, A., Akpınar, A. (2019). Feature of Plant-Based Probıotıc Dairy Products in Vegan and Vegetaııan Nutrition. *The Journal of Food* 44 (3): 453-462.

European Commission. Council Regulation (EC) No 1234/2007 of 22 October 2007 establishing a common organisation of agricultural markets and on specific provisions for certain agricultural products (Single CMO Regulation). http://data.europa.eu/eli/reg/2007/1234/oj. Published 2009.

Farinon, B., Molinari, R., Costantini, L., Merendino, N. (2020). The seed of industrial hemp (Cannabis sativa l.): nutritional quality and potential functionality for human health and nutrition. *Nutrients* 12: 1–60.

Fleming, S.E., Sosulski, F.W. (1977). The utilization of sunflower protein in milk-like beverages. *Canadian Institute of Food Science and Technology Journal* 10(4): 229-232

Godfrey P. Soy Products as Ingredients- Farm to the Table. *Innov Food Technol.* 14:10-13.

Grompone, M.A., (2005). Sunflower oil. In: Shahidi, F. (ed.) Bailey's Industrial Oil & Fat Products. Volume 2, Edible Oil & Fat Products. Edible oil. 6th Ed.

Gürsoy, O., Gökçe R. (2001). Soya ve Ürünlerinde Fenolik Bileşikler ve Beslenmeyi Kısıtlayıcı Faktörler. *Pamukkale Ünv Müh Bil Derg.* 7(1):87-93.

Gürsoy, O., Gökçe, R., Kınık Ö. (1999). Beslenmede Yeni Yaklaşımlar: Soya Sütü ve Ürünleri. *Pamukkale Üniversitesi Mühendislik Bilim Derg.* 2(3):1123-1130.

Gürsoy, O., Gökçe, R., Kınık, Ö. (1999). Beslenmede Yeni Yaklaşımlar: Soya Sütü ve Ürünleri. *Pamukkale Üniversitesi Mühendislik Fakültesi Mühendislik Bilimleri Dergisi* 5(2): 1123-1130.

Hegazi, S.M., Gabrial, G.N., Taha, R.A., Shehata, O. (1976). Comparative Studies on Some Leguminous Protein Sources and Soybean Proteins. *Z Ernahrungswiss* 15(2):177-181.

Huang, Y., Schoonmaker, J.P., Bradford, B.J., Beitz, O.C. (2008). Response of Milk Fatty Acid Composition to Dietary Supplementation of Soy Oil, Conjugated Linoleic Acid, or Both. *J Dairy Sci.* 91(1):260-270.

Iancu, C., Barbu, V., Nicolau, A., dan Iordachescu, G. (2010). Attempts to obtain a new symbiotic product based of soy milk. *Journal Innovative Romanian Food Biotechnology* 7: 21-29.

Idriss, R.M. (2013). Development Of Lactose-Free Mılk Analogue Based On Sunflower Seed Kernel. M.Sc. Thesis, Ahfad University for Women School of Health Sciences M.Sc. in Human Nutrition, Sudan.

Isanga, J., Zhang, G-N. (2009). Production and Evaluation of Some Physicochemical Parameters of Peanut Milk Yoghurt. *LWT - Food Science and Technology* 42(6): 1132–38.

Jasper, G.W. (1973). Peanuts: Production, processing products. Published by The Ave Publishing Company, Inc., Westport, Connecticut, 2: 266–269.

Jeske, S., Zannini, E., Arendt, E.K. (2017). Evaluation of Physicochemical and Glycaemic Properties of Commercial Plant-Based Milk Substitutes. *Plant Foods Hum Nutr.* 72(1):26-33.

Jeske, S., Zannini, E., Arendt, E.K. (2018). Past, present and future: The strength of plant-based dairy substitutes based on gluten-free raw materials. *Food Research International* 110:42–51.

Kamaly, K.M. (1997). Bifidobacteria fermentation of soybean milk. *Food Research International*, 30(9): 675–682

Kant, R., Brodway, A.A. (2015). The Benefits of Consuming Soya Milk-A Review. *Trends Biosci.* 8(5):1159-1162.

Karabudak, E. Vejetaryen Beslenmesi. *Sağlık Bakanlığı Yayını*. 2012; 7:8.

Karaçıl, M.Ş. ve Acar Tek N. (2013). Dünyada Üretilen Fermente Ürünler: Tarihsel Süreç ve Sağlık ile İlişkileri. *UÜ Ziraat Fakültesi Derg.* 27(2):163-173.

Kesenkaş, H., Akbulut, N., Yerlikaya, O., Akpınar, A., Açu, M. (2013). Kefir dondurması üretiminde soya sütünün kullanim olanakları üzerine bir araştırma. Ege Üniversitesi Ziraat Fakültesi Dergisi 50(1): 1-12.

Kesenkaş, H, Dinkçi, N, Seçkin, K. (2011) Antioxidant properties of *kefir* produced from different cow and soya milk mixtures. *Tarım Bilimleri Dergisi* 17: 253–259.

Kınık, Ö. (1992). Bazı Süt Mamullerinin Üretiminde Soya Sütünden Yararlanma Olanakları Üzerinde Araştırmalar. Doktora Tezi. Ege Üniv. Fen Bil. Enst. Süt Tek. A.B.D., Bornova, İzmir.

Kınık, Ö., Akbulut, N. (1994). Aromalı Yoğurt Üretiminde Soya Sütünden Yararlanma Olanakları Üzerinde Bir Araştırma. *Ege Üniversitesi Ziraat Fakültesi Dergisi* 31(2-3): 131-138.

Kınıkoğlu, M. Vegan Beslenme. 1. Baskı. İstanbul: Oğlak Yayıncılık; 2015.

Kneepkens, C. F MY. (2009). Clinical Practice. Diagnosis and Treatment of Cow's Milk *Allergy. Eur J Paediatr.* 168(8):891-896.

Kuru, C., Tontul, I. (2020). Optimisation of Plant-based Milk Formulation using Hazelnut, Sunflower Seed and Pumpkin Seed by Mixture Design. *Turkish Journal of Agriculture - Food Science and Technology* 8(11): 2441-2448.

Kwok, K.C., Shiu, Y.W., Yeung, C.H., Niranjan, K. (1998). Effect of thermal processing on available lysine, thiamine and riboflavin content in soy milk. *Journal of Science Food and Agriculture* 77(4): 473-478.

Larsson, C.L., Rönnlund, U., Johansson, G., Dahlgren, L. (2003). Veganism as Status Passage: The Process of Becoming a Vegan Among Youths in Sweden. *Appetite* 41(1):61-67.

Lee, C., Beuchat, L.R. (1992). Chemical, Physical and Sensory 88 Characteristics of Peanut Milk as Affected by Processing Conditions. *Journal of Food Science* 57(2): 401–5.

Leitzmann, C. (2014). Vegetarian Nutrition: Past, Present, Future. *Am J Clin Nutr.* 100:496-502.

Leizer, C., Ribnicky, D., Poulev, A., Dushenkov, S., Raskin, I. (2000). The composition of hemp seed oil and ıts potential as an ımportant source of nutrition. *Journal of Nutraceuticals, Functional & Medical Foods*, 2(4):

Lindmark-Mansson, H., Akesson, B. (2000). Antioxidative factors in milk. *Br J Nutr.* 84 Suppl 1:103-110.

Liu, K. (1999). Soybeans Chemistry, Technology, and Utilization. Aspen Publ. Gaithersburg, Maryland; 1999.

Liu, K. (2004). Soybean as Functional Foods and Ingredients. AOCS Press. Champaign, IL, USA.; 2004.

Mann, S.E. (2014). More Than Just a Diet: An Inquiry into Veganism. Anthropol Sr Theses. University of Pennsylvania, USA.

Metin, M. (2005). Süt Teknolojisi, Sütün Bileşimi ve İşlenmesi. E.Ü. Mühendislik Fakültesi Yay. No: 33. Ege Üniversitesi Basımevi. Bornova-İzmir.

Miller, G.D., Jarvis, J.K., McBean, L.D. (2000). Handbook of Dairy Foods and Nutrition. National Dairy Council. Second edition

Mitchell, R., Shammet, K.M. (2008). Hemp food product base and processes. Patent No: US20080241339A1

Nazlıcan, A.N. (2006). Soya Yetiştiriciliği. www.cukurovataem.gov.tr/ Soya%20 Yetistiriciligi-WEB.pdf. 2006.

Nissen, L., di Carlo, E., Gianotti, A. (2020). Prebiotic potential of hemp blended drinks fermented by probiotics. *Food Research International*, 131: 109029.

Onurluba,ş E., Çakırlar, H. (2016). Tüketicilerin süt ve süt ürünleri tüketimini etkileyen faktörlerin belirlenmesi üzerine bir araştırma. *Çankırı Karatekin Üniversitesi SBE Dergisi*, 7(1): 217-242.

Ötles, S., Cağındı, Ö. (2003). Kefir: A Probiotic Dairy-Composition, Nutritional and Therapeutic Aspects. *Pakistan Journal of Nutrition*, 2(2): 54-59.

Ötleş, S. (1998). Tofu'nun Bileşimi ve Önemi. *Gıda ve Teknoloji* 3(1): 86-90.

Özbey, F., Topçu, A., Saldamlı, İ. (2007). Probiyotik yoğurt üretiminde soya sütü kullanımının yoğurdun kimyasal ve duyusal özellikleri üzerine etkisi. *Gıda* 32(1): 3-11

Özcan, T., Delikanlı, B. ve Akın Z. (2015). Soya Biyoaktif Bileşenleri ve Sağlık Üzerine Etkisi. *Türk Tarım-Gıda Bilim ve Teknoloji Dergisi* 3(6), 350-35.

Öztürk, E., Ova, G. (2010). Yağlı Tohum Kabuklarının Biyoaktif Bileşen Potansiyeli ve Gıdalarda Kullanımı, *Akademik Gıda* 15(3), 315-321.

Paul, A.A., Kumar, S., Kumar, V., Sharma, R. (2020). Milk Analog: Plant based alternatives to conventional milk, production, potential and health concerns. *Critical Reviews in Food Science and Nutrition* 60(18): 3005-3023

Peng, M., Bitsko, E., Biswas, D. (2015). Functional properties of peanut fractions on the growth of probiotics and foodborne bacterial pathogens. *Journal of Food Science*, *80*(3), 635–641.

Pereira, P.C. (2014). Milk nutritional composition and its role in human health. *Nutrition, 30*: 619–627.

Petti et. al. Vegetarianism and veganism: Not Only Benefits but Also Gaps. A Review. *Prog Nutr.* 19:229-242.

Prabhakaran, M.P., Perera, C.O. Effect of Extraction Methods and UHT Treatment Conditions on the Level of İsoflavones During Soymilk Manufacture. *Food Chem*. 99:231-237.

Quasem, J.M., Mazahreh, A.S., Abu-Alruz, K. (2009). Development of vegetable based milk from decorticated sesame (sesamum indicum). *American Journal of Applied Science* 6: 888-896.

Röös, E., Garnett, T., Watz, V. and Sjörs, C. (2018). The role of dairy and plant based dairy alternatives in sustainable diets. SLU Future Food Reports 3, London

Scalabrini, P., Rossi, M., Spettoli, P., Matteuzzi, D. (1998). Characterization of Bifidobacterium strains for use in soymilk fermentation. *International Journal of Food Microbiology* 39: 213–221

Sethi, S., Tyagi, S.K., Anurag, R.K. (2016). Plant-based milk alternatives an emerging segment of functional beverages: A review. *Journal of Food Science and Technology* 53(9):3408–3423.

Silva, J.G.S., Rebellato, A.P., Caramês, ET dos S., Greiner, R., Pallone, J.A.L. (2020). *In vitro* digestion Effect on Mineral Bioaccessibility and Antioxidant Bioactive Compounds of Plant-Based Beverages. *Food Res Int.* 130(January):108993

Sim, E. W., Lai, S. Y., Chang, Y. P. (2012). Antioxidant capacity, nutritional and phytochemical content of peanut (Arachis hypogaea L.) shells and roots. *African Journal of Biotechnology*, *11*(53), 11547–11551.

Sobiecki, J.G., Appleby, P.N., Bradbury, K.E., Key, T.J. (2016). High compliance with dietary recommendations in a cohort of meat eaters, fish eaters, vegetarians, and vegans: results from the European Prospective Investigation into Cancer and Nutrition Oxford study. *Nutr Res*, 36: 464-477.

Son, G.Y., Bulut, M. (2016) Yaşam tarzı Olarak Vegan ve Vejetaryenlik. *Int J Hum Sci.* 13(1):830-843.

Suchoszek-Łukaniuk, K., Jaromin, A., Korycińska, M., Kozubek, A. (2011). Health Benefits of Peanut (Arachis hypogaea L.) Seeds and Peanut Oil Consumption. In Nuts and Seeds in Health and Disease Prevention (pp. 873–880).

Sunny-Roberts, E., Otunola E.T., Iwakun, B.T. (2004). An Evaluation of Some Quality Parameters of a Laboratory-Prepared Fermented Groundnut Milk. *European Food Research and Technology* 218(5): 452–55.

Swagerty, D.L., Walling, A.D. (2002). Lactose Intolerance. *Am Fam Physician.* 65(9):1845-1850.

Szparaga, A., Tabor, S., Kocira, S., Czerwińska, E., Kuboń, M., Płóciennik, B., Findura, P. (2019). Survivability of probiotic bacteria in model systems of non-fermented and fermented coconut and hemp milks. *Sustainability*, 11(21): 6093.

Şahingöz, S., Arlı M. (2002). Bireylerin Soya Fasulyesi ve Ürünleri Konusundaki Bilgileri, Bu Ürünleri Tanıma ve Tüketim Düzeyleri. *Gazi Üniversitesi Endüstriyel Sanatlar Eğitim Fakültesi Dergisi* 10:57-70.

Tekgezer, D. (2004). Bazı Soya Ürünlerinin Antioksidan Kapasitelerinin ve Protein İçeriklerinin Belirlenmesi. Yüksek Lisans Tezi, İstanbul Üniversitesi, Fen Bilimleri Enstitüsü, Kimya Anabilim Dalı, İstanbul.

Temiz, H., Hurşit, A.K. (2005). İnek ve Soya Sütü Karışımların Duyusal ve soya sütü karışımların duyusal özelliklerine Peynir Suyu ve Karbonat Kullanımının Etkisi. *Anadolu Tarım Bilimleri Dergisi* 20(1): 1-5

Türkmen, A. B. (2015). Topyekûn ve Bütünsel bir Özgürlük Talebi: Veganlığın Felsefesi. *Gaia Dergi*. https://gaiadergi.com/topyekun-ve-butunsel-bir-ozgurluk-talebi-veganliginfelsefesi/ erişim tarihi: 01.12. 2020.

Ümmetoğlu, M., Taşkın, Tan, A. Ş. (2015). Manisa İl ve İlçelerinde Yetiştirilen Susam Çeşitlerinin Dağılımı ve Mevcut Durumunun Araştırılması, *Anadolu* 25(2): 37 – 58.

Ünal, M. K. (2006). Susam Yağının Antioksidan Özellikteki Başlıca Bileşenlerinin Nitelik Nicelikleri Üzerine Araştırmalar, Ege Üniversitesi, Fen Bilimleri

Enstitüsü, Gıda Mühendisliği Anabilim Dalı, İzmir, 2006, 85s. (Yüksek lisans tezi)

Valdez, G.F., de Giori, G.S. (1993). Effectiveness of Soy Milk as Food Carrier for *Lactobacillus acidophilus. Journal of Food Protection*, 56 320-322

Verduci E., D'Elios, S., Cerrato, L., et al. (2019). Cow's Milk Substitutes for Children: Nutritional Aspects of Milk from Different Mammalian Species, Special Formula and Plant-Based Beverages. *Nutrients.* 11(8):1739.

