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**SuperPro Design Programı İle Prina Üretimi ve Muhtemel  
Biyoteknolojik Değerlendirme Süreçlerinin Optimizasyonu ve  
Tekno-ekonomik Analizi**

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**Optimization and Techno-Economic Analysis  
of Prina Production and Potential  
Biotechnological Assessment Processes with  
SuperPro Design Program**

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## **Ozet**

Zeytin posası atığının (pirina) yönetimini, tarımda kullanılacak katma değeri yüksek bir ürün eldesi olarak kullanılmasını sağlamak için optimize etmeyi amaçlamaktadır. Atık, zeytinyağı üreticileri ve üreticilerinden kaynaklanmaktadır ve çiftçiler, fabrika sahipleri ve tarım ticaret odaları gibi paydaşlar dahil edilmektedir. Üniversitelerin tarım mühendisliği ve biyomühendislik bölümleri de atık yönetimine katkıda bulunabilir. Atık ve katkı miktarı zeytin posası üretimiyle birlikte artmakta ve Ege Bölgesi gibi bölgeleri araştırma için ideal hale getirmektedir. Zeytin posası, biyodizel üretimi ve tarımsal büyüme dahil olmak üzere çeşitli endüstrilerde potansiyel uygulamalara sahiptir. Ancak, henüz yeterince değerlendirilmemiştir. Tez, üretimi artırmayı ve çevresel değişime katkıda bulunmayı amaçlayarak zeytin posası kullanımının teknik ve finansal faydalarına odaklanmaktadır.

## **Abstract**

Prior to being regarded as trash following the manufacturing of olive oil, the goal of this thesis is to optimise the management of olive pomace waste in order to guarantee its use as an agricultural additive. The manufacturing line's purchase phase is the first stage of this optimisation process. Olive pomace is typically extracted from olives and purchased from olive oil manufacturers and producers. When evaluating waste from olive pomace, stakeholders including farmers, factory owners, and agricultural trade chambers are important. Universities' agricultural engineering and bioengineering departments can also be useful in acquiring waste from olive pomace. Working together, these units may generate more trash and advance technology, both of which can lead to financial gains in the long run. The waste and contribution rise in tandem with the amount of olive pomace. As a result, areas like the Aegean Region that produce a lot of olive oil are ideal for research. There are several possible applications for olive pomace. Numerous technologies are used across the nation, from the manufacture of biodiesel from olive pomace to other industries. In the agricultural industry, olive pomace may be converted into biodiesel, which can hasten the economic growth of the sector. Olive pomace can help the nation's agricultural economy grow. Olive pomace hasn't been sufficiently valorised yet, though. This thesis looks at the technical and financial benefits of using olive pomace and focusses on how it may be used more effectively and profitably. When these goals are accomplished, the production and use of olive pomace will increase and contribute more to environmental change.

**Symbols/ Abriviations**

mg: milligram

ppm: parts per million

ton:1000 kilos



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## 1. Introduction

All around the world industrial wastes increasingly; based on this sharp raise of industries triggers of the most important problems which is waste treatment. Food industry waste are known for waste recycle between other industries supporting as valuable waste recycle technoies and as materials. Moreover olive has important producing techniques and bazaar in Turkey. Stratejically, Turkey is one of the most important countries in production of olive based products such as olive oil, olive pomace and etc. When olive based products are shown as maintenance of production step, from grain based pasta to production of biodiesel may be the product of olive based production systems. Additionally, not only primary maintenance of production steps but also reducing the environmental pollution pomace has significant both affect and support of countries economy.

After raw olive oil is produced, the goal of this thesis is to optimise the waste of olive pomace in waste management so that it can be used as a useful contribution before being thrown away as garbage. The supply stage, one of the first stages of the manufacturing line, is notable among these optimisations. Olives are often the source of olive pomace. It can be supplied by stakeholders like olive growers and facilities that make olive oil. Authorities that have a big say in how much value is placed on waste from olive pomace include farmers, factory owners, and agricultural trade associations. (Aouidi, Okba, & Hamdi , 2017) The secondary entities to be contacted for the acquisition of waste from olive pomace are university departments of agricultural engineering and biotechnology, in addition to producers. In addition to increasing the quantity of trash produced, combining the industrial production and research topics of these units would also greatly advance technological advancements and outcomes. The most significant of these contributions will be the technological and economic advantages for our nation. (Takac) Therefore, waste and contribution will increase with the amount of olive pomace collected. As a result, I have selected the Aegean Sea region, which is among the areas with the highest output of olive oil. Apart from its well-known advantages, olive pomace is used in a variety of industries, such as the chemical industry and architecture, for both production and consumption. The manufacture of biodiesel from olive pomace has already been expanded in our nation using well-known and used methods. Due to farmer understanding, olive pomace—which is often used as animal feed—is now also utilised to produce biodiesel in agricultural areas. The confluence of this chemical knowledge and technology is important given the supported agricultural and economic initiatives in our nation. It will both accelerate and boost agricultural economic growth and lessen or halt the migration of people from

rural to urban areas. Despite its crucial importance in our country, olive pomace is not adequately valorized. To enhance its value, this thesis aims to explore the techno-economic values of olive pomace and target its more efficient and economically beneficial utilization. If the objectives of the thesis are achieved, olive pomace production and consumption in the Aegean region will not only be used as animal feed but will also become a more economically contributing product, adding another link to environmental transformation rather than being evaluated as waste.

### 1.1. Olive and Morphology of Olive Plant

In today's culture olive plant is mostly separated to use as olive oil, an addition separation of olive is using as to brine the green and black olive. To culturing olive and olive trees; *Oleaceae* from olive family named as *Olea europaea* Linne's sub-cultured olive tree named as *Olea europaea sativa* (London Arcangeli) is using (Euro MEB Plant Based, 2011). On the other hand; *Olea* family has at least twenty different topic nad subtropical relatives based in their tropik/mediterranean like climate. I one of the known member of the *Olea* family is "Olea europaea oleaster(Hoffmanns. & Link) Negodi" (Euro MED Plant Based , 2011). Additionally, *Olea Europea L.* Is one of the species that after some applications on fruit, it may use on different areas of industrial. *Olea European L.* is a tree which has at least 25 different family member addition the 600 and more species diverse to each family member as observed on Table 1: Olive oil classification. (Khan, Soherwardy , & Sarwar, 2015) (García-González, Morales, & Aparicio, 2010)

**Table 1:**Olive tree Classification

<b>Regnum</b>	<b>Plantae</b>
<b>Divisio</b>	<i>Tracheophyta</i>
<b>Subdivisio</b>	<i>Spermatophytina</i>
<b>Class</b>	<i>Magnoliopsida</i>
<b>Superordo</b>	<i>Asteranae</i>
<b>Ordo</b>	<i>Lamiales</i>
<b>Familia</b>	<i>Oleaceae</i>
<b>Genus</b>	<i>Olea L.</i>
<b>Species</b>	<i>Olea europaea L.</i>

All around the world; there are 37 countries that significant production of olive. Moreover; olive tree as mentioned before have plenty of various both on family and species as around twelve

hundred family members addition to at least three thousand different species. Turkey is one of the known countries which has more than ninety different species may produce not only Anatolian based but also Mediterranean based. Ecologically Turkey is one of the most various olive family differentiation of species which shown in the Olive Genome Bank study supported by Zeytincilik Arastirma Institution Kemalpaşa Production and Research Center. (Zeytinde cesit tanimlama ve cesitlerimiz, 2017)

## 1.2. General Feature of Olive

An olive tree which grow on the natural way has a bushlike petals, for this reason, petal prevent to entrance of sunlight directly to the leaf. Under natural circumstances, height of olive tree reaches fifteen meter, however, there are some reasons why olive trees had been modified by human are first, difficult to reach the fruits and late rape of olive fruit. Due to prevent those negative effects of olive trees first, short or dwarf trees were hybridized to each other to reach their height to three to five meter from the ground. Then, early fruit maturation was evolved to the three to four years of the tree. Not only early maturation of the fruit but also height of tree was optimized through years has five to seven meter plantation distance to collect fruits more efficiently then previous techniques.

According to a research was done by Ministry of Tarim Koyisleri to Institute of Bornova Zeytincilik, all around the world sountries has eight hundred olive oil tree at eight million hectares in fourteen different country, on the other hand, most of these olive oil trees found in Mediterranean countries as 97% of the world. For this reason, Mediterranean is accepted as fatherland of the olive. As mentioned before, olive trees lived significant both morphological and genetic modification through years. Thus, olive and olive oil become one of the most solid parts of Mediterranean culture and cuisine. Through years both olive and olive oil becomes the most important parts of socioeconomic and socioculture of Mediterranean living culture. Olive has production on American continent by the help of European migration to the continent. (Nergiz & Engez, 2000)

To observe the improvement of olive trees as *Olea europeae* specie of the tree; there are two types of trees as subcultured and non cultured. Spreading of cultured olive tree around the world is placed between 30 to 45 latitudes. Those latitude has specific climate conditions known as Mediterranean climate which has warm, short and rainy winters, on the other hand, springs are somewhat cold-fresh and rainy, and summers are drought throughout the year. Addition to the climate conditions

for olive tree, it may require 16-to-21-degree celcius temperature during the year, addition to the tempereture of the environment; total rain fall should be between five hundred to twelve hundred. Moreover, climate should have at least five thousand hours of sun all year. Even though all the conditions are suitable olive tree need at least a few cold days. All requirements of olive tree is not only climate but also topographically optimum for the tree which are altitude from see is at maximum four hundred meters. There are some optimum temperatures that tree require during growth which are for spring seven degree below zero- and forty-degree fo summer in maximum conditions.