Wang, H.L. (1986). Production of Soymilk and Tofu. *French Soy Food Industry*. March 12-15, Paris, France.

Wang, Q., Jiang, J., Xiong, Y.L. (2018). High pressure homogenization combined with pH shift treatment: A process to produce physically and oxidatively stable hemp milk. *Food Research International*, 106, 487-494.

Yıldırım, D., Özen, H. (2017). Medical Nutrition Therapy in Lactose Intolerance: A Case Report. *Bes Diy Derg*, 45(3): 294-297.

Yılmaz-Ersen, L., Topçuoğlu, E. (2019). Badem Sütü ile Zenginleştirilmiş Probiyotik Yoğurtların Mikrobiyolojik ve Bazı Fiziko-Kimyasal Özellikleri. *Journal of Agricultural Faculty of Bursa Uludag University*, 33(2): 321-339.

CHAPTER 12

SEED PRIMING IN SOME INDUSTRIAL PLANTS

Assoc. Prof. Dr. Ilkay YAVAS[1]
Prof. Dr. Emre ILKER[2]

[1] Aydin Adnan Menderes University, Kocarli Vocational School, Department of Crop and Animal Production, Aydin, TURKEY, (ORCID. 0000-0002-6863-9631), iyavas@adu.edu.tr
[2] Ege University, Faculty of Agricultural, Department of Field Crops, Izmir, TURKEY, (ORCID. 0000-0002-4870-3907), emre.ilker@ege.edu.tr

1. INTRODUCTION

Today global warming and greenhouse gases are a serious problem in relation to climate change. This situation causes an increase in extreme weather conditions such as drought, flood, heat and cold, which are serious threats in terms of agriculture and food security. In addition, climate change threatens biodiversity, increases the number of pests and directly affects the production amount by affecting the biological cycle of plants. Changing precipitation patterns cause crop failures in the short term and decrease the production amount in the long term. Along with the temperature, losses in agricultural production increase and threaten food security at global, regional and local levels. Seed priming is a technology used for rapid, uniform seed emergence, high seedling viability and is highly effective in achieving better plant growth and higher yields (Bourioug et al., 2020).

Seed priming, which is a low-cost method, is widely used to increase the germination percentage, especially in adverse conditions. Especially under drought stress conditions, priming applications are an easy and applicable solution for increasing the stress tolerance by changing the antioxidant enzyme activity and the amount of organic matter in order to protect and maximize plant yield. Therefore, priming is a widely used technique to increase the tolerance of plants to abiotic stress conditions.

Seed germination is an important development process in the plant life cycle. Priming is a pre-planting process used to improve seedling formation by promoting metabolic activity in the seed before germination. Generally, it increases the germination rate and plant performance. Priming processes shorten the time the seed spends in the seed bed by absorbing water. Therefore seed priming applications increase the germination rate of the seed and improve the seedling emergence.

With priming application, especially in adverse environmental conditions, the percentage of germination increases and the physiological heterogeneity in the seed mass decreases. As a result of priming, the germination time is effectively reduced, resulting in faster germination and therefore higher yield (Ataei Somagh et al., 2017).

Priming provides rapid and homogeneous germination, reduces absorption time, activates enzymes before germination, and ensures the production of metabolites and regulation of osmosis, thus repairing damaged

DNA. In addition, it increases antioxidant enzyme activity and reduces lipid peroxidation (Khan et al., 2021).

Priming improves seed performance, increases plant yield, provides greater tolerance to environmental stress conditions and helps to eliminate dormancy (Raj and Raj, 2019; Rima, 2021). Priming is affected by factors such as light, aeration, temperature, time and seed quality. Priming methods include hydro-priming, osmo-priming, halo-priming, solid matrix-priming, biopriming, hormonal-priming, priming with plant growth regulators, nutrient-priming and priming with plant extracts (Figure 1). Priming applications with different priming methods accelerate germination, improve plant growth, increase nutrient and water use efficiency, stress resistance and provide better weed control (Raj and Raj, 2019; Khadijah E'rahim et al., 2021).

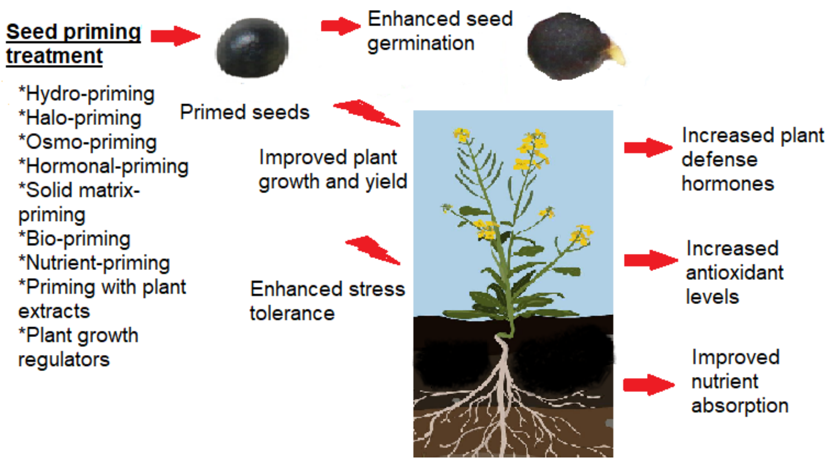


Figure 1: Seed priming applications and its influence on plants (Modified by Kubala et al., 2015).

Priming increases germination as it triggers a series of biochemical changes in the seed such as enzyme activation, starch hydrolysis and elimination of dormancy. It also activates processes such as respiration, gene transcription and translocation which are related to germination. The increase in growth parameters especially in root length after priming increases the uptake of water and nutrients which leads to an increase in photosynthesis and protein synthesis. The increase in photosynthesis is associated with increased stomatal conductivity and transpiration in plants. Under stress conditions, the beneficial effects of priming are due to the accumulation of solutes compatible with the cell resulting in an osmotic reduction that allows the maintenance of cell turgor (Figure 1).

After priming, more water absorbed in the seed is associated with an increase in total soluble sugars (Zhao et al., 2018). During priming, the cotyledon and root are essential organelles for ROS accumulation (Khan et al., 2021). Priming can be used to alleviate the negative effects of senescence on seed germination (Weerasekara et al., 2021). Priming processes improve antioxidant defense mechanism in aged seeds and consequently reduce cell membrane damage caused by ROS accumulation due to lipid peroxidation (Thant et al., 2017).

The effect of different priming methods on some industrial plants

Priming applications are widely used to reduce the effects of salinity stress and increase seed germination. Pre-planting priming improves germination characteristics including germination rate, germination percentage and homogeneity. In hydro-priming, the seeds are kept at a low water potential for hydration. During the germination of seeds, hydration consists of three stages. The first is stage 1, the water uptake phase that occurs in dormant or non-dormant seeds. Stage 2 is the lag phase in which little water uptake occurs and metabolic activities prepare the dormant seeds to germinate the germinating root. Stage 3 is the phase where water uptake increases and is associated with root growth. Priming increases the germination rate of Stage 2 (Moatter et al., 2020). With the priming application, the germination time of the seeds is shortened, root and hypocotyl length and fresh weight increase. In addition, an improvement is observed in the accumulation of proline and anthocyanin, which are osmoregulatory defense molecules, and the induction of antioxidant enzyme systems, so that plants adapt to severe salt stress (Iseri et al., 2014).

Priming the soybean seeds with 0.2 g/L humic acid for 5 hours increased the germination of the seeds and provided a homogeneous emergence (Weerasekara et al., 2021). In another research, canola seeds were grown under salt stress conditions using the bio-priming method using a plant growth promoting microorganism and it was observed that the germination percentage, root length and seedling viability index were significantly improved (Ataei Somagh et al., 2017). Biostimulant priming is a technique used for some basic metabolic processes, such as protein synthesis and/or repair of damaged proteins using RNA and DNA, allowing early germination in seeds (Jafarlou et al., 2022). In another priming application, it was observed that the germination of dill seeds was positively affected when iron and boron were used together (Mirshekari, 2012). Biological priming with microalgae extracts improved germination and plant growth in *Gossypium barbadense* L. seeds (Yanni et al. 2020). The germination rate increased in sesame seeds treated with hydro-priming (Ahmad and Lee, 2011) and humic acid priming (Souguiri et al., 2017). In medicinal plant seeds such as cumin and marigold a positive effect of priming applications on seedling emergence was observed (Tabrizian and Osareh, 2007). Priming of another medicinal plant, fennel seeds with iron, molybdenum and boron solutions, increased the seedling vigor index (Radpoor and Rimaz, 2007). Under salt stress conditions priming of marigold and sweet fennel seeds with GA_3 and NaCl increased germination and seedling growth (Sedghi et al., 2010).

Germination potential, germination rate, germination index, biomass, antioxidant, photosynthesis and seed viability index increased significantly in rapeseed seeds treated with five priming treatments (salicylic acid, gibberellic acid, sodium nitroprusside, calcium chloride and abscisic acid). In addition, indoleacetic acid, gibberellic acid, cytokinin and abscisic acid levels were also stabilized. In rapeseed, it was observed that the most important effect against low temperature and drought conditions was 300 mg/L gibberellic acid application and 89.4 mg/L sodium nitroprusside (Zhu et al., 2021).

Nanopriming processes using nanomaterials is one of the methods applied to increase seed germination and stress tolerance (Raja et al., 2019). Priming cotton seeds with cerium oxide nanoparticles improved the biomass. However, no increase in germination rate of cotton seeds was observed under salinity conditions (An et al., 2020). The application of polyacrylic acid coated nanoceria nanopriming to rapeseed seeds increased salt tolerance in seeds by reducing oxidative damage and maintaining the Na^+/K^+ ratio, as well as providing more water absorption and higher α-amylase activity (Khan et al., 2021). In another study, priming of rapeseed seeds with KH_2PO_4 performed better than $CaCl_2$. It has been reported that the decrease in seed viability and germination is associated with biochemical changes such as viability, electrical conductivity, decrease in soluble proteins and sugar content associated with seed aging (Abdolahi et al., 2012). Similarly, priming of sunflower seeds with $CaCl_2$, KH_2PO_4, NaCl, $ZnSO_4$, ascorbic acid and succinic acid improved seedling emergence and growth (Kathiresan et al., 1984). It has been observed that primed seeds have better plasma membrane structure due to slow hydration (Jett et al., 1996).

In rapeseed, hydro-priming and solid matrix-priming applications play an important role in improving the electrical conductivity (Bijanzadeh et al., 2010). Hydropriming of old Brassica seeds on the other hand increased the total protein content and decreased the total starch and total sugar content (Bedi et al., 2005). Seeds that were magnetically treated and treated with 3% moringa leaf extract significantly improved emergence, growth and sunflower yield (Afzal et al., 2021).

Priming treatments in soybean resulted in lower plant population density compared to control conditions. Due to the lower competition among these plants the available resources were used more efficiently. After priming, more pods, grain formation and higher grain yield were obtained in soybean (Ghassemi-Golezani et al., 2011).

Priming palm seeds with midacloprid had a significant effect on plant height, leaf area and germination rate. In contrast, treatment with gibberellic acid resulted in maximum germination percentage while no change in chlorophyll content was observed (Qureshi et al., 2016). Priming of soybean seeds under both irrigation conditions and drought stress resulted in improvement in seed yield, seed weight and harvest index (Daneshvar et al., 2014).

Aymen et al. (2012) reported that plant height, plant fresh and dry weight were 15-30% higher in primed safflower seeds compared to control conditions. This was due to the increase in total leaf area and the effect of photosynthetic activity.

Exposure of sunflower seedlings to priming with NaCl caused an increase in chlorophyll a, chlorophyll b, total chlorophyll and photosynthetic pigment contents, and decreased membrane integrity and MDA content (Zhang et al., 2018). However, priming applications have been observed to significantly increase photosynthesis in black cumin and safflower plants

(Ashrafi and Razmjou, 2010; Fallah et al., 2018). Priming of sunflower with polyethylene glycol (PEG) under water stress conditions increased the germination capacity, fresh and dry biomass, proline content, soluble sugar and chlorophyll content, resulting in higher yields (Bourioug et al., 2020).

Salt stress is one of the environmental stresses that negatively affect cotton (*Gossypium hirsutum* L.) growth. Priming cotton seeds with 25 μM melatonin increases the efficiency of photosynthesis, strengthens the reactive active oxygen system and increases the salt stress tolerance of cotton seedlings by coordinating phytohormone signaling pathways (Zhang et al., 2021).

Priming in saline soils has a significant effect on the percentage of emergence, relative moisture content of leaves, relative chlorophyll content, maturation time, shoot length and grain yield in soybean (Bejandi et al., 2009).

Priming improved germination of weakly vigorous soybean seeds (Wartidiningsih et al., 1994). According to Tiryaki et al. (2004) emphasized that cytokinin and ethylene secretion are stimulated by priming treatments, that ethylene or its precursor, 1-aminocyclopropane -1-carboxylic acid (ACC) is the simplest unsaturated hydrocarbon that regulates various metabolic and developmental processes in plants including seed germination. (Bejandi et al., 2009).

Soybean seeds subjected to priming (-1.1 MPa) had faster and better germination capacity and yield increases were observed. Also, priming time of 6 hours was more effective on germination. As a result, priming processes accelerated and improved the emergence of soybean and increased grain yield (Arif et al., 2008).

Positive effects of priming were also detected in sunflower (Singh, 1995) and sugar beet (Sadeghian and Yavari, 2004) plants. Park et al. (1997) indicated that priming increased germination and seedling growth in old soybean seeds. With priming early seedlings emerged in cotton (Murungu et al., 2004), and higher germination rates and emergence were observed in canola (Basra et al., 2003) and soybean (Salinas, 1996) seeds primed with PEG. .

Depending on priming processes soybean germination percentage, seedling dry weight and field emergence percentage decreased, while the mean emergence time was prolonged in drought conditions. The number of pods, seed number and yield per plant increased significantly as a result of priming processes. It has been emphasized that seed quality can be increased after priming either by production techniques or by means of water, osmotic solutions and matrix materials. Since the priming process is kept at a water potential that allows the seeds to take in water but prevents root elongation, it has been reported that after this process, the seedling emergence and plant per unit area of sunflower decreased (Ghassemi-Golezani et al., 2011).

It has been observed that priming treatments negatively affect seed germination and seedling growth by decreasing the germination percentage and seedling dry weight in soybean (Ghassemi-Golezani et al., 2011) and sunflower (Hussain et al., 2006). Priming parsley seeds with water or gibberellic acid and hydro-priming of Kentucky bluegrass seeds reduced the germination percentage (Pill and Kilian, 2000). But hydropriming of safflower seeds increased plant/m^2, capitula per plant, kernel per capita, 1000 seed weight, kernel yield and oil content (Bastia et al., 1999).

Under salinity conditions, priming of *Beta vulgaris* L. seeds with $PbSO_4$ and $FeSO_4$ increased germination and seedling growth, and the highest shoot and root length was obtained after 200 ppm $FeSO_4$ application. Therefore, it was concluded that priming can reduce the effects of salinity (Moatter et al., 2020).

El-Saidy et al. (2011) emphasized that sunflower priming has a positive effect on yield and yield components. Under low temperature and drought conditions, abscisic acid can control bud dormancy in plants by regulating transcription factors so that the plant can develop normally (Sami et al., 2020). Under salinity stress conditions Bajehbaj et al. (2010) found that sunflower seed priming with NaCl and KNO_3 showed better germination percentage.

The application of spermidine priming to rapeseed seeds increases salt tolerance by reducing the negative impacts of salt stress (Stassinos et al., 2021). Under abiotic stress conditions, sunflower priming caused an increase in proline content (Vassilevska-Ivanova et al., 2013; Yan 2015). Similarly, under water stress the soluble sugar content of sunflower achenes improved with priming (Wahid et al., 2008).

The use of various priming agents such as salicylic acid, abscisic acid, gibberellic acid, jasmonic acid, ethylene, potassium nitrate, monopotassium phosphate, polyethylene glycol, mannitol and NaCl on cotton and rapeseed seeds under abiotic stress (drought, temperature and lead) conditions increased stress tolerance. (Casenave and Toselli, 2007; Kohli et al., 2019). In sesame, germination percentage, root and shoot length, viability index were significantly affected by priming and seed coating treatments. In addition, a higher germination percentage was recorded in seeds primed with water (Tizazu et al., 2019).

Depending on priming processes soybean germination percentage, seedling dry weight and field emergence percentage decreased, while the mean emergence time was prolonged in drought conditions. The number of pods, seed number and yield per plant increased significantly as a result of priming processes. It has been emphasized that seed quality can be increased after priming either by production techniques or by means of water, osmotic solutions and matrix materials. Since the priming process is kept at a water potential that allows the seeds to take in water but prevents root elongation, it has been reported that after this process, the seedling emergence and plant per unit area of sunflower decreased (Ghassemi-Golezani et al., 2011).

2. CONCLUSIONS

Plants are generally exposed to various abiotic stresses in field conditions which adversely affect plant performance. Among these stresses drought and salinity cause significant reductions in plant growth and yield all over the world. Today, different applications are used to eliminate the harmful effects of drought. Priming emerges as an effective and practical approach to increase plant tolerance against various stress factors such as drought. Primer applications, which are a low-cost, effective and low-risk method to achieve high viability in industrial plants, provide rapid and homogeneous seed emergence, better plant growth in adverse environmental conditions, and increase yield and quality by positively affecting morphological, physiological and biochemical properties.

REFERENCES

Abdolahi, M., Andelibi, B., Zangani, E., Shekari, F., Jamaati-e-Somarin, S. (2012). Effect of accelerated aging and priming on seed germination of rapeseed (*Brassica napus* L.) cultivars. *International Research Journal of Applied and Basic Sciences* 3(3): 499-508.

Afzal, I., Saleem, S., Skalicky, M., Javed, T., Bakhtavar, M. A., Kamran, M., Shadid, M., Saddiq, M.S., Afzal, A., Shafqat, N., Dessoky, E.S., Gupta, A., Korczyk-Szabo, J., Brestic, M., Sabagh, A.E.L. (2021). Magnetic Field Treatments Improves Sunflower Yield by Inducing Physiological and Biochemical Modulations in Seeds. *Molecules* 26(7): 2022.

Ahmad, G., Lee, H.C. (2011). Response of sesame (*Sesamum indicum*) cultivars to hydropriming of seeds. *Australian Journal of Basic and Applied Sciences* 1: 638–642

An, J., Hu, P., Li, F., Wu, H., Shen, Y., White, J.C., Tian, X., Li, Z., Giraldo, J.P. (2020). Emerging investigator series: molecular mechanisms of plant salinity stress tolerance improvement by seed priming with cerium oxide nanoparticles. *Environmental Science: Nano Journal* 7:2214-28.

Arif, M., Jan, M.T., Marwat, K.B., Khan, M.A. (2008). Seed priming improves emergence and yield of soybean. *Pakistan Journal of Botany* 40(3): 1169-1177.

Ashrafi, A., Razmjou, K. (2010). Evaluation of hydropriming effect on safflower physiological and biochemical characteristics under drought stress. *Journal of Crop Ecophysiology* 1(1): 34-44.

Ataei Somagh, H., Mousavi, S.M., Omidi, H., Mohammadian, E., Hemmati, M. (2017). Canola seed germination and seedling growth in response to saline condition and bio-priming. *Iranian Journal of Plant Physiology* 7(4): 2149-2156.

Aymen, E.M., Zhani, K., Meriem, B.F., Hannachi, C. (2012). Seed priming for better growth and yield of safflower (*Carthamus tinctorius*) under saline condition. *Journal of Stress Physiology & Biochemistry* 8(3):135-143

Bajehbaj, A.A. (2010). The effects of NaCl priming on salt tolerance in sunflower germination and seedling grown under salinity conditions. African Journal of Biotechnology. 9(12).

Basra, M.A.S., Ehsanullah, E.A. Warraich, M.A., Afzal, I. (2003). Effect of storage on growth and yield of primed canola (*Brassica napus*) seeds. *International Journal of Agriculture and Biology* 5:117-120

Bastia, D.K., Rout, A.K., Mohanty, S.K., Prusty, A.M. (1999). Effect of sowing date sowing methods and seed soaking on yield and oil content of rainfed safflower grown in Kalahandi, Orissa. *Indian Journal of Agronomy* 44:621-623.

Bedi, S., Kaur, R., Gupta, S. (2005). Effect of accelerated ageing on seeds of different maturity levels in Brassica. *Environment and Ecology* 23S: 855-860

Bejandi, T.K., Sedghi, M., Sharifi, R.S., Namvar, A., Molaei, P. (2009). Seed priming and sulfur effects on soybean cell membrane stability and yield in saline soil. *Pesquisa Agropecuária Brasileira* 44(9): 1114-1117.

Bijanzadeh, E., Nosrati, K., Egan, T. (2010). Influence of seed priming techniques on germination and emergence of rapeseed (*Brassica napus* L.). *Seed Science and Technology* 38: 242-247.

Bourioug, M., Ezzaza, K., Bouabid, R., Alaoui-Mhamdi, M., Bungau, S., Bourgeade, P., Alaoui-Sossé, L., Alaoui-Sossé, B., Aleya, L. (2020). Influence of hydro- and osmo-priming on sunflower seeds to break dormancy and improve crop performance under water stress. *Environmental Science and Pollution Research* 27(12):13215-13226.

Casenave, E.C., Toselli M.E. (2007). Hydropriming as a pre-treatment for cotton germination under thermal and water stress conditions. *Seed Science and Technology* 35(1): 88-98.

Daneshvar, R.R., Sadeghipour, O., Pazoki, A. (2014). Effect of seed priming of soybean on germination parameters in vitro and yield and yield components in the field under drought stress. *Iranian Journal of Seed Science and Technology* 3(1):53-66

El-Saidy, A.E.A., Farouk, S., Abd El-Ghany, H.M. (2011). Evaluation of different seed priming on seedling growth, yield and quality components in two sunflower *Helianthus annuus* L. cultivars. *Trends in Applied Sciences Research s*6:977-991

Fallah, S., Malekzadeh, S., Pessarakli, M. (2018). Seed priming improves seedling emergence and reduces oxidative stress in *Nigella sativa* under soil moisture stress. *Journal of Plant Nutrition* 41(1): 29-40.

Ghassemi-Golezani, K., Farshbaf-Jafari, S., Shafagh-Kolvanagh, J. (2011). Seed priming and field performance of soybean (*Glycine max* L.) in response to water limitation. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 39(2):186-189.

Harris, D.B.S.R., Raghuwanshi, B.S., Gangwar, J.S., Singh, S.C., Joshi, K.D., Rashid, A., Hollington, P.A. (2001). Participatory evaluation by farmers of on-farm seed priming in wheat in India, Nepal and Pakistan. *Experimental Agriculture* 37(3):403-415.

Hussain, M., Farooq, M., Basra, S.M.A., Ahmad, N. (2006). Influence of seed priming techniques on the seedling establishment, yield and quality of hybrid sunflower. *International Journal of Agriculture And Biology* 8:14-18

Iseri, O.D., Sahin, F.I., Haberal, M. (2014). Sodium chloride priming improves salinity response of tomato at seedling stage. *Journal of Plant Nutrition* 37(3): 374-392**.**

Jafarlou, M.B., Pilehvar, B., Modaresi, M., Mohammadi, M. (2022). Interactive effects of seaweed and microalga extract priming as a biostimulant agent on the seed germination indices and primary growth of milkweed (*Calotropis procera* Ait.). *Biologia*, 1-11.

Jett, L.W., Welbau, G.E., Morse, R.D. (1996). Effect of matric and osmotic priming treatments on broccoli seed germination. *Journal of the American Society for Horticultural Science* 121: 423- 429

Kathiresan, K., Kalyani, V., Gnanarethinam, J.L. (1984). Effect of seed treatments on field emergence, early growth and some physiological processes of sunflower (*Helianthus annus* L.). *Field Crops Research* 9: 215-217.

Khan, M.N., Li, Y., Khan, Z., Chen, L., Liu, J., Hu, J., Wu, H., Li, Z. (2021). Nanoceria seed priming enhanced salt tolerance in rapeseed through modulating ROS homeostasis and α-amylase activities. *Journal of Nanobiotechnology* 19(1): 1-19.

Kohli, S.K., Bali S., Tejpal R., Bhalla V., Verma V., Bhardwaj, Alqarawi, A.A., Abd Allah, E.F., Ahmad, P. (2019). In-situ localization and biochemical analysis of bio-molecules reveals Pb-stress amelioration in *Brassica juncea* L. by co-application of 24-Epibrassinolide and Salicylic Acid. *Scientific reports* 9(1):1-15. https://doi.org/10.1038/s41598-018-37186-2 PMID: 30626917

Kubala, S., Garnczarska, M., Wojtyla, Ł., Clippe, A., Kosmala, A., Żmieńko, A., Lutts, S., Quinet, M. (2015). Deciphering priming-induced improvement of rapeseed (*Brassica napus* L.) germination through an integrated transcriptomic and proteomic approach. *Plant Science* 231: 94-113.

Mirshekari, B. (2012). Seed priming with iron and boron enhances germination and yield of dill (*Anethum graveolens*). *Turkish Journal of Agriculture and Forestry* 36(1): 27-33.

Moatter, K., Khan, A.M., Iqbal, S., Dilshad, I., Qadri, T.A., Abdullah, F., Gilani, S.A. (2020). Effects of seed priming with $PbSO_4$ and $FeSO_4$ on germination and growth of seedlings of *Beta vulgaris* L. under NaCl stress. *Pure and Applied Biology (PAB)*, 9(2): 1405-1423.

Murungu, F.S., Chiduza, C., Nyamugafata, P., Clark, L.J., Whalley, W.R. (2004). Effect of on-farm seed priming on emergence, growth and yield of cotton and maize in a semi arid area of Zimbabwe. *Experimental Agriculture,* 40: 23-26

Khadijah E'rahim, N.I., Nordin, M.S., Salleh, M.S. (2021). Effects of Seed Priming on Seed Germination and Early Seedling Growth of Chili (*Capsicum annum* L.) Under Water Deficit Condition. *Tropical Agrobiodiversity* 2(1):37-41.

Park, N., Song, J., Sangyang, L. (1997). Effects of precooling and packaging methods on the vegetable soybean storage. *RAD Journal of Crop Science* 39: 46-52

Pill, W.G., Kilian, EA. (2000). Germination and Emergence of Parsley in Response to Osmotic or Matric Seed Priming and Treatment with Gibberellin. *HortScience* 35(5): 907-909

Qureshi, U.S., Shakeel, M., Qureshi, K.M., Saman, C., Aamir, S.A., Mir, A.R., Qureshi, A.A. (2016). Effect of seed priming through gibberellic acid (GA3) and imidacloprid on bismarckia palm seed. *International Journal of Biosciences* 8(4):18-27.

Radpoor, R., Rimaz, A. (2007) Rapid germination and higher vigor in seedlings of fennel (*Foeniculum vulgare*) due to seed priming with microelements. *Iranian Journal of Crop Sciences* 7: 237-248

Raj, A.B., Raj, S.K. (2019). Seed priming: An approach towards agricultural sustainability. *Journal of Applied and Natural Science* 11(1):227-234.

Raja, K., Sowmya, R., Sudhagar, R., Moorthy, P.S., Govindaraju, K., Subramanian, K.S. (2019). Biogenic ZnO and Cu nanoparticles to improve seed germination quality in blackgram (*Vigna mungo*). *Mater Lett* 235:164-7.

Rima, R. (2021). Seed Priming Significantly Affects Germination and Post Germination Early Seedling Growth in Okra. *Malaysian Journal of Halal Research 4*(1): 11-13.

Sadeghian, S.Y., Yavari, N. (2004). Effect of water deficit stress on germination and early seedling growth in sugar beet. *Journal of Agronomy and Crop Science* 190:138-144.

Salinas, A.R. (1996). Influence of *Glycine max* (L.) Merrill seed quality on crop establishing and overcoming of ambiental stress. *Pesquisa Agropecuaria Brasileira* 31: 379-386

Sami, A., Shah, F.A., Abdullah, M., Zhou, X., Yan, Y., Zhu, Z., Zhou, K. (2020). Melatonin mitigates cadmium and aluminium toxicity through modulation of antioxidant potential in *Brassica napus* L. *Plant Biology* 22(4). https://doi.org/10.1111/plb.13093 PMID: 32003103

Sedghi, M., Nemati, A., Esmaielpour, B. (2010). Effect of seed priming on germination and seedling growth of two medicinal plants under salinity. *Emirates Journal of Food and Agriculture* 17(1):130-139.

Singh, B.G. (1995). Effect of hydration-dehydration seed treatments on vigor and yield of sunflower. *Indian Journal of Plant Physiology* 38: 66-68.

Souguiri, M., Hannachi, C. (2017). Respons of Sesame Seedling to Different Eoncentration of Humic Acids or Calcium Nitrate at Germination and Early Growth. *Cercetări agronomice în Moldova* 50: 65-77

Stassinos, P.M., Rossi, M., Borromeo, I., Capo, C., Beninati, S., Forni, C. (2021). Enhancement of *Brassica napus* Tolerance to High Saline Conditions by Seed Priming. *Plants* 10(2): 403.

Tabrizian, F., Osareh, A.M. (2007) Improved seed emergence and yield related traits of marigold (*Calendula officinalis* L.) by on-farm seed micronutrient treatment trials. *Iranian Journal of Crop Sciences* 9: 124- 141.

Thant, P.S., Puteh, A.B., Sinniah, U.R., Firdaus, M., Ismail, B. (2017). Effect of Priming on Physiological and Chromosomal Changes of Aged Soybean Seeds. In Proceedings of the 6th International Conference on Chemical, Agricultural, Biological and Environmental Sciences (CAFES-17), Manila, Philippines, 18-19 September 2017, pp. 17–20.

Tiryaki, I., Korkmaz, A., Ozbay, N., Nas, M.N. (2004). Priming in the presence in the plant growth regulators hastens germination and seedling emergence of dormant annual ryegrass (*Lilium multiflorum* Lam.) seeds. *Asian Journal of Plant Science* 3: 655-659.

Tizazu, Y., Ayalew, D., Terefe, G., Assefa, F. (2019). Evaluation of seed priming and coating on germination and early seedling growth of sesame (*Sesamum indicum* L.) under laboratory condition at Gondar, Ethiopia. *Cogent Food & Agriculture* 5(1): 1609252.

Vassilevska-Ivanova, R., Shtereva, L., Kraptchev, B., Karceva, T. (2013) Response of sunflower (*Helianthus annuus* L.) genotypes to PEG mediated water stress. *Central European Journal of Biology* 9:1206-1214

Wahid, A., Noreen, A., Basra, S.M.A., Gelani, S., Farooq, M. 2008. Priming-induced metabolic changes in sunflower (*Helianthus annuus*) achenes improve germination and seedling growth. *Botanical Studies* 49: 34

Wartidiningsih, N., Geneve, R.L., Kester, S.T. (1994). Osmotic priming or chilling stratification improves seed germination of purple coneflower. *HortScience* 29(12): 1445-1448.