Rather than aerial requirements of olive tree, as soil, it requires both clayey and sandy soil. When all conditions were secured, after plantation of the tree, olive tree would possibly give fruits in five to six years. Moreover, it may reach economic stabilization after tenth year. That economic return may change based on climate, for instance, it may reach to twenty years when the soil quality does not ensure well enough. Not only soil quality but also drought and heavy rain is the other factor for economic return in olive oil tree. One of the most specific characterizations of olive trees is when they aged more than a century, they reach economic efficiency at age 50, then they have to reage the plantation of the tree. In addition to life span and crop of olive oil tree, first seven years of its life span called as youth, eight to forty years of its life span crop reducing years. Even though in some trees forty-one to hundred years till hundred and fifty years mentioned as crop reducing tiem of its life span. However, depends on caring of tree, life span of tree may increase to five hundred years. Resent research of archeology shows that Gobeklitepe(turkiye) and Crete has tracked those three thousand years old olive trees.

Olive oil tree has medium size in their growth, so it has naturally global plant. It first approved itself as drought and subtropical Mediterreanean environment. It adaptate itself to high temperature and different earth types. Its height depends on its environment, for this reason, olive oil tree has morphological changes even though they do not have physical change.

(IOC 1997)(International Olive Council 1997).

Olive tree gives blossoms at spring around April through may when it grows at north hemisphere. Around September and October, it reaches brine ripe. Countries with drought climate starts harvesting after mason season.(IOC 1997)

Olive tree's fruit name is olive likewise to the other fruits of the trees olive has different sub-layers as peel, pulp and seed. Those components of fruit shows changes based on the country and area

tree grows. On the other hand not only area but also growth techniques as traditional and newby, fertilizers and water quality are other factors affects olive tree growth. Those factors gives variaties even though applying the same species. When the factors affected to the tree does not limitisize with only one, comparing the chemical materials of the fruit and shape may cause varieties of the fruit which named as olive. Ther are some features and chemicals of olive which mentioned on Table 2 and Table 3. Mainly physical properties of olive contain four subtitles as weight of grain, ratio of fruit's peel, ratio of seed and ratio of pulp. Weight of grain hs changes between 1-12 grams per olive and ratio of fruit's peel is 1,5 to 3,5% of the olive. Additionally, ratio of seed changes between 13-30% and ratio of pulp changes between 66-85% of the olive as seen on Turkiye.

**Table 2:**Physical Properties of Olive

<b>Olive</b>	<b>Amount</b>
<b>Weight of Grain (g)</b>	2-12
<b>Ratio of fruit's peel(%)</b>	1,5-3,5
<b>Ratio of seed (%)</b>	13-30
<b>Ratio of Pulp(%)</b>	66-85

Addition to physical properties of the olive, there are some chemical components as water,oli,nitrogen based components,sugar, cellulose, minerals,polyphenols and other chemicals. Their percentace of mentioned features have been examined in three different parts which are fruit extract, core and seed and the obtained data are in the Table 3

**Table 3:**Chemical Components of Olive (Boskou & Dimitrios, 2006) (Kailis & Harris , 2007) (Susamci & Erkan, 2011)

<b>Components</b>	<b>Fruit Extract (%)</b>	<b>Core (%)</b>	<b>Seed (%)</b>
<b>Water</b>	50-60	9,3	30
<b>Oil</b>	15-30	0,7	27,3
<b>Nitrogen Based Components</b>	2-5	3,4	10,2

<b>Sugar</b>	3-7,5	41	26,6
<b>Cellulose</b>	3-6	38	1,9
<b>Minerals</b>	1-2	4,1	1,5
<b>Polyphenols</b>	2-2,25	0,1	0,5-1,0
<b>Others</b>	-	3,4	2,4

On the other hand, those components which are mentioned on Table 3 changes type of olives as natural black olive and green olive. Moreover chemical components percentage and density changes based on countries which mentioned on Table 4 as chemical components of olives in Italy.

**Table 4:**Chemical composition of olives depending on the production process in Italy (Lanza , 2012)

<b>Nutrients/100g.e.p</b>	<b>Natural black olives</b>	<b>Natural green olives</b>
<b>Energy(kcal)</b>	235	193
<b>Proteins(g)</b>	1,4	1,5
<b>Carbohydrates(g)</b>	6,5	5,0
<b>Sugar(g)</b>	0,3	0,6
<b>Fats(g)</b>	21,7	17,7
<b>Saturated fatty acid(g)</b>	2,7	2,8
<b>Monounsaturated fatty acid(g)</b>	17,7	14,0
<b>Polyunsaturated fatty acid(g)</b>	1,3	0,9
<b>Fibre(g)</b>	4,0	3,6
<b>Sodium(g)</b>	1,5	1,2
<b>Calcium(mg)</b>	28,9	21,9
<b>Polyphenols(mg)</b>	211	109

In contrast, Olive planted in Turkey has different components as energy, carbohydrate, water, protein, oil and dietary fiber rather than olive trees planted in Italy as observed in Table 5.

**Table 5:** Nutritional Composition of Olive Fruit in Turkey (Ozturk & Borcakli, 2012)

<b>Compounds</b>	<b>Weight percent %</b>
<b>Energy(kcal/100g)</b>	273,84 - 335,94
<b>Carbohydrate(g/100g)</b>	15,24 – 7,03
<b>Water(g/100g)</b>	56,10 – 52,09
<b>Ash (g/100g)</b>	2,8 – 1,71
<b>Protein(g/100g)</b>	1,38 – 1,13
<b>Oil (g/100g)</b>	23,04 – 33,70
<b>Dietary fibre(g/100g)</b>	1,44 – 4,34

### 1.3. Chemical Composition of Olive Fruit

Due to its phenolic components of the olive, it increases supporting of human health. Oleuropein is the name of the phenolic component of the olive which gives bitter taste to the fruit. Olive is the only fruit which has oleuropein all around the world. (Kapellakis, Tsagarakis, & Crowther, 2007) Olives are a low-calorie fruit since they contain little carbs, protein, and fibre. Yet, the protein quality is ideal because it contains the majority of the important amino acids. Because of the presence of phenols such as chlorogenic acids, oleanolic acid, cholinergic and maslinic acid, olives have been shown to have antioxidant, antimicrobial, anti-inflammatory, chemopreventive, and anti-proliferative properties. Several olive phenols also serve as intermediates in the prevention of hyperglycemia, Alzheimer's (dementia), and Parkinson's disease.

Olives can be green or black. These are classified depending on their degree of ripeness. Green olives are gathered before they begin to ripen, whereas black olives are harvested after they have fully ripened. Olives darken as a result of phenolic component oxidation.

Green olives are commonly used at the table. Fresh olives contain oleuropein, which makes them bitter and unsuitable for consumption. To prepare for consumption, olives are processed by methods such as canning and fermentation.

Additionally, 90% of olives are processed for oil due to their high oleic acid concentration. Organic acids promote metabolic activity in the human body and are intermediary results of the production and breakdown of other substances.

As compare to other components found in olive there are som average or component factors found in olive as water, protein,oil, carbohydrate,cellulose,inorganic substance, pkhenolic matter and others as pectin, organic acids,pigments) has changeds in weight as shown in Table 6.

**Table 6:**Nutritional Composition of Olive Fruit (Boskou & Dimitrios, 2006) (Kailis & Harris , 2007)

<b>Compounds</b>	<b>Weight percent%</b>
<b>Water</b>	50 - 60
<b>Protein</b>	1,6
<b>Oil</b>	22
<b>Carbohydrate</b>	3,8
<b>Cellulose</b>	5,8
<b>Inorganic substances</b>	1,5
<b>Phenolic matter</b>	1-3
<b>Others(pectin,organic acids,pigment Etc.)</b>	2,0 – 12,0

#### **1.4. Carbohydrate**

Compared to other fruit that is consumed, olives have a low carbohydrate content. Fruits have an average total sugar content of roughly 0.52%. The main sugar found in olives is glucose, subsequent to fructose. Inositol, a carbocyclic sugar, is also found in minute levels in olives and helps hormones work in the brain.

#### **1.5. Protein**

Olive has lower than 1% protein density.On the other hand, olive includes approximately whole of essential amino acids. Amounts of amino acis in ppm values are shown in Table 7 name by name and amount.

**Table 7:**Amino acid composition of olives

<b>Amino acids</b>	<b>Quantity (ppm)</b>
<b>Threonine</b>	1290
<b>Isoleucine</b>	860
<b>Leucine</b>	1730
<b>Lysine</b>	180
<b>Histidine</b>	260
<b>Phenylalanine + Tyrosine</b>	1680
<b>Valine</b>	1040
<b>Alanine</b>	1150
<b>Aspartic acid</b>	2140
<b>Glutamic acid</b>	2260
<b>Glycine</b>	1150
<b>Serine</b>	1240

### **1.6. Dietary Fibre**

Olives are also poor in dietary fibre. Consuming ten olives provides 1.5 g of grain. Olives have a regular grain content of 3.3 g per 100 g of the fruit. Nonetheless, the fibre included is of digestible nature quality. On a typical basis, cellulose, hemicellulose, and lignin make about 70% of the total grain content of fruit. The fibre in the apple accounts for 52-86% of its total carbohydrate density.