Weerasekara, I., Sinniah, U.R., Namasivayam, P., Nazli, M.H., Abdurahman, S.A., Ghazali, M.N. (2021). Priming with Humic Acid to Reverse Ageing Damage in Soybean [*Glycine max* (L.) Merrill.] Seeds. *Agriculture* 11(10): 966.

Yan, M. (2015). Seed priming stimulate germination and early seedling growth of Chinese cabbage under drought stress. *South African Journal of Botany* 99: 88-92

Yanni, Y.G., Elashmouny, A.A., Elsadany, A.Y. (2020). Differential response of cotton growth, yield and fiber quality to foliar application of *Spirulina platensis* and urea fertilizer. *Asian Journal of Advances in Agricultural Research* 29-40. https:// doi. org/ 10. 9734/ ajaar/ 2020/ v12i1 30072

Zhang, F., Yu, J., Johnston, C.R., Wang, Y., Zhu, K., Lu, F., Zhang, Z., Zou, J. (2015). Seed Priming with Polyethylene Glycol Induces Physiological Changes in Sorghum (*Sorghum bicolor* L. Moench) Seedlings under Suboptimal Soil Moisture Environments. *PLoS ONE* 10: e0140620.

Zhang, Y., Li, X., Zheng, X., Han, H. (2018). Effect of seed priming on sunflower seed germination and seedling physiological characteristics under salt stress. *Journal of Henan Agricultural Sciences* 47(4): 43-48.

Zhang, Y., Zhou, X., Dong, Y., Zhang, F., He, Q., Chen, J., Zhu, S., Zhao, T. (2021). Seed priming with melatonin improves salt tolerance in cotton through regulating photosynthesis, scavenging reactive oxygen species and coordinating with phytohormone signal pathways. *Industrial Crops and Products* 169: 113671.

Zhao,, M., Zhang, H., Yan, H., Qiu, L., Baskin, C.C. (2018). Mobilization and role of starch, protein, and fat reserves during seed germination of six wild grassland species. *Front Plant Sci* 9:1-11

Zhu, Z.H., Sami, A., Xu, Q.Q., Wu, L.L., Zheng, W.Y., Chen, Z.P., Jin, X.Z., Zhang, H., Li, Y., Yu, Y. Zhou, K.J. (2021). Effects of seed priming treatments on the germination and development of two rapeseed (*Brassica napus* L.) varieties under the co-influence of low temperature and drought. *Plos One* 16(9): e0257236.

CHAPTER 13

USE OF MOLDS IN SOME INDUSTRIAL FOODS

Assoc.Prof. Dr. Nural KARAGOZLU[1]
Dr. Derya SAYGILI[2]

[1] Manisa Celal Bayar University, Engineering Faculty, Food Engineering Department, Yunusemre-Manisa, Türkiye. ORCID NO: 0000-0003-3754-0724 nural.karagozlu@cbu.edu.tr
[2] Izmir Kavram Vocational School, Culinary Programme, Konak-İzmir, Türkiye. ORCID NO: 0000-0002-5286-4359 derya.saygili@kavram.edu.tr

FERMENTATION AND FERMENTED FOOD PRODUCTS

Fermentation is one of the first methods used in the preservation and long-term storage of food, and it is estimated that the first fermented foods were produced by natural fermentation by chance, while foods prepared in this way can also be stored for a long time without spoiling. Today, fermented products are produced with traditional properties in various parts of the world from raw materials such as meat, milk, various cereals, fruit and vegetables with the use of non-toxic microorganisms.

An important part of the foods consumed in daily life consists of fermented products produced as a result of microorganism activities. The shelf life of fermented foods such as yogurt, cheese, pickles and sausage is longer than the shelf life of the raw materials used in the production of these foods. Fermented foods also have characteristic taste and aroma in relation to the properties of microorganisms involved in fermentation. The digestibility of the raw material used in the production of some fermented foods increases after the fermentation process; at the same time, the vitamin content of fermented food increases compared to raw materials. It has also been found that the toxic effect of raw materials in some fermented foods, such as gari, decreases as a result of fermentation.

Production of fermented alcoholic beverages; The conversion of sugars in raw materials into alcohol as a result of the activity of yeasts is based on its essence, and in vinegar production, it is based on the conversion of alcohol to acetic acid with acetic acid bacteria. In cases where raw materials such as wheat, barley and corn are used in the production of some fermented products, the starch in these raw materials must first be broken down into sugars, mainly glucose. In such fermentation products, great differences are observed in eastern and western countries. In Western countries, amylolytic enzymes used for saccharification are generally obtained from malt, while in eastern countries, molds such as *Aspergillus* and *Rhizopus* are used as amylolytic enzyme sources (Hui, 2012; Hutkins, 2006).

Although the use of bacterial starter cultures is more common in the production of fermented foods in the world, there are also foods that ripened with mold to a significant extent. More than a third of the world's population feeds on products fermented with molds, which increased durability and made better consumable. Products fermented with molds vary greatly depending on the type of mold used and the source of the foodstuff. For example, foods in which molds are used as a starter are generally of animal origin in many European countries, including Turkey, while in Asian countries they are mostly of plant origin (Hui, 2012; Hutkins, 2006).

Fermentation is a food production and preservation method that has been applied since ancient times. Since ancient times, besides traditional fermentation, the processes of smoking, drying and salting have been used to preserve and consume nutrients, and these processes are an important step in the history of food culture for humanity (Karaçıl and Acar Tek, 2013; Tamang and Kailasopaty, 2010).

In addition to preserving foods from spoilage, fermentation is a natural method that increases the nutritional value of foods by synthesizing essential amino acids and vitamins. While the digestibility of foods is increased by fermentation, the detoxification and destruction of unwanted substances such as phytates, tannins and polyphenols in raw foods are also carried out (Zucchini and Dobson 2011).

Soy and other legumes are protein-based plant foods. The legumes widely grown and consumed in the world are soy, peas, black lentils and french beans (Tamang, 2010). 90% of fermented legumes are fermented soy-based products and the rest are non-soy products. In Asian countries such as Korea, China and Japan, soy consumption has been going on for more than 1000 years, while consumption of other fermented legume products is more common in Africa (Chen et al., 2012; Tamang, 2010). Commonly consumed fermented products are miso, soy sauce, natto, tempeh, and tofu (Chai et al., 2012; Chen et al., 2012; Karaçıl and Acar Tek, 2013).

The class Fungi Imperfecti, in which molds are included, is divided into four orders, and one of them, the *order Moniliales*, includes three families. *Moniliaceae*, one of these families, includes two important mold genera, *Aspergillus* and *Penicillium*, which play a role in the production of fermented foods produced using molds in the food industry. Apart from these genera, the genus *Rhizopus* is also widely used in the production of various products (Doyle, 2018).

The traditional fermented products produced and consumed in Japan are fermented soy sauce (shoyu), fermented soy paste (miso), fermented rice wine (sake), distilled sake (shochu), rice vinegar, amasake, natto, pickles and similar products. The common feature in these fermented products other than natto and pickles is that molds belonging to the *genus Aspergillus* such as A. *oryzae*, A. *sojae*, *A. niger* cause fermentation with amylase, protease, lipase, cellulase, pectinase and similar enzymes in all or part of the raw material. Although molds belonging to the genus *Aspergillus* are generally used in the production of fermented foods in the Far East countries, molds belonging to *the genus Rhizopus*, *Mucor* are also widely used in the production of various products. In addition, mold genera such as *Actinomucor*, *Amylomyces*, *Neurospora* are also used as starters in the ripening of some foods (Akamine et. al. 2022; (Doyle, 2018).

Starter cultures and their characteristics;

In the production of fermented products; The ability to perform fermentation healthily, and therefore to produce a product of the desired quality, depends on various factors such as the purity and activity of the starter cultures used in fermentation. The starter cultures used are added to the raw material as pure as well as mixed culture. Although the types of mold used as starter cultures are carefully selected, some unwanted toxins or biological metabolites may be present in foods and these can cause various health problems.

The use of molds as a starter in the maturation of foods; With the various lipase, protease and amylase enzymes secreted by molds into the environment, it increases the digestibility of food on the one hand and allows the formation of a more aromatic product on the other hand. It is also stated that moldy foods are enriched with some vitamins, while some bacteria or molds that cause food poisoning do not develop well in such foods (Doyle, 2018; Ray and Montet, 2015).

To provide these benefits in a fermented product, some properties must be present in the mold cultures to be used as a starter. These features can be listed as follows (Doyle, 2018; Ray and Montet, 2015).

- The culture should not have toxigenic and pathogenic properties.
- It should have amylolytic and lipolytic activity.
- It should provide the product's desired taste, aroma and appearance.
- It should form micelles of the desired color and amount in the product.

- It should have a characteristic musty aroma.
- It should not produce antibiotics and similar metabolites.
- It must be able to develop well on the surface or in food.
- Its activity should not be affected by the other microorganisms.

Mold stock cultures used as starter cultures are usually developed on the oblique surface of a suitable medium such as Malt Extract Agar and the spore phase can be maintained for a long time by a method such as lyophilization (Hutkins, 2006).

Different methods are applied in the preparation of sports or micellar cultures. Some of these methods can be specified as follows:

- Development on the surface of a liquid or solid media in Erlenmeyer or a similar suitable carrier.
- Superficial development of the medium on the surface in a tray and similar carrier (tray).
- Development in moist wheat bran with acidified or added liquid nutrients such as corn-soaking water.
- Development in sterilized and moistened bread or crackers.
- Development by the method of ventilated deep culture, which results in pellet development of mycelium with or without spores.

Depending on these methods, mold spores are also obtained in different ways; they can be washed or taken directly from the dry surface and stored in powder form.

Mold starters to be used as inoculum in deep culture fermentation on an industrial scale are usually prepared in the form of mycelium mass or pellets obtained from deep culture. When superficial development is desired in dandruff or liquid or solid media, spores can be prepared with one of the methods described above (Doyle, 2018; Ray and Montet, 2015).

In the production of fermented products such as koji, soy sauce, *A. oryzae* is often used in pure culture, or mixed culture with yeast and *Lactobacillus delbrueckii*. The mold culture used in this type of product is developed on the surface of cooked and sterilized rice.

SOY-BASED FERMENTED FOODS

There are many foodstuffs ripened with molds almost everywhere in the world. As mentioned before, foods ripened with mold are generally of animal origin in European and American countries, while in Asian countries they are mostly of plant origin.

Although fermented foods of plant origin, where molds are used as a starter, are encountered in some African countries, such foods are produced in high quantities in Asian countries and have the opportunity to be consumed. The raw material of the foods of vegetable origin ripened with mold consists of soybeans, legumes, rice, wheat, coconut, butcher (Ray and Montet, 2015; Tamang, 2011).

The two countries that use plant products the most in the production of fermented foods in the world are China and India. These countries depend on vegetable proteins as a staple food due to their very dense populations. Indonesia and Japan, on the other hand, consume fermented foods at a high rate, mainly using raw materials including soybeans. In general, the countries where traditional fermented products are produced using various plant foods, especially soybeans, are consumed the most in China, Taiwan, Indonesia, Thailand, the Philippines, Korea, Japan, Burma, Malaysia and Singapore. Products prepared from such fermented foods are used either to add flavor to other rice and vegetable dishes or to be consumed as a direct protein source (Chai et al., 2012; Ray and Montet, 2015; Tamang, 2011).

There are several reasons for the use of soy in the production of fermented moldy foods. These reasons can be listed as follows:

- Compounds such as naturally occurring and unwanted trypsin inhibitors in soybeans are neutralized during processes such as soaking and heating legumes or by enzymes synthesized by microorganisms.
- In addition, products such as soy sauce, which can be perishable in a short time before fermentation, can be durable for a long time without the need for cooling after fermentation.
- On the other hand, the product obtained at the end of fermentation under the influence of proteolytic and lipolytic enzymes has a digestible property.

- The resulting final product has a different flavor, which makes it more attractive to consumers.
- In addition, in some cases where bacterial fermentation is present, depending on the bacterial activity, the product increases in riboflavin, vitamin B_{12} various nutrients.
- In many cases, the physical structure of the product changes completely as a result of fermentation. Soybeans, for example, turn into a dark brown liquid drink in soy sauce.
- Fermentation reduces the need for energy.

Although soy is important in terms of meeting protein needs due to its higher protein content (38-40%) compared to other cereals and legumes, it is also an important oilseed that ranks second among legumes with 18-20% fat content. For these reasons, it is used as a raw material in the production of various fermented foods.. 90% of fermented vegetable products are fermented soy-based products and the rest are non-soy products (Nilüfer and Boyacıoğlu, 2008). Commonly consumed fermented products are miso, soy sauce, natto, tempeh, and tofu (Chai et al., 2012; Chen et al., 2012; Karaçıl and Acar Tek, 2013).

Miso

Miso (Bean Puree) is a Japanese name given to puree-like products used as a flavoring agent and in soups. It can be obtained in different forms depending on the components, the fermentation time and the amount of salt used. According to the raw material used, miso is called miso of rice, barley and soybeans. Miso is sweet, moderately sweet and salty; can be white, light yellow and red in color. This product is produced in almost all eastern countries, including Indonesia, China, Japan, Korea, Taiwan, the Philippines and Indochina (Clifford, W.H.,1989: Yokotsuko, T., 1985).

Koji is used to make the miso. Koji is a product obtained as a result of incubation of rice soaked, cooked and cooled in water with Aspergillus *oryzae* and *Aspergillus soyae* strains (Clifford, 1989). The preparation of koji is an important step in the fermentation of various foods consumed in the east. The process is based on the development of molds on a solid substrate such as seeds, soybeans or grains, creating hydrolytic enzymes. Koji is used as a source of various enzymes that allow raw materials to be converted into substrates that yeast and bacteria can use in fermentation (Lotong, 1985). Enzymes in koji break down proteins, fats and carbohydrates in the medium, such as malt in beer (Haytowitz and Matthews, 1989). Koji obtained from soybeans has been found to contain various enzymes such as amylase, cellulase, invertase, lipase and protease. Among these enzymes, amylolytic enzymes are important for the breakdown of starch and oligosaccharides and the provision of fermentable sugars (Lotong, 1985). Different types of miso can be obtained by applying different fermentation times (Clifford, 1989; Kim et. al. 2022).

Miso is frequently used in the formulation of some new foods in the east and west due to the following properties (Clifford, 1989):

1. Different ingredient ratios and the application of fermentation time and temperature, resulting in the development of a wide variety and desired taste and color
2. Formation of flavor similar to that of fresh meat
3. Not losing quality characteristics during storage and long shelf life at room temperature
4. Low risk of spoilage due to its high salt content
5. The product obtained as a result of fermentation can be easily mixed with other food components and used
6. Can be used as a thickener
7. The components used are cheap

Soy sauce (Shoyu)

Soy sauce was produced in China 2500 years ago. It is also said that soy sauce was first made by a Buddhist bishop in 1254. Traditional soy sauce; in wood tanks ferment for 1-2 years. The production time of soy sauce is significantly affected by the concentration of heat and sodium chloride (Chen et al., 2012), today it is produced under more controlled technological conditions (Tamang and Samuel 2010).

Depending on the ratio of raw materials used, microorganisms and fermentation conditions, soy sauces are diverse. They are sauces made from fish and grains in China and Southeast Asia and resemble soy sauce in appearance (Murooka and Yamshita, 2008). Especially in Japan, soy sauce is used as a liquid condiment in dishes (Karaçıl and Acar Tek, 2013; Nagai and Tamang, 2010).

Soy sauce is a soybean product produced by two-stage fermentation and is used to add flavor to meat, chicken and fish dishes. As a result of the incubation of wheat and soybeans with A. *oryzae and A. soyae* strains, salt water is added to the koji and a porridge called moromy is formed. This poultice is fermented with *Pediococcus halophylus* and yeast cultures (*Saccharomyces rouxii, Torulopsis* sp.) and left to mature. Then the ripe porridge is pressed to obtain soy sauce, which is the liquid part. Pasteurizing soy sauce at high temperatures gives the product a darker color and a stronger flavor. In some cases, *Rhizopus* species can be used instead of *Aspergillus* (Clifford, W.H.,1989; Turantaş, F., 1998).

Sufu (Chinese Cheese)

Sufu is a cheese-like soft product obtained as a result of fermenting the soybean product called tofu with a suitable mold and then soaking it in brine. It is possible to obtain sufu in different colors and flavors with different ingredients used in the brine. The task of the salt in the environment is to release the proteolytic enzymes in the mycelium (Clifford, 1989).

Tofu

Tofu is obtained as a result of coagulating traditional soy milk with the help of a coagulant agent. It is similar to soft white cheese or a tight yoghurt. Calcium sulfate is used for this purpose, resulting in a soft, gelatinous and perishable soybean product (Wolf and Cowan, 1975). The sterilized tofu is inoculated with *Actinomucor elegans* and kept for 3-7 days at a temperature below 20^{o}C. Tofu cubes with mold growth are taken into a solution containing 12% salt and 12% alcohol and ripened for 1-2 months (Yokotsuko, 1985). *Although Actinomucor elegans are* used in factory production, *some types of Mucor, such as Mucor dispersus*, can also be used during production at home. When fresh tofu is fermented with *Mucor hiemalis* or *Actinomucor elegans*, the product known as sufu or Chinese cheese is obtained.

During processing, proteases break down soy protein into peptides and amino acids, while soy lipids are also broken down into fatty acids. As a result of ester formation that occurs when alcohol reacts with fatty acids, the flavor of the product is improved (Clifford, 1989).

Humanatto (Black Beans)

It is a soybean product used in certain parts of Japan. The product, which is brown in color, has a flavor similar to that of soy sauce and is used as a flavoring agent and in snack foods. Whole soybeans, soaked in water and steamed, are used for fermentation. Koji produced from roasted wheat or barley is added to the beans. The grains are dried, soaked in salted water and subjected to re-drying. The duration of the procedure varies from 6 to 12 months. The cost of production is high and the product is not of the desired quality in appearance (Clifford, 1989).

Natto

It is a soybean product produced in Japan, China, Taiwan and Thailand. It is consumed with rice as a flavor enhancer or as a sauce. The product is obtained by fermentation of whole soybeans with *Bacillus natto* or sometimes with certain strains of *Bacillus subtilis* (Clifford, 1989). It is formed as a result of inoculating the cooked softened soy with *Bacillus natto* and coating the grains with bacteria in a white sticky way. The surface of the fermented product, which is grey in color, is covered with a sticky substance produced and composed of glutamic acid polypeptides and fructose polymers (Clifford, W.H.,1989; Yokotsuko, T., 1985). The product has a different smell, similar to ammonia. Due to its sticky and slippery appearance, it is not accepted in western societies. It is possible to consume the product by modifying it in different ways, such as covering it with bran flour and smoking (Clifford, 1989).

Soy is soaked in water with the classical method and left overnight. After boiling, heat-resistant spores are sprayed and wrapped with rice stalks, making paper packs of 30-100 grams. The packages are transferred to the incubators and left to cool for 6-8 hours after staying at about 40 °C for 16 hours. It is a product that has been consumed in Japan for 400 years, 1 person in 4 Japanese people consumes it at least once a week. Recently, it has been consumed with the addition of pasta, pizza and sushi (Haytowitz and Matthews, 1989; Karaçil and Acar Tek, 2013; Murooka and Yamshita, 2008; Nagai and Tamang, 2010).

Tempeh (Tempe)

It is a product that is consumed in Indonesia and Malaysia but was unknown in China and Japan until recently. Tempe is a white-colored cake formed by soybeans that are connected by mold mycelium. When tempe is mentioned, it is understood that peeled soybeans are used as a substrate. When another substance is used as a substrate, tempe is referred to by the name of this food. The solid mass left over during tofu making can also be used as a substrate (Ito vd 2020).

The main microorganism used to make tempe in Indonesia is *Rhizopus oligosporus* Saito, and the type strain of this species, NRRL 2710, is also used to make tempe in the United States. *R.arrhizus* Fischer, *R. oryzae* Went and Geerligs, *R. formosaensis* Nakazawa and *R. achlamydosporus* Takeda are among other microorganisms used. In the traditional method, mold residues taken from the previous tempe cake or molds that develop on different plant leaves can be used as inoculates. New methods are being developed to provide a pure inoculum culture(Clifford, 1989).

The cooked soybeans are inoculated with *Rhizopus oligosporus* and then wrapped in banana leaves and kept at 30^{o}C for 40 hours. 1-2 days after fermentation, they are pressed in blocks. The color of the product varies according to the type and mold of soy used. It is consumed by adding it to pasta, pizza, hamburger and sandwich (Murooka and Yamshita, 2008; Nagai and Tamang, 2010; Karaçıl and Acar Tek, 2013). The fermented product can be consumed fresh or eaten after deep frying (Yokotsuko, 1985).

During fermentation, changes occur in the nutrient quality of the tempe. The protein content of the product decreases, the protein quality increases due to the increased bioavailability of some amino acids and the synthesis of other amino acids. With the breakdown of triglycerides, free fatty acids are released. Complex carbohydrates are broken down. There is a decrease in the content of trypsin inhibitors and other antinutritional elements, as well as in the amount of stachyose and raffinose, which are thought to cause gas formation in humans. *The phytase enzyme produced by Rhizopus* *oligosporus* breaks down phytic acid and increases the usefulness of minerals in the body. The nutrient content of tempe varies depending on the fermentation time (Turantaş, 1998).

REFERENCES

Akamine, Y., Millman, J. F., Uema, T., Okamoto, S., Yonamine, M., Uehara, M., Kozuka, C., Kaname, T., Shimabukuro, M., Kinjo, K., Mitsuta, M., Watanabe, H., Masuzaki, H (2022). Fermented brown rice beverage distinctively modulates the gut microbiota in Okinawans with metabolic syndrome: A randomized controlled trial. Nutrition Research (103) 68–81.

Chai C, Kyoung H, Kim SC, Park JG, Lim J, Kwon SW and Lee J. (2012). Determination of bioactive compounds in fermented soybean products using GC/MS and further investigation of correlation of their bioactivities. *Journal of Chromatography* B, 880:42-49.

Chen KI, Erh MH, Su NW, Liu WH, Chou CC and Cheng KC. (2012). Soyfoods and soybean products: from traditional use to modern applications. *Appl Microbiol Biotechnol* 96:9–22

Clifford, W.H., (1989). Fermented Products, Legumes, Chemistry, Technology and Human Nutrition, Matthews, R., H., Ed., Marcel Dekker Inc., New York, 389 p.

Doyle, M. P. (2018). Innovations in Technologies for Fermented Food and Beverage Industries. Springer Switzerland. 331 p.

Haytowitz, D.B., Matthews, R.H. (1989). Nutrient Content of Other Legume Products, Legumes, Chemistry, Technology and Human Nutrition, Matthews, R., H., Ed., Marcel Dekker Inc., New York, 389 p.

Hui, Y. H. (2012). Handbook of Plant-Based Fermented Food and Beverage Technology. CRC Press, London. 771 p.

Hutkins, R. W. (2006). Microbiology and Technology of Fermented Foods. IFT Press Blackwell Publishing, Australia. 457 p.

Ito, M., Ito, T., Aoki, H., Nishioka, K., Shiokawa, T., Tada, H., Takeuchi, Y., Takeyasu, N., Yamamoto, T., Takashiba, S. (2020). Isolation and identification of the antimicrobial substance included in tempeh using Rhizopus stolonifer NBRC 30816 for fermentation. International Journal of Food Microbiology, 325 108645.

Kabak B. ve Dobson A. D. W. (2011). An Introduction to the Traditional Fermented Foods and Beverages of Turkey. *Critical Reviews in Food Science and Nutrition* https://doi.org/10.1080/10408390903569640

Karaçıl M. Ş. ve Acar Tek N. (2013). Dünyada Üretilen Fermente Ürünler: Tarihsel Süreç ve Sağlık ile İlişkileri. U. Ü. Ziraat Fakültesi Dergisi 27(2): 163-173.

Kim D. Y., Kim, J., Shin, H. (2022). Improving the quality of fermented soybean products using low-frequency airborne ultrasonicated Koji. LWT - Food Science and Technology 168 113936.

Lotong, N., (1985). Koji, Microbiology of Fermented Foods, Vol. II, Wood, B., J., B., Elsevier Applied Science Publishers Ltd., London, 371 p.

Nagai T and Tamang JP. (2010). Fermented Legumes: Soybean and Non-Soybean Products. In: Fermented Foods and Beverages of the World, Tamang JP, Kailasapathy K (ed), CRC Press Newyork, United States of America, pp. 191-254.

Nilüfer D., Boyacıoğlu D. (2008). Soya ve soya ürünlerinin fonksiyonel gıda bileşenleri GIDA, 33 (5) : 241-250.

Ray, R. C., Montet, D. (2015). Microorganisms and Fermentation of Traditional Foods. CRC Press, Boca Raton. 373 p.

Tamang JP and Kailasapathy K (ed). (2010). Fermented Foods and Beverages of the World. CRC Press Newyork, United States of America, 435 p.

Tamang JP and Samuel D. (2010). Dietary Cultures and Antiquity of Fermented Foods and Beverages. In: Fermented Foods and Beverages of the World, Tamang JP, Kailasapathy K (ed), CRC Press Newyork, United States of America, pp. 1-40.

Tamang JP. (2010). Diversity of Fermented Foods. In: Fermented Foods and Beverages of the World, Tamang JP, Kailasapathy K (ed), CRC Press Newyork, United States of America, pp. 41-84.

Tamang, J. P. (2011).Hımalayan Fermented Foods Microbiology, Nutrition, And Ethnic Values. CRC, Press London. P. 285.

Turantaş, F., (1998). Food Microbiology, Ünlütürk, A., Turantaş, F., Ed., 1. Edition, Mengi Tan Press, 605 pp.

Wolf, W., I., Cowan, J., C., (1975). Soybeans as a Food Source, Revised Edition, CRC Press Inc., Ohio, 101 p.

Yokotsuko, T., (1985). Fermented Protein Foods in the Orient, with Emphasis on Shoyu and Miso in Japan, Microbiology of Fermented Foods, Vol. I, Wood, B., J., B., Elsevier Applied Science Publishers Ltd., London, 371 p.

CHAPTER 14

RELATIONSHIP BETWEEN YIELD COMPONENTS AND BIRD DAMAGE IN HYBRID SUNFLOWER VARIETIES UNDER RAINFEED CONDITION

Assoc. Prof. Dr. Ismail DEMIR[1]

[1] Kırşehir Ahi Evran University Faculty of Agriculture Department of Field Crops, Kırşehir, Turkey Orcid ID:0000-0002-8950-5253
E-mail: ismail.demir@ahievran.edu.tr

1. INTRODUCTION

Sunflower (Helianthus annuus L.), belonging to the Asteraceae family, is one of the fourth most widely grown oilseed crops in the world. World sunflower production was 50,2 million tons from an area of 27,9 M ha in 2020 (FAO, 2022). It is cultivated mostly in Russia, Ukraine, Argentina, Romania, Tanzania and China in the world, and the highest production comes from Russia, Ukraine, Argentina, China, Romania and Turkey, respectively.

The cultivation of sunflower in so many different countries is due to the plant's ability to adapt to various climatic and soil conditions (Canavar et al., 2010; Demir, 2016). With the use of hybrid varieties in sunflower agriculture, a significant increase in yield has been achieved (Demir, 2020a). Hybrid sunflower varieties show more stability than non-hybrid varieties (Demir, 2020b). Hybrid varieties provide higher and more stable yields as they exhibit low genotype-environment interaction (Göksoy et al., 1999).

Flocks of granivorous birds, ranging in size from a few to millions, can be found in every sunflower growing region, causing serious economic losses (Linz et al. 2011). Sparrows (Emberizidae, Passeridae), doves, and crows (Corvidae) caused most of the damage in Europe, whereas parakeets and parrots did the similar damage in India (De Grazio, 1989). There are several bird families that damage ripening sunflower in different countries. Recently, house sparrows (Emberizidae, Passeridae) and doves (Columbidae) have caused most of the damage in Kırşehir, Turkey. Regional surveys of bird damage to sunflowers reached to 25% of a field as reported in various countries (Bomford, 1992; Linz and Hanzel, 1997; Khaleghizadeh, 2011). Kıllı et al. (2004) reported that sowing date played an important role on bird dame and bird damage rate changed 62% to 85% in Kahramanmaraş Province. Seed yield of the sunflower cultivars is determined by genetic and environmental factors along with interaction between them. Uncertainties in climatic conditions, especially in addition to the irregularities in the amount of precipitation, heat stress significantly affects the yield of sunflower. In addition, bird damage in sunflowers significantly reduces production and causes economic losses. Therefore, the aim of this study is to determine the seed yield and oil content of sunflower cultivars and to determine which cultivars are less affected by bird damage in arid and rainy conditions.

2. MATERIALS AND METHODS

This study, which aims to compare the yield and yield components of different oil hybrid sunflower varieties and to determine the bird damage rate of the varieties, was carried out in Kırşehir Ahi Evran University Faculty of Agriculture Research and Application Area in 2017. The trial area is located at an altitude of 1045 meters above sea level, at 39.14° North latitude and 34.11° East longitude.

According to soil analysis, experimental soil was salt-free, clayed-loamy textured, low in organic matter and slightly alkaline reaction. It was classified as poor soil in terms of available phosphorus, but rich in potassium (Table 1).

Table 1. The results of soil analysis in trial areas

Texture	Ph	Ec (mmhos/ Cm)	Salinity (%)	Available P_2o_5 (Kg Ha^{-1})	$Caco_3$ %	Available K_2o (Kg Ha^{-1})	Om (%)
Clayed-Loamy	7.59	0.52	0.02	21.4	27.90	666.2	1.81

According to the climatic data (as can be seen in Table 2), the relative humidity between April and September (the period the study was conducted) was slightly below the long-term annual average in 2017.

Table 2. Meteorological data of research area

	Total Precipitation (mm)		Mean Temperature (°C)		Relative Humidity (%)	
April	29	42.4	10.7	10.9	52.4	63.3
May	49.9	45.6	15.2	15.4	59.5	61.3
June	18.4	36.4	20.7	19.7	54.3	55.5
July	0.4	8.9	26	23.3	36.1	48.9
August	16	8.8	25.6	23.4	43.2	48.1
September		14.5	23.1	19.1	31.6	51.6
Total/Mean	113.7	156.6	20.2	18.6	46.2	54.8

Total precipitation of sunflower cultivation period (April to September) was 113,7 mm in 2017, which was below the long-term average precipitation values. Total monthly precipitation was observed as irregular and below during the months of sunflower cultivation. Temperature values during the cultivation period were above the long-term average for the region.