### **1.7. Lipids / Fats in olive fruit**

Olives have the highest fat content of any temperate fruit. Fruit has an average of 15.32 g of oil per 100 g of weight. The pericarp of the fruit contains the majority of the oil (96-98%), whereas the seed has just 2-4 g per 100 g. The oil is primarily monounsaturated, with a little quantity of saturates and a large proportion of polyunsaturated (14%). Oleic acid is the main fatty acid (63.4-80.7%), followed by palmitic (63.4-80.7%) and linolenic (4.3–13.6%). (Boskou & Dimitrios, 2006) (Viola & Viola, 2009) (Lanza , 2012) (Blekas , Tsimidou, & Boskou, 2006) (López-López, Rodríguez-Gómez, Cortés Delgado, García-García, & Garrido Fernández, 2010) (Ghanbari, Anwar, Alkharfy, Gilani, & Saari, 2012).

### 1.8. Vitamins

The main vitamin found in olives is tocopherol, a fat-soluble vitamin. According to reports, the fruit contains all four forms of tocopherols— $\alpha$ ,  $\beta$ ,  $\gamma$ , and  $\delta$ —with  $\alpha$ -tocopherol having the greatest content (300 ppm). Still, the amount of tocopherol is altered. Vitamins found in olive are A, B1, B2, B3, B6, B9, Choline, E and K determine by their 100 g of olive determine as 20 $\mu$ g, 0,021mg, 0,007mg, 0,237mg, 0,031mg, 3 $\mu$ g, 14,2mg, 3,81mg and 1,4  $\mu$ g as shown at Table 8.

**Table 8:** Vitamin composition of olive fruit in Spain (Ghanbari, Anwar, Alkharfy, Gilani, & Saari, 2012)

<b>Vitamin</b>	<b>Quantities/100g</b>
<b>A</b>	20 $\mu$ g
<b>B1</b>	0,021mg
<b>B2</b>	0,007mg
<b>B3</b>	0,237mg
<b>B6</b>	0,031mg
<b>B9</b>	3 $\mu$ g
<b>Choline</b>	14,2mg
<b>E</b>	3,81mg
<b>K</b>	1,4 $\mu$ g

On the other hand, vitamins observed on the olive grown in Turkiye includes B1, B2, B6, B3, Folic acid and E. Amount of those vitamins as mg per 100 g of olive fruit was shown in table 9.

**Table 9:** Vitamin composition of olive fruit in Turkey (Ozturk & Borcakli, 2012)

<b>Vitamin</b>	<b>Quantities</b>
<b>B1(mg/100g)</b>	0,35 – 0,06
<b>B2 (mg/100g)</b>	0,82 – 0,04
<b>B6 (mg/100g)</b>	0,35 – 1,80
<b>B3 (mg/100g)</b>	2,08 – 0,53
<b>Folic acid (mg/100g)</b>	2,12 – 0,50
<b>E(mg/100g)</b>	9,31 – 8,50

## **1.9. Minerals**

Numerous vital elements, including calcium, iron, potassium, zinc, copper, phosphorous, and selenium, are found in olives. Nonetheless, zinc, iron, and calcium are the most common among them. Calcium helps in hormone secretion, bone development, and blood clotting enzyme stabilisation for DNA and protein synthesis. (Viola & Viola, 2009)

## **1.10. History of Olive**

Olives have found a place in the mythology, legends, inscriptions and holy books of many civilizations from ancient times to the present. The history of olive dates back to 8,000 years ago. It is understood from fossils from geological periods that the olive tree has a very ancient history. The oldest source of olive trees found is a 39,000-year-old olive leaf fossil unearthed during archaeological excavations on Santorini Island. Olive fossils found in Santorini, Mongardino (Italy), Relilai (North Africa), Spain and other regions belong to wild olives, not domesticated olives. In archaeological excavations carried out in the Sahara region of Africa, olive tree remains dating back to 12,000 BC (BC) were found. Historical sources indicate that olives were first grafted in the Mediterranean regions and date back to B.C. It has been learned that olive oil has been grown for use since 4,000 BC.

The Phoenicians discovered olives in B.C. From the 16th century to the Greek islands, B.C.14. They exported it to Greece between the 12th and 12th centuries.

The olive tree was carried to different regions by the Phoenicians for centuries. Because the Phoenician civilization is one of the oldest known civilizations in the Eastern Mediterranean region, especially in olive and wheat production. B.C. In 1500, they brought olives to more than one island in the Aegean Sea, such as Cyprus, Crete and Egypt. In the following years (1300 - 1100 BC), olives reached Greece. B.C. It was brought to Libya and then to Tunisia around 700 BC. Olive production in the Greek region dates back to B.C. It gained great importance in the 4th century. Spain started olive production in B.C. It started when it was brought to Spain by the Phoenicians around 1050. But B.C. Thanks to the importance given to olive cultivation by the Romans and then the Arabs between 212-245, the Spanish had a great say in olives. Some kingdoms in the Eastern Mediterranean played an active role in Mediterranean trade during the Bronze Age. They exported olive oil and wine from Ugarit in the Syrian region to countries such as Cyprus and Egypt. (Eitam & Heltzer, 1996)

According to archaeological and geological research, olive has been around since B.C. It indicates that it has been utilised since 6000. Although there is no clear consensus about the age and homeland of the olive tree, which is a Mediterranean plant and whose history dates back to ancient times, according to scientific literature, the homeland of the olive tree covers the Mardin, Kahramanmaraş and Hatay triangle of Anatolia.