The experiment was set-up in a randomized complete block design with three replications and eleven hybrid sunflower cultivars cultivars (Bosfora, LG5550, LG5580, Maximus, Reyna, Sanay, Sanbro, Sirena, Tarsan, Transol and Tunca) were used to determine seed yield, oil yield and bird damage on sunflower cultivars in 2017 at the Research Farm of Ahi Evran University in Kırşehir Province. Based on soil analysis, all trial parcels were fertilised with 80 kg N ha-1 and 60 kg P ha-1. Seeds were planted to the 6 m to 4.2 m parcels in 6 rows at 70 x 30 cm intervals on the second week of April (13 April 2017). The sunflower seeds were sown by putting three seeds to hills by hand. Post emergence, plants were thinned to one plant per hill 15 days after sowing. The trial was established in the 150 ha sunflower cultivated area so that the bird damage was homogeneously detected. Seed yields were obtained from an area 2.8 m wide and 5 m long of the center 4 rows of each plot. Plants in the two rows of the center four rows of each plot were protected by placing a cloth bag over the head after fertilization of the flowers. Fertilization of the flowers was indicated by withering and receding of the stigmas (Kıllı et al., 2004). Heads of plants in the other row were not protected in order to determine the bird damage. Average protected seed yield (APSY), unprotected seed yield (AUPSY) and yield loss or bird damage (BD) per head were recorded. Bird damage was calculated as: [(APSY – AUPSY) / APSY] x 100. Data were analysed by using MSTAT-C statistical program. LSD test was used to compare the means.

3. RESULTS AND DISCUSSION

Plant height

The differences occurred as a result of variance analysis of plant heights of sunflower cultivars were found to be significant at $P<0.01$ probability level. Plant height varies according to varieties, ecological conditions, and agricultural practices (Demir, 2020a). In the study, plant height values varied between 118.33 cm and 139.83 cm (Table 3). While the highest plant height was observed from Bosfora variety, the lowest plant height was obtained from Tunca variety. Tunca cultivar was the lowest plant height with 118.33 cm and Reyna was second lowest but there was no statistical difference with Reyna and Tunca in terms of plant height. The average plant height of the cultivars was calculated as 129.61 cm. Higher plant is not suitable for machine harvesting, and it also causes plant lodging. In semi-arid climate conditions, precipitation is an important factor since there is no irrigation at rainfed agriculture. It can also be evaluated as the response of varieties to drought stress in dry farming conditions. These differences in plant height may also be attributed to the genetic potential of hybrids and the other prevailing environmental conditions, especially precipitation and temperature (Demir, 2020b).

Head diameter

Comparative performance of head diameter in sunflower hybrids depicted that the differences between the observed head diameter values of hybrid sunflower cultivars were statistically significant at the $P<0.01$ significance level as a result of variance analysis. The head diameter values of the cultivars varied between 16.47 cm and 21.33 cm. Among the sunflower varieties, the highest head diameter was observed in the Sirena variety, while the lowest head diameter was observed in the Sanay variety. The average head diameter of the cultivars was 18.60 cm. The results were in accordance with Sassikumar and Gopalan (1999), Goksoy et al. (1999), Khan (2003) and Demir (2020) who reported significant genetic differences for head diameter among hybrids. Head diameter is among the yield parameters that affect the yield at a significant level. The head diameter of sunflowers may differ depending on the ecological conditions, cultivation techniques, soil structure, and whether or not irrigation is applied (Gürbüz et al., 2003, Arıoğlu, 2007, Demir, 2019a). There is generally a direct proportion between the large diameter of the head and the number of grains in the head, and this feature can directly affect the seed yield. In this study, the variety with the highest head diameter did not have the highest seed yield. Although the head diameter is very large in dry conditions, it does not always provide the highest yield due to the low number of full grains in the head.

Table 3. Some agronomic characters of sunflower cultivars

	Plant Height (cm)	***Head diameter (cm)***	***Thousand-seed Weight (g)***
$MS_{cultivars}$	165.47**	5.51**	110.80**
CV(%)	3.70	4.06	4.51
Cultivars			
Bosfora	139.83a	19.17bc	61.33a
LG5550	138.50ab	18.57bcd	57.43abc
LG5580	134.00abc	18.10cde	56.40abcd
Maximus	131.67abc	18.67bc	43.60f
Reyna	118.60d	18.40cd	44.53f
Sanay	127.60bcd	16.47e	46.17ef
Sanbro	125.07cd	20.20ab	56.43abcd
Sirena	137.07ab	21.33a	51.50de
Tarsan	125.73cd	18.37cd	52.83cd
Transol	129.33abcd	18.53bcd	59.57ab
Tunca	118.33d	16.83de	55.27bcd
Mean	129.61	18.60	53.19
LSD	11.13	1.75	5.57

*, ** significant at the 0.05 and 0.01 level, respectively. For each main effect, values within columns MS: mean squares, CV: Coefficient of variation, LSD: Least Significant Difference, means within a column followed by the different letters are significantly different p = 0.01. ("ns": not statistically significant; * and **: statistically significant for a significance level of $P<0.05$ and $P < 0.001$ respectively).

Thousand-seed weight

The difference in thousand-seed weight between sunflower cultivars was statistically significant at the $P<0.01$ significance level. The thousand grain weight of the cultivars varied between 43.60 g and 61.33 g. While the highest thousand kernel weight value was observed from Bosfora variety, the lowest thousand kernel weight was observed from Maximus variety. The average thousand-grain weight of the cultivars used in the study was 53.19 g. Maximus cultivar was the lowest thousand-seed weight with 43.60g and Reyna was second lowest but there was no statistical difference with Reyna and Maximus in terms of thousand-seed weight. Thousand seed weight is one of the major yields contributing attributes (Akcay and Dagdelen, 2016).

Kernel ratio

Average kernel ratio of sunflower variety grown under semi-arid and rainfed condition and their variance analysis were given Table 4. The kernel ratio differences of sunflower cultivars were statistically significant at P<0.01 significance level. While the highest kernel ratio was 73.57%, the lowest kernel ratio was determined as 66.60%. The average kernel ratio of cultivars was determined as 70.39%. While the highest core ratio was obtained from LG5580 variety, the lowest core ratio was obtained from LG5550 variety. Kernel ratio directly affects crude oil ratio in sunflower. The high kernel ratio makes a positive contribution to the crude oil content and oil yield. Therefore, it is very important quality criterion. EL-Shaer et al. (1993) mentioned that sunflower seeds contained approximately 30 % hull and 70% kernel, and the hulls contain the high fiber, low protein and high wax and only 2 - 3 % oil (Gamea, 2003). Kernel ratio had a positive relationship with crude oil rate.

Table 4. Some agronomic characters of sunflower cultivars

	Kernel Ratio (%)	***Bird Damage (%)***	***Crude oil rate (%)***
$MS_{cultivars}$	12.67**	25.61**	8.47**
CV(%)	1.83	14.86	2.46
Cultivars			
Bosfora	69.77bcd	11.00d	47.30ab
LG5550	66.60e	12.13cd	43.70cd
LG5580	73.57a	15.40abcd	48.30a
Maximus	70.53bcd	15.93abcd	43.17d
Reyna	71.40abc	17.53ab	43.67cd
Sanay	67.80de	18.03ab	45.37bcd
Sanbro	69.53cde	18.87a	45.97abc
Sirena	69.60cd	17.13abc	45.30bcd
Tarsan	72.73ab	18.47a	45.13bcd
Transol	70.70abcd	12.87bcd	46.63ab
Tunca	72.03abc	11.83cd	47.40ab
Mean	70.39	15.38	45.63
LSD	2.99	5.31	2.61

*, ** significant at the 0.05 and 0.01 level, respectively. For each main effect, values within columns MS: mean squares, CV: Coefficient of variation, LSD: Least Significant Difference, means within a column followed by the different letters are significantly different p = 0.01. ("ns": not statistically significant; * and **: statistically significant for a significance level of P<0.05 and P < 0.001 respectively).

Bird Damage (%)

According to the results of different sunflower varieties calculated bird damage values were varied from 11.00% to 18.87%. Calculated bird damage data differed between cultivars and this difference was statistically significant at the P<0.01 significance level. from Bosfora variety with 11.00%. Mean bird damage of sunflower varieties was 15.28%. While the highest bird damage rate of sunflower varieties was obtained from Sanbro variety with 18.87%, the lowest bird damage rate was obtained Although the highest bird damage rate was observed in Sanbro cultivar, there was no statistical difference between Tarsan and Sanbro variety. According to the observation of Khaleghizadeh (2011), the sunflower heads suffering lower bird damage had special characteristics such as greater diameter, flat and convex shape (edges curled outside), fewer angles to the horizon, more down-faced heads, open and longer bracts, longer distances between adjacent stems or heads, longer distance of petiole from head, and lower seed density. The present bird damage results and Khaleghizadeh (2011)' study concluded that choosing the proper hybrid sunflower cultivar is very important for economic and efficient seed yield production and decrease of bird damage.

Crude oil rate

It was determined that hybrid sunflower cultivars were different in terms of crude oil yield and this difference was statistically significant at the P<0.01 significance level. Crude oil yield ranged from 760.40 kg/ha to 1097.00 kg/ha. The highest crude oil yield was 1097.00 kg/ha from the Transol variety. The lowest crude oil yield was obtained from Reyna variety with 760.40 kg/ha. Since there was no statistical difference between the crude oil yield obtained from the Reyna variety and the crude oil yield obtained from the Bosfora variety, both varieties were in the highest crude oil yield group. The average crude oil yield of the cultivars was 931.91 kg/ha. The crude oil yield is obtained by multiplying the seed yield by the crude oil ratio. Increases and decreases in seed yield affect crude oil yield at a higher level (Table 5). Seed oil content is affected by genotype, environmental conditions and cultural practices (Harris et al., 1978; Dedio, 1985; Amir and Khalifa, 1991; Esechie et al., 1996).

Seed yield

It was determined that hybrid sunflower cultivars were different in terms of seed yield and this difference was statistically significant at the P<0.01 significance level. The seed yield ranged from 1740.00 kg/ha to 2353.30 kg/ha. The highest seed yield was 2353.30 kg/ha from the Transol variety. The lowest seed yield was obtained from Reyna variety with 1740.00 kg/ha. The average seed yield of the varieties was 2040.30 kg/ha (Table 5). The environmental factors, especially from flowering to seed-filling, affect seed yield dominantly (Petcu et al., 2001; Monotti, 2003; Ali et al., 2009). In the present study, seed yield of 1740.00-2353.30 kg/ha were similar to those obtained previously researches in Turkey and the other countries (Özer et al., 2004, Ali et al., 2012, Sincik et al., 2013 Demir, 2019a) but lower than those reported by some other authors (Sarwar, et al., 2013, fetri et al., 2013, ada and Tamkoç, 2015).

Table 5. Some agronomic characters of sunflower cultivars

	Seed Yield kg/ha	***Crude oil yield kg/ha***
$MS_{cultivars}$	102370.0**	30298.9**
CV(%)	4.63	4.79
Cultivars		
Bosfora	2276.70ab	1075.30a
LG5550	1976.70d	863.70cd
LG5580	1866.70de	900.80c
Maximus	1983.30d	856.60cd
Reyna	1740.00e	760.40d
Sanay	1936.70de	879.00c
Sanbro	2240.00abc	1029.80ab
Sirena	2070.00bcd	937.20bc
Tarsan	2050.00cd	926.20bc
Transol	2353.30a	1097.00a
Tunca	1950.00de	925.00c
Mean	2040.30	931.91
LSD	219.63	103.67

*, ** significant at the 0.05 and 0.01 level, respectively. For each main effect, values within columns MS: mean squares, CV: Coefficient of variation, LSD: Least Significant Difference, means within a column followed by the different letters are significantly different p = 0.01. ("ns": not statistically significant; * and **: statistically significant for a significance level of P<0.05 and P < 0.001 respectively).

Previous literature reported seed yield values change from 1662 to 5563 kg/ha. The high variations in seed yield values can be due to genetic potential of cultivars, environmental conditions and agricultural practise.

Oil yield

According to the results of different sunflower varieties calculated oil yield values were varied from 760.40 kg/ha to 1097.00 kg/ha. Calculated oil yield data differed between cultivars and this difference was statistically significant at the P<0.01 significance level. The amount of oil calculated on the basis of seed yield and oil content per hectare is very important in terms of oil yield obtained. The highest average oil yield (1097.00 kg /ha) was obtained from Transol, while the lowest average oil yield (760.40 kg/ha) was obtained from Reyna. Although Transol cultivar had the highest crude oil yield, there was no significant differences between Transol and Bosfora variety in terms of crude oil yield. It is seen that these differences were related to variations in yield components, especially seed yield.

CONCLUSION

In the in the it is aimed that to determine the yield and yield components of eleven hybrid sunflower varieties. Also, the resistance of sunflower cultivars to bird damage was investigated in rainfed conditions. Yield and yield components of sunflowers cultivars in rainfed and arid conditions generally showed considerable sensitivity to climate conditions. Therefore, climate condition, especially rainfall during the growing season is very important to take sufficient yield in rainfed conditions.

When the yield and yield parameters are compared by the sunflower varieties, the highest plant height (Bosfora), head diameter (Sirena), 1000 seed weight (Bosfora), kernel ratio (LG5580), bird damage (Sanbro and Tarsan), seed yield (Transol), oil rate (LG5580) and oil yield (Taransol and Bosfora) are compared. When the yield and yield parameters of the cultivars were compared under dry farming conditions, very significant differences were observed. These differences are thought to be due to both climatic conditions and genetic abilities. When evaluated as the final product, the most important parameter is seed and oil yield. While Transol variety differed significantly from other cultivars in terms of both seed and oil yield, Bosfora variety was in the same highest group in term of crude oil yield. In terms of bird damage, which causes significant economic loss in sunflower, the lowest bird damage rate is calculated with 11.00% from Bosfora variety, while the highest bird damage is 18.87% and 18.47% for Sanbro and Tarsan varieties, respectively. It was observed that Transol and Bosfora cultivars provided better results for similar region conditions.

4. REFERENCES

Akcay, S. and N. Dagdelen (2016). Water use efficiency, yield and yield components of second crop sunflower under deficit irrigation. *Turk J Field Crops* 21: 190-199.

Ali, Q., M. Ashraf and F. Anwar. 2009. Physico-chemical attributes of seed oil from drought stressed sunflower (Helianthus annuus L.) plants. *Grasas y Aceites*. 60: 475-481.

Amir, H. and F. Khalifa (1991). Performance and yield of sunflower (Helianthus annuus) cultivars under rainfed and irrigated conditions in Sudan. *The Journal of Agricultural Science* 116(2): 245-251.

Anandhan, T., N. Manivannan, P. Vindhiyavarman and P. Jeyakumar (2010). Correlation for oil yield in sunflower (Helianthus annuus L.). *Electronic Journal of Plant Breeding* 1(4): 869-871.

Bomford M . 1992. Review of research on control of bird pests in Australia. Pages 93–96 in Borrecco JE Marsh RE , eds. *Proceedings of the Fifteenth Vertebrate Pest Conference* . University of California Press.

Canavar, Ö., Ellmer, F., Chmielewski, F.M., 2010. Investigation of yield and yield components of sunflower (Helianthus annuus L.) cultivars in the ecological conditions of Berlin (Germany). *Helia*, 33 (53), 117

Chikkadevaiah, Sujatha, H.L. and Nandini. 2002. Correlation and path analysis in sunflower. *Helia*, 25: 109 −118.

De Grazio JW. 1989. Pest birds: An international perspective. Pages 1–8 in Bruggers RL, Elliot CCH, eds. Quelea quelea: Africa's Bird Pest. Oxford University Press.

Dedio, W. (1985). Effects of seeding and harvesting dates on yield and oil quality of sunflower cultivars. *Canadian journal of plant science* 65(2): 299-305.

Demir, İ., 2016. Determination of the yield and yield components performance of some sunflowers (Helianthus annuus L.) under rainfed conditions. *19th International Sunflower Conference*. Edirne, Turkey, 985-992.

Demir, I. (2019a). The effects of sowing date on growth, seed yield and oil content of sunflower (Helianthus annuus L.) cultivars under rainfed conditions. *Fresenius Environmental Bulletin*, 28(9), 6849-6857.

Demir, İ. (2019b) Bazı hibrid ayçiçeği çeşitlerinin sulu ve kuru koşullarda verim ve verim öğelerindeki değişimler. *Uluslararası Tarım ve Kırsal Kalkınma Kongresi*, Siirt

Demir, İ. (2020a). Inter and intra row competition effects on growth and yield components of sunflower (Helianthus annuus L.) under rainfed conditions. *The Journal of Animal &Plant Sciences*, 30(1), 2020.

Demir, İ. (2020b). Comparing The Performances of Sunflower Hybrids in Semi-Arid Condition. *Türk Tarım ve Doğa Bilimleri Dergisi*, 7(4), 1108-1115.

El-Shaer, M. S., Abdelazez, A., Kandel. M. H.and Elsayed. (1993).Oil and suger crops, book. Faculity of Agricultural. Cairo university, Egypt

Esechie, H., S. Elias, V. Rodriguez and H. Al-Asmi (1996). Response of sunflower (Helianthus annuus) to planting pattern and population density in a desert climate. *The Journal of agricultural science* 126(4): 455-461.

FAO. 2022. Food and Agriculture Organization of the United Nations http://www.fao.org/faostat/en/#data/QC (Accessed September 22, 2022)

Gamea G. R., 2003. Physical Properties of Sunflower Seeds Components Related to Kernel Pneumatic Separation. *International Journal of Engineering & Technology IJET-IJENS* Vol:13 No:01.

Göksoy, A. T., A. Türkeç and Z. M. Turan (1999). A Research on Determination of Superior Hybrid Combinations in Sunflower (Helianthus annuusL.). *Turkish Journal of Agriculture and Forestry* 23(1): 25-30.

Harris, H. C., J. McWilliam and W. Mason (1978). Influence of temperature on oil content and composition of sunflower seed. *Australian Journal of Agricultural Research* 29(6): 1203-1212.

Khaleghizadeh A., 2011. Effect of morphological traits of plant, head and seed of sunflower hybrids on house sparrow damage rate. *Crop Protection*, 30, 360-367

Killi F., Kilic B. & Goner K. 2004. The effect of different planting dates on the extent of bird damage in confection and oilseed sunflowers. Journal of Agronomy 3(1): 36–39.

Linz, G. M., & Hanzel, J. J. (1997). Birds and sunflower. *Sunflower technology and production*, *35*, 381-394.

Mijić, A., I. Liović, Z. Zdunić, S. Marić, A. Marjanović Jeromela and M. Jankulovska (2009). Quantitative analysis of oil yield and its components in sunflower (Helianthus annuus L.). *Romanian Agriculture Research* 26: 41-46.

Monotti, M. 2003. Growing non-food sunflower in dryland conditions. *Ital. J. Agron*. 8: 3-8.

Petcu, E., A. Arsintescu and D. Stanciu. 2001. The effect of drought stress on fatty acid composition in some Romanian sunflower hybrids. *Roman. Agric. Res*. 15: 39-43.

Ramasubrahmanyam, S.V., Ranganatha A.R.G. and S. Sudeer Kumar. 2002. Genetic variability for seed yield and seed parameters in sunflower. J. *Oilseeds Res*., 19: 171- 174.

Teklewold A., Jayaramaiah H., Ramesh S., 1999. Genetic variability studies in sunflower (Helianthus annuus L.). *Crop Impro*., 26 (2): p. 236-240.

Volkan, G. Ü. L., & Çoban, F. (2020). Determination of yield and quality parameters of oil sunflower genotypes grown in Turkey. *Turkish Journal Of Field Crops*, 25(1), 9-17.

Sarwar, M.A., Khalil-Ur-Rahman, M.N., Javeed, H.M.R., Ahmad, V., Shehzad, M.A., Iqbal, S. & Abbas, H.T. (2013). Comparative performance of various sunflower hybrids for yield and its related attributes. *Cercetări Agronomice în Moldova*, 4 (156): 57-64

Özer, H., Polat, T., & Öztürk, E. (2004). Response of irrigated sunflower (Helianthus annuus L.) hybrids to nitrogen fertilization: growth, yield and yield components. *Plant Soil Environ*., 50 (5): 205– 211

Ali, A., Ahmad, A., Khaliq, T. & Akhtar, J. (2012). Planting density and nitrogen rates optimization for growth and yield of sunflower (Helianthus annuus L.) hybrids. *The Journal of Animal & Plant Sciences*, 22(4): 1070-1075.

Sincik, M., Goksoy, A.T. & Dogan, R. (2013). Responses of sunflower (Helianthus annuus L.) to irrigation and nitrogen fertilization rates. *Zemdirbyste-Agriculture*, 100 (2): 151-158.

Fetri, M., Ghobadi, M.E., Asadian, G. & Rajabi, M. (2013). Effect of sowing date on yield and yield components of sunflower (Helianthus annus L.). *Annals of Biological Research*, 4 (2): 90-93

Canavar, Ö., Ellmer, F. & Chmielewski, F.M. (2010). Investigation of yield and yield components of sunflower (Helianthus annuus L.) cultivars in the ecological conditions of Berlin (Germany). *Helia*, 33: 117-130.

Ada, R. & Tamkoç, A. (2015). Determination of some agricultural characteristics in the sunflower genotypes developed as second crop. Selcuk J Agr. Food Sci., 29(2):44-50.

CHAPTER 15

SOYBEAN AS A PROTEIN SOURCE FOR PLANT-BASED MEAT ALTERNATIVES

Dr. Ceyda SOBELI[1]

[1] Manisa Celal Bayar University, Faculty of Engineering, Department of Food Engineering, Manisa, Turkey. Soy Bean as a Protein Source in Plant-Based Meat Alternatives,. ORCID: 0000-0001-8275-8410; e-mail:ceyda.zengin@cbu.edu.tr

1. INTRODUCTION

Soybean, *Glycine max (*L.*),* is a popular plant of Asian origin belonging to the family *Leguminosae* and subfamily *Papilionaceae* and a major source of vegetable protein in the world. (Grassini et al., 2021; Mahmudiono et al., 2022; Pratap et al., 2012). It is also called as "Shu" in ancient Chinese and one of the five main plant foods in China along with rice, wheat, barley and mille (He & Chen, 2013). Soybean was first introduced to Southeast Asia, then to Europe in 18th century and to America in 19th century. Since 1940s, soybean has become one of the most important economic crops in America (He & Chen, 2013). Worldwide producers of soy bean are USA, Brazil, Argentina, China and India with world production volumes of 35%, 28%, 17%, 4% and 3%, respectively (Rizzo & Baroni, 2018).

Soybean is considered as an important food source to meet protein demand for the human (Pratap et al., 2012; Qin et al., 2022). Soybean consists of high amount of fiber, protein, oil, minerals, vitamins, phytochemicals, antioxidants, and unsaturated fatty acids and used for supplying calories (Mahmudiono et al., 2022; Medic et al., 2014). Soybean contains 35–40% protein on a dry-weight basis, of which, 90% is comprised of two storage globulins, 11S glycinin and 7S β-conglycinin. These proteins contain all amino acids essential to human nutrition with the highest amino acid score and closest to the standard set by the Food and Agriculture Organization (FAO) and World Health Organization (WHO), which makes soy products almost equivalent to animal sources in protein quality but with less saturated fat and no cholesterol (Burssens et al., 2011; Dixit et al., 2011).

Nowadays, the soy consumption has risen greatly because there is an increase in the amounts of commercial soy-based foods. Some products have become progressively widespread and they are mostly consumed by individuals, such as soy sauces and soy-based beverages. On the other hand, soy protein products are largely used as ingredients in meat products, breads, soups, and beverages, among others. Besides this, new soy foods including cheese, salami, drinks and plant based meat alternatives are also continuously being developed (Villares et al., 2011).

In this chapter, the use of soybean products (soy isolates, textured soy protein, soy flour) for plant-based meat alternatives was reviewed.

2. PLANT-BASED MEAT ALTERNATIVES

Research on plant-based meat alternatives has increased since 2010. There are various reasons for this increase, such as health benefits and environmental factors that create problems in meat consumption, like animal welfare. Ethical concerns about animal welfare and slaughter have led consumers to reduce their meat consumption or to remove it completely from their diets. Instead, consumers began to consume plant based meat alternatives (Baune et al., 2022; Herz et al., 2021; Jung et al., 2022; Michel et al., 2021; Zheng et al., 2022). The reason of this choice may be the rapid increase in the world population and the consequent limited natural resources, which also makes animal protein production an increasingly unsustainable practice (Dekkers et al., 2018). Besides, since meat products have higher prices than vegetable proteins, the food industry started up to produce nonmeat products (Asgar et al., 2010).

Plant based meat alternatives are defined as meat-like products that resemble meat in the texture, flavour, and appearence as much as the nutritional quality but made from non-animal protein sources (Alcorta et al., 2021; Boukid, 2021; Chantanuson et al., 2022; Chiang et al., 2021; Yuliarti et al., 2021; Zhao et al., 2022). These products have lower fat content, are higher in dietary fiber and so have more desirable nutritional value that make them a good alternative to animal-based meat products (Zhao et al., 2022). To obtain the sustainability of these products, researches on meat alternatives have focused on the physical characteristics besides the nutritional quality (Kyriakopoulou et al., 2021; Messina et al., 2022).

3. SOYBEAN PRODUCTS USED IN THE MANUFACTURING OF MEAT ALTERNATIVES

Various plant protein sources are used to produce meat alternatives such as soy protein, wheat gluten, pea, peanut lupin and mung bean obtaining similar texture and taste like meat (Ahmad et al., 2022; Bakhsh et al., 2021; Chiang et al., 2021; Qin et al., 2022; Yuan et al., 2022). Among these, soy protein derived from soybean has an important role in order to meet the protein needs of consumers by being rich in nutrients and possessing excellent gelling properties and other characteristic functional properties such as water-holding, fat-absorbing and emusifying capacities (Ahmad et al., 2022; Jung et al., 2022;

Kyriakopoulou et al., 2018; Qin et al., 2022). Soy proteins are the most extensively used raw materials for meat-alternative products because of their low cost, global availability and processing capabilities (Chantanuson et al., 2022).

Soybean meal (defatted soyben flake; a by-product remaining after oil extraction) is used to obtain soybean protein products. These include textured soy proteins, soy flour (56-59% protein); soy protein isolates (≥90% protein); and soy protein concentrates (65%-72% protein) (Ahmad et al., 2022; Balandrán-Quintana et al., 2019; Colletti et al., 2020; Kyriakopoulou et al., 2018). The defatted and ground soybean grains are subjected to a solvent removal-toasting process before processing into soybean meal. The aim is to remove residual hexane and inactivate anti-nutritional factors such as lectins and protease inhibitors (Balandrán-Quintana et al., 2019).

Textured soy protein (TSP) is the most popular raw material used in the production of plant based meat alternatives and also known as soy nuggets or granules (Ali, 2010; Strahm, 2006). TSP is produced by extrusion technology from defatted soybeans or flour, and isolated soy protein concentrates (Katayama & Wilson, 2008). In the extrusion of protein-based formulations with high moisture content, the cooling die at the end of the barrel provides the formation of a fibrous meat-like structure. This type of die ensure the preservation of moisture in the product and the formation of the fibrous structure (Figure 1) (Saerens et al., 2021).

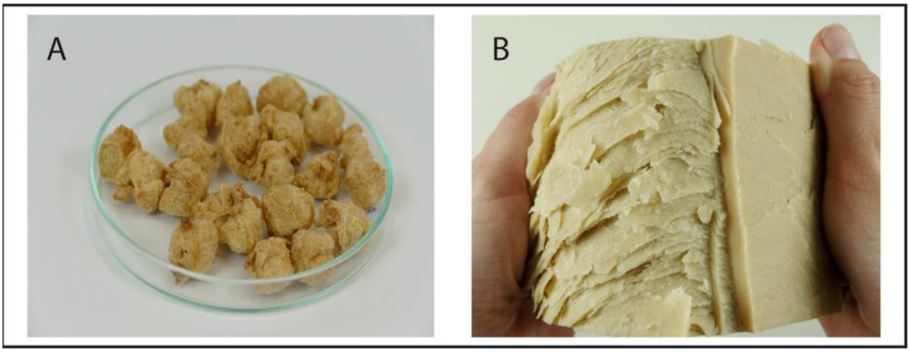


Figure 1. Extrusion Products from Soy Concentrate; (A) TSP Balls; (B) Fibrillar Texture of High Moisture Extrusion (Saerens et al., 2021)

TSP allows product to have different size and shape (Alcorta et al., 2021). Soy protein concentrate made by aqueous alcohol washing is the most used material for TSP (Sha & Xiong, 2020).

Textured soy protein has been widely used in food industry because of and its high nutritional value (containing app. 50% protein and other nutrients) and its high imitation of texture, taste, appearance of meat (Fang et al., 2014). The protein content and quality of the plant-based protein sources are generally lower because of one or more essential amino acid deficiencies (Van Mierlo et al., 2022). However, TSP provides a digestible protein source with the digestibility for 66.1% for TSP defatted soy flour and TSP protein concentrate, respectively (Rizzo & Baroni, 2018).

Soy protein isolate (SPI) is the highly refined and purified form of protein from soybean, with a protein content of more than 90% on a dry-matter basis. Due to its high protein content, soy protein isolate is frequently used in the food industry to improve food quality, including meat alternatives. In addition, SPI is one of the few types of plant protein that can replace animal protein for its effects such as lowering blood lipids and cholesterol. SPI has an important role in establishing viscoelastic textural properties in plant-based meat alternatives (Zheng et al., 2022).

Although SPI is the main raw material used in meat analogues having the advantages of high nutritional quality, broad supply source, and low cost, it produces an undesirable off-flavor, which is a major drawback to its utilization in plant- based meat analogues (Li & Li, 2020).

Soybean isolates and concentrates are obtained by simply crushing defatted soybeans. Soy isolates are subjected to precipitation at low acidic pH following extraction in alkaline solution and have 90% protein content, while soybean concentrates are extracted in liquid alcohol and have a protein content of 70%. Besides being high in protein, soy protein isolate has a light colour and a bland flavour compared to other proteins. which is a desirable characteristic for the formation of meat alternatives (Ahmad et al., 2022).

Soy flour is the least processed soy product and is used both in the preparation of textured soy protein and soy protein concentrate and isolate (Alcorta et al., 2021). Different kinds of flours are present in the market as full fat and defatted flours because of being made with or without removal of oil during processing (Ali, 2010). Defatted flour can be synthesized by mashing the flakes of soy that is defatted and it contains the protein about 50% (Ahmad et al., 2022).

The use of soy protein products in meat alternatives and the influence of the products on the quality characteristics of meat alternatives were shown in Table 1.

Table 1. Soy Protein Products and Effect on Quality Characteristics of Meat Alternatives (Malav et al., 2015)

Attributes	**Product based on**		
	Soy flour	**Soy concentrate**	**Soy isolate**
Flavor	Moderate to high	Low	Low
Retort stable	Yes	Yes	Yes
Flavor development on retorting	High	Low	Low
Flatulence	Yes	No	No
Form/shape	Granules or chunks	Granules or chunks	Fibers
Cost (dry basis)	Low	Low	Low
Recommended hydration level	2:1	3:1	4:1
Fat retention	Moderate	High	Moderate
Optimum usage level in meat extension	15-20	30-50	35-50

There are few studies about the soy protein products in manufacturing meat alternatives by using various processing techniques. Lin et al., (2002) studied 90% SPI and 10 % WS by using high moisture extrusion. They found that the product had strong toughness and chewiness and more layered and fibrious structure. In another study Macdonald et al. (2009) were used the same ratios and extrusion technique and they concluded that the products had high degree of fibrosis, ordered directional structure and no change were observed in nutritional value. Grahl et al., (2018) studied the spiriluna and soy protein concentrate on sensorial quality of plant based alternatives. They investigated that high spirulina content caused a black color, an intense flavor with earthy notes and an algae odor; and also, the higher the share of spirulina, the lower were the elasticity, fibrousness and firmness of extruded samples.