The first places where the olive tree was found were the Southeastern Anatolia region, upper Mesopotamia and Southern Asia Minor. Information regarding olive production is included in Hittite inscriptions in Cilicia (Adana region).

The olive tree spread to Southeastern Anatolia, Syria, Jordan, Lebanon, Palestine, Israel and Egypt, and later to other parts of the Mediterranean. According to documents found in archaeological excavations in Palestine and Jordan, B.C. It has been observed that olive cultivation was done around 3750 BC. Additionally, olives have been found in ancient Egyptian tombs. In Sakkarah, the world's first step pyramid, there is an olive pressing tool and images of the pressing process on the walls. Historical findings show that olives were found in Palestine approximately B.C. 3700 BC in Egypt. It states that it has been produced and operated since 2450.

It is recognised that olives are of inestimable value to the ancient inhabitants of the Mediterranean area and the Mediterranean climate. The fruit of the tree, which has been produced under Mediterranean conditions until today, has been used in different areas by many civilizations in ancient times. (Aktas, 2008)

The word olive was first mentioned in written texts and BC. It can be seen visually on the walls of the Knossos Palace on the island of Crete, around 3000 BC. (Bardakci & Gorgun, 2020)

B.C. Olives produced on the island of Crete can be found in archaeological findings dating back to 3000 BC. Evidence of olive cultivation can be seen in Linear B tablets found in archaeological studies from the Bronze Age. Around 600 BC; Olives were brought to France by the Romans, firstly in Marseille, then spreading to Gaul. B.C. In the 6th century, olive oil production came from the Mediterranean basin; Archaeological remains have been found during archaeological excavations in the Northern regions, extending to Tripoli, Tunisia, Sicily and Italy. Ancient Egyptian documents also contain information about the production of oil used in the illumination of the Holy Palace during the reign of Ramses II. (Bartolini & Petrucelli, Classification, origin, diffusion and history of the olive;, 2002) (Bartolini, Prevost, Messeri , & Carignani, 1998) (Eitam & Heltzer, 1996)

Archaeological remains found from the Minoan Kingdom Period have shown that pressing arm presses were produced in Crete during the Bronze Age. (2800–1050 BC) (Frankel , Presses for Oil and Winw in the Southern Levant in the Byzantine Period, 1997) (Frankel, Ancient oil mills and presses in the land of israel , 1994) (Frankel, Wine and Oil Production in Antiquity in Israel and Other Mediterranean Countries, 1999)

B.C. in the Israeli region. We learn from archaeological research that oil was exported to Egypt in 1500, and olive oil was produced with a round stone mill on Mount Manasseh, and in Cyprus, B.C. A building with many amphora remains was identified, which is thought to be an olive processing unit, warehouse or shop, where the pressing arm press system dating back to the 13th century and later was identified. It is understood that presses with press arms for intensive production were used in Rasshamra, located in the Levant region, at the end of the Bronze Age. (Eitam & Heltzer, 1996) (Nicholson & Ian, 2000)

Olive cultivation and olive oil production, which existed in Greece especially in the Ancient Age, were largely carried out on small farms and mostly in simple mills. Athens met its grain needs by exporting the oil it produced in this way.

B.C. In the 3rd century, in the Maresha region of Hellenistic Israel, a high-capacity pressure arm press system was applied. In addition, amphora remains from the Hellenistic Period show that olive oil was produced and exported in ancient settlements such as Rhodos, Chios, Lesbos, Thassos and Knidos. (Vossen, 2007) (Fabbri, 2023)

After the discovery of America, the Spanish brought olives and olive oil to the USA and Latin America. In 1769, priests first established an olive garden in San Diego Bay, California.

### **1.11. Olive Around the World and Turkiye**

Olive; It is a plant that was born in Anatolia and its cultivation has become a tradition in the Mediterranean basin for thousands of years. In Northwest Mesopotamia, which is considered the homeland of olives, olives and olive oil have been considered an important food and commercial product since ancient times. Table olive and olive oil production and consumption have grown in importance in recent years, as the globe has become more interested in good living and nutrition. The role of our olive cultivation in the agricultural economy is indisputably great. In addition to the increase in value created by the product obtained from our olive groves, which have a share of roughly 3% in our agricultural areas and evaluated in different ways, in our national economy, the

values it has in terms of land utilization, soil conservation, labor force employment and human nutrition and health further increase its importance. Olive fruit is a product that may be processed for oil and table usage, as well as the byproducts of this processing, and its popularity is growing due to its health benefits. Because of the olive plant's unique climatic conditions, it is mostly grown in Mediterranean-bordering nations (Spain, Italy, Greece, Turkey, Tunisia, Syria, Morocco, France, and Portugal). Currently, these nations account for around 93% of the world's olive trees. According to figures for 2021, 23 million tonnes of olives are produced on around 10.3 million hectares of land worldwide. (FAO(Food and Agriculture Organization, 2023) Although pomace oil, which is a by-product of olive oil, is mostly used in feed and industrial areas and is partially used as cooking oil, it is not defined as olive oil.

Olive oil is an important product demanded all over the world. Olive oil is defined in foreign trade by the hexagonal GTIP codes 150910 (pure olive oil) and 150990 (other olive oil and olive oil fractions, not chemically modified). HS Code 150910 has been abolished in world foreign trade as of 2022, and HS codes 150920 (extra pure olive oil), 150930 (pure olive oil) and 150940 (other pure olive oil) have been implemented. The European Union (EU), other Mediterranean Countries and Turkey are also important producers and exporters of olive oil. (TUIK 2023)

#### **1.12. Olive Groves in the World**

Olive fruit is an agricultural product that can be processed for oil and table purposes and the by-products resulting from this processing can be evaluated. Due to the special climatic requirements of the olive plant, olive cultivation is mostly done in countries bordering the Mediterranean (Spain, Tunisia, Italy, Morocco, Turkey, Greece, Syria, Algeria, Portugal, Libya). At the moment, these nations account for around 93% of the world's olive trees. According to FAO (Food and Agriculture Organization) 2021 data, 23 million tons of olives are produced in approximately 10.3 million hectares of land in the world. (FAO(Food and Agriculture Organization, 2023) To make one unit of olive oil, about four or five oil olives are needed. Due to the increasing demand for olive products such as olive oil and table olives in the world in recent years, olive cultivation has begun to be cultivated economically in countries with a Mediterranean climate, such as Argentina, Chile and Peru, as well as in countries with a Mediterranean coast. There are some values of olive exported countries and amount which have taken from the FAO shown on the Table 10.

**Table 10:** Olive production areas and exports based on countries (FAO(Food and Agriculture Organization, 2023))

<b>Years</b>	<b>Countries</b>	<b>Spain</b>	<b>Tunasia</b>	<b>Italy</b>	<b>Morocco</b>	<b>Turkiye</b>
<b>2013</b>	olive area	2507	1823	1147	922	826
	Export	2630948	504593	1721128	21959	294780
<b>2014</b>	olive area	2516	1589	1157	947	826
	Export	367278	285697	1727854	39847	89586
<b>2015</b>	olive area	2351	1625	1148	1006	837
	export	2934607	948587	1603344	75767	60030
<b>2016</b>	olive area	2522	1646	1145	1008	846
	export	3522314	402454	1697146	53766	69625
<b>2017</b>	olive area	2555	944	1142	1021	846
	export	4146526	406640	1669330	33503	200432
<b>2018</b>	olive area	2579	2995	1139	1045	864
	Export	3588541	784225	1665012	50552	239601
<b>2019</b>	olive area	2602	1281	1139	1073	879
	Export	3281360	466327	1475729	67168	143197
<b>2020</b>	olive area	2624	3660	1146	1069	887
	Export	3214614	812883	1618429	36511	129296
<b>2021</b>	olive area	2623	1281	1129	1104	889
	Export	3875172	594865	1764517	40906	170158
<b>Years</b>	<b>Countries</b>	<b>Greece</b>	<b>Syria</b>	<b>Portugal</b>	<b>Others</b>	<b>World</b>
<b>2013</b>	olive area	797	697	352	1195	10517
	Export	656528	50904	45273	68644	6155729
<b>2014</b>	olive area	818	697	352	1261	10417
	Export	345916	41761	495482	67564	3979541
<b>2015</b>	olive area	821	695	351	1223	10338
	export	702467	39973	481518	73990	7132128
<b>2016</b>	olive area	798	692	356	1046	10544
	export	646476	89167	455636	78618	7161568
<b>2017</b>	olive area	793	692	358	1408	10004
	export	543738	97689	567644	79389	8005733
<b>2018</b>	olive area	963	693	361	1334	12206
	Export	960774	134004	755849	81158	8578170
<b>2019</b>	olive area	903	693	378	1445	10634
	Export	392698	123209	612533	88881	6802048

<b>2020</b>	olive area	906	696	381	1393	12999
	Export	562487	122717	646936	82099	7378012
<b>2021</b>	olive area	819	693	380	1420	10574
	Export	677974	125882	829836	113893	8390405

### 1.13. Olive Oil in the World

Countries with 90% of olive oil production; Spain, Italy, Portugal, Greece, Tunisia, Türkiye, Syria and Morocco. Türkiye ranks 6th in world production with 5%.

In the 2021/2022 period, olive oil production increased by 12.5% compared to the previous season. It is anticipated that global olive oil production would decline in 2022–2023. More olive oil is produced and exported from Spain (39.0%) and Italy (19.5%) than any other nation in the world. Apart from these countries, the most important countries exporting olive oil are Tunisia (17.1%) Turkey (6.1%) Portugal. It was determined as (4.8%). (TUIK 2023)

### 1.14. Processes of Olive Oil Production

#### 1.14.1. Obtaining Pomace

The basic methods used in olive oil production are batch (classical pressing process) and continuous production (centrifugal process) processes.

##### 1.14.1.1. Classic Press Process (Batch Production Process)

This production system consists of feeding, raw material storage, cleaning, shell breaking and crushing, drying-roasting, squeezing, filtration/decantation units. Olives are washed, crushed and ground and kneaded by adding hot water (400C). The resulting dough is then squeezed to remove excess oil. The liquid waste from the presses is a combination of olive juice and water, with the remainder containing oil. Finally, olive oil is extracted from water using vertical centrifuges or decanters. The solid phase is produced as pomace. Press technique uses little water but generates extremely contaminated wastewater. Nowadays, press technology continues to play an important role in olive oil production.

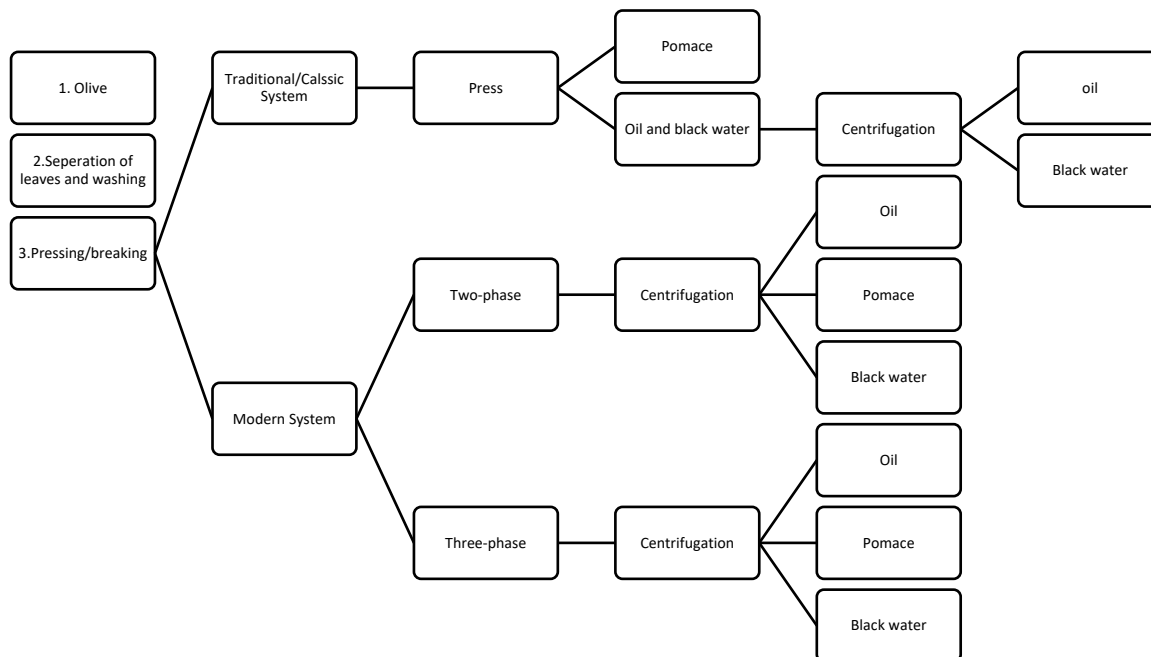
#### **1.14.1.2. Two- Phase Continuous (Sequential) Systems in Olive Oil Production**

Two-phase production systems were developed to address the shortcomings of three-phase continuous plants while keeping their advantages. The steps of the process are similar to those in three-phase systems. The olives are cleaned, then crushed with metal crushers and kneaded in "malaxers" before entering the decanter. The distinction begins, then, in two-phase systems, the decanter receives no extra water. Two different products are produced by this separation process, which is also based on density difference: fresh pomace, which contains the black liquid from the olives, and olive oil. This is why the system is referred to as a two-phase system. The olive oils produced by these methods are commonly referred to as "cold pressed" since the olive paste is left uncooked and no boiling water is added. Two-phase manufacturing does have certain benefits. First, because it is a sequential production procedure, there is little interaction with air and no risk of waiting or accumulation. The