Samard et al. (2019) aimed to investigate the effect of wheat gluten on physicochemical properties of meat alternatives and concluded that wheat gluten addition contributed to textural structure of extrudates to be fibrous and compact as much as muscle meat.

Geerts et al. (2018) aimed to investigate the effect of aqueous soy protein fractions on the fibrous structure of meat alternatives. They concluded that aqueous fractionation of soy with desired functionality could be used for the application of meat alternatives.

Grabowska et al. (2014) and Krintiras et al. (2015, 2016) studied the different ratios of wheat gluten on the fiber structure of soy protein based meat alternatives by using shear structuring and Coutte Cell technology, respectively.

4. CONCLUSION

Soy-based proteins have been frequently used in the production of meat-like products with their amino acid composition that provides meat-like structure, flavor profile and meat-like protein quality after hydration. However, the trend towards plant-based meat alternatives is increasing day by day. This increase also increases the expectations of consumers from the market at the same rate. For this reason, it is necessary to develop meat alternatives by using different raw materials, with increased nutritional value fortified with essential vitamins and minerals, low in saturated fat, and improved functional properties. While trying to provide all these features, basically meat-like fibrous texture, juiciness, taste and aroma, and cooking properties should not be neglected. Therefore, comprehensive evaluations should be made by comparing plant-based meat alternatives with animal-based products.

REFERENCES

Ahmad, M., Qureshi, S., Akbar, M. H., Siddiqui, S. A., Gani, A., Mushtaq, M., Hassan, I., & Dhull, S. B. (2022). Plant-based meat alternatives: Compositional analysis, current development and challenges. *Applied Food Research*, *2*(2), 100154. https://doi.org/10.1016/j.afres.2022.100154

Alcorta, A., Porta, A., Tárrega, A., Alvarez, M. D., & Vaquero, M. P. (2021). Foods for Plant-Based Diets: Challenges and Innovations. *Foods*, *10*(2), 293. https://doi.org/10.3390/foods10020293

Ali, N. (2010). Soybean Processing and Utilization. In G. Singh (Ed.), *The Soybean: Botany, Production and Uses* (pp. 345–374). CABI Publishing.

Asgar, M. A., Fazilah, A., Huda, N., Bhat, R., & Karim, A. A. (2010). Nonmeat protein alternatives as meat extenders and meat analogs. *Comprehensive Reviews in Food Science and Food Safety*, *9*(5), 513–529. https://doi.org/10.1111/j.1541-4337.2010.00124.x

Bakhsh, A., Lee, S.-J., Lee, E.-Y., Hwang, Y.-H., & Joo, S.-T. (2021). Traditional Plant-based Meat Alternatives, Current, and Future Perspective: A Review. *Journal of Agriculture & Life Science*, *55*(1), 1–11. https://doi.org/10.14397/jals.2021.55.1.1

Balandrán-Quintana, R. R., Mendoza-Wilson, A. M., Ramos-Clamont Montfort, G., & Huerta-Ocampo, J. Á. (2019). Plant-Based Proteins. In *Proteins: Sustainable Source, Processing and Applications*. https://doi.org/10.1016/B978-0-12-816695-6.00004-0

Baune, M. C., Terjung, N., Tülbek, M. Ç., & Boukid, F. (2022). Textured vegetable proteins (TVP): Future foods standing on their merits as meat alternatives. *Future Foods*, *6*(September). https://doi.org/10.1016/j.fufo.2022.100181

Boukid, F. (2021). Plant-based meat analogues: from niche to mainstream. *European Food Research and Technology*, *247*(2), 297–308. https://doi.org/10.1007/s00217-020-03630-9

Burssens, S., Pertry, I., Diasolua, D., Kuo, Y.-H., Van, M., & Lambei, F. (2011). Soya, Human Nutrition and Health. In *Soybean and Nutrition*. InTech. https://doi.org/10.5772/21951

Chantanuson, R., Nagamine, S., Kobayashi, T., & Nakagawa, K. (2022). Preparation of soy protein-based food gels and control of fibrous structure and rheological property by freezing. *Food Structure*, *32*(August 2021), 100258. https://doi.org/10.1016/j.foostr.2022.100258

Chiang, J. H., Tay, W., Ong, D. S. M., Liebl, D., Ng, C. P., & Henry, C. J. (2021). Physicochemical, textural and structural characteristics of wheat gluten-soy protein composited meat analogues prepared with the mechanical elongation method. *Food Structure*, *28*(February). https://doi.org/10.1016/j.foostr.2021.100183

Colletti, A., Attrovio, A., Boffa, L., Mantegna, S., & Cravotto, G. (2020). Valorisation of By-Products from Soybean (Glycine max (L.) Merr.) Processing. *Molecules*, *25*(9), 2129. https://doi.org/10.3390/molecules25092129

Dekkers, B. L., Boom, R. M., & van der Goot, A. J. (2018). Structuring processes for meat analogues. *Trends in Food Science and Technology, 81*(August), 25–36. https://doi.org/10.1016/j.tifs.2018.08.011

Dixit, A. ., Antony, J. I. ., Sharma, N. K., & Tiwari, R. K. (2011). Soybean constituents and their functional benefits. *Research Signpost*, *661*(2), 367–383. http://www.trnres.com/ebook/uploads/tiwari/T_1302158885Tiwari-12.pdf

Fang, Y., Zhang, B., & Wei, Y. (2014). Effects of the specific mechanical energy on the physicochemical properties of texturized soy protein during high-moisture extrusion cooking. *Journal of Food Engineering*, *121*(1), 32–38. https://doi.org/10.1016/j.jfoodeng.2013.08.002

Geerts, M. E. J., Dekkers, B. L., van der Padt, A., & van der Goot, A. J. (2018). Aqueous fractionation processes of soy protein for fibrous structure formation. *Innovative Food Science and Emerging Technologies*, *45*(September 2017), 313–319. https://doi.org/10.1016/j.ifset.2017.12.002

Grabowska, K. J., Tekidou, S., Boom, R. M., & van der Goot, A. J. (2014). Shear structuring as a new method to make anisotropic structures from soy-gluten blends. *Food Research International*, *64*, 743–751. https://doi.org/10.1016/j.foodres.2014.08.010

Grahl, S., Palanisamy, M., Strack, M., Meier-Dinkel, L., Toepfl, S., & Mörlein, D. (2018). Towards more sustainable meat alternatives: How technical parameters affect the sensory properties of extrusion products derived from soy and algae. *Journal of Cleaner Production*, *198*, 962–971. https://doi.org/10.1016/j.jclepro.2018.07.041

Grassini, P., Cafaro La Menza, N., Rattalino Edreira, J. I., Monzón, J. P., Tenorio, F. A., & Specht, J. E. (2021). Soybean. In *Crop Physiology Case Histories for Major Crops* (pp. 282–319). Elsevier. https://doi.org/10.1016/B978-0-12-819194-1.00008-6

He, F. J., & Chen, J. Q. (2013). Consumption of soybean, soy foods, soy isoflavones and breast cancer incidence: Differences between Chinese women and women in Western countries and possible mechanisms. *Food Science and Human Wellness*, *2*(3–4), 146–161. https://doi.org/10.1016/j.fshw.2013.08.002

Herz, E., Herz, L., Dreher, J., Gibis, M., Ray, J., Pibarot, P., Schmitt, C., & Weiss, J.

(2021). Influencing factors on the ability to assemble a complex meat analogue using a soy-protein-binder. *Innovative Food Science & Emerging Technologies*, *73*, 102806. https://doi.org/10.1016/j.ifset.2021.102806

Jung, A. H., Hwang, J. H., Jun, S., & Park, S. H. (2022). Application of ohmic cooking to produce a soy protein-based meat analogue. *Lwt*, *160*(August 2021), 113271. https://doi.org/10.1016/j.lwt.2022.113271

Katayama, M., & Wilson, L. A. (2008). Utilization of Soybeans and Their Components through the Development of Textured Soy Protein Foods. *Journal of Food Science*, *73*(3), 158–164. https://doi.org/10.1111/j.1750-3841.2008.00663.x

Krintiras, G. A., Gadea Diaz, J., Van Der Goot, A. J., Stankiewicz, A. I., & Stefanidis, G. D. (2016). On the use of the Couette Cell technology for large scale production of textured soy-based meat replacers. *Journal of Food Engineering*, *169*, 205–213. https://doi.org/10.1016/j.jfoodeng.2015.08.021

Krintiras, G. A., Göbel, J., Van Der Goot, A. J., & Stefanidis, G. D. (2015). Production of structured soy-based meat analogues using simple shear and heat in a Couette Cell. *Journal of Food Engineering*, *160*, 34–41. https://doi.org/10.1016/j.jfoodeng.2015.02.015

Kyriakopoulou, K., Dekkers, B., & van der Goot, A. J. (2018). Plant-based meat analogues. In *Sustainable Meat Production and Processing*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-814874-7.00006-7

Kyriakopoulou, K., Keppler, J. K., & van der Goot, A. J. (2021). Functionality of Ingredients and Additives in Plant-Based Meat Analogues. *Foods*, *10*(3), 600. https://doi.org/10.3390/foods10030600

Li, X., & Li, J. (2020). The Flavor of Plant-Based Meat Analogues. *Cereal Foods World*, *65*(4). https://doi.org/10.1094/cfw-65-4-0040

Lin, S., Huff, H. E., & Hsieh, F. (2002). Extrusion process parameters, sensory characteristics, and structural properties of a high moisture soy protein meat analog. *Journal of Food Science*, *67*(3), 1066–1072. https://doi.org/10.1111/j.1365-2621.2002.tb09454.x

Macdonald, R. S., Pryzbyszewski, J., & Hsieh, F. H. (2009). Soy protein isolate extruded with high moisture retains high nutritional quality. *Journal of Agricultural and Food Chemistry*, *57*(9), 3550–3555. https://doi.org/10.1021/jf803435x

Mahmudiono, T., Khaydarov, N. K., Jasim, S. A., Hammid, A. T., Failoc-Rojas, V. E., Shalaby, M. N., Jannat, B., Nouri, M., & Fadel, A. (2022). Systematic review and meta-analysis of randomized, controlled trials on the effects of soy and soy products supplementation on serum adiponectin levels. *Diabetes and Metabolic Syndrome: Clinical Research and Reviews*, *16*(7), 102558.

https://doi.org/10.1016/j.dsx.2022.102558

Malav, O. P., Talukder, S., Gokulakrishnan, P., & Chand, S. (2015). Meat Analog: A Review. *Critical Reviews in Food Science and Nutrition*, *55*(9), 1241–1245. https://doi.org/10.1080/10408398.2012.689381

Medic, J., Atkinson, C., & Hurburgh, C. R. (2014). Current Knowledge in Soybean Composition. *Journal of the American Oil Chemists' Society*, *91*(3), 363–384. https://doi.org/10.1007/s11746-013-2407-9

Messina, M., Sievenpiper, J. L., Williamson, P., Kiel, J., & Erdman, J. W. (2022). Perspective: Soy-based Meat and Dairy Alternatives, Despite Classification as Ultra-processed Foods, Deliver High-quality Nutrition on Par with Unprocessed or Minimally Processed Animal-based Counterparts. *Advances in Nutrition*, *13*(3), 726–738. https://doi.org/10.1093/advances/nmac026

Michel, F., Hartmann, C., & Siegrist, M. (2021). Consumers' associations, perceptions and acceptance of meat and plant-based meat alternatives. *Food Quality and Preference*, *87*(April 2020), 104063. https://doi.org/10.1016/j.foodqual.2020.104063

Pratap, A., Gupta, S. K., Kumar, J., & Solanki, R. K. (2012). Soybean. In S. K. Gupta (Ed.), *Technological Innovations in Major World Oil Crops, Volume 1* (Vol. 1, pp. 293–321). Springer New York. https://doi.org/10.1007/978-1-4614-0356-2_12

Qin, P., Wang, T., & Luo, Y. (2022). A review on plant-based proteins from soybean: Health benefits and soy product development. *Journal of Agriculture and Food Research*, *7*, 100265. https://doi.org/10.1016/j.jafr.2021.100265

Rizzo, G., & Baroni, L. (2018). Soy, soy foods and their role in vegetarian diets. In *Nutrients* (Vol. 10, Issue 1). https://doi.org/10.3390/nu10010043

Saerens, W., Smetana, S., Van Campenhout, L., Lammers, V., & Heinz, V. (2021). Life cycle assessment of burger patties produced with extruded meat substitutes. *Journal of Cleaner Production*, *306*, 127177. https://doi.org/10.1016/j.jclepro.2021.127177

Samard, S., Gu, B. Y., & Ryu, G. H. (2019). Effects of extrusion types, screw speed and addition of wheat gluten on physicochemical characteristics and cooking stability of meat analogues. *Journal of the Science of Food and Agriculture*, *99*(11), 4922–4931. https://doi.org/10.1002/jsfa.9722

Sha, L., & Xiong, Y. L. (2020). Plant protein-based alternatives of reconstructed meat: Science, technology, and challenges. *Trends in Food Science and Technology*, *102*(February), 51–61. https://doi.org/10.1016/j.tifs.2020.05.022

Strahm, B. (2006). Meat Alternatives. In M. N. Riaz (Ed.), *Soy Applications in Food* (pp. 135–154). Taylor & Francis Group, LLC.

Van Mierlo, K., Baert, L., Bracquené, E., De Tavernier, J., & Geeraerd, A. (2022). Moving from pork to soy-based meat substitutes: Evaluating environmental impacts in relation to nutritional values. *Future Foods*, *5*(December 2021), 100135. https://doi.org/10.1016/j.fufo.2022.100135

Villares, A., Garcia-Lafuente, A., Palacios, I., Lozano, M., Moro, C., & Guillamo, E. (2011). Soy and Soy-Based Foods: Role in Health and Nutrition. In *Soybean and Nutrition* (Vol. 32, Issue tourism, pp. 137–144). InTech. https://doi.org/10.5772/18001

Yuan, X., Zhu, X., Sun, R., Jiang, W., Zhang, D., Liu, H., & Sun, B. (2022). Sensory attributes and characterization of aroma profiles of fermented sausages based on fibrous-like meat substitute from soybean protein and Coprinus comatus. *Food Chemistry*, *373*(PB), 131537. https://doi.org/10.1016/j.foodchem.2021.131537

Yuliarti, O., Kiat Kovis, T. J., & Yi, N. J. (2021). Structuring the meat analogue by using plant-based derived composites. *Journal of Food Engineering*, *288*(January 2020), 110138. https://doi.org/10.1016/j.jfoodeng.2020.110138

Zhao, Y., Zhao, X., Sun, P., Zhao, D., Dou, W., Zhang, X., Jiang, L., & Sui, X. (2022). Effects of adding other protein products on textural properties of soy protein concentrate-based meat analogs. *Journal of Texture Studies*, *September*, 1–10. https://doi.org/10.1111/jtxs.12721

Zheng, L., Regenstein, J. M., Zhou, L., & Wang, Z. (2022). Soy protein isolates: A review of their composition, aggregation, and gelation. *Comprehensive Reviews in Food Science and Food Safety*, *21*(2), 1940–1957. https://doi.org/10.1111/1541-4337.12925

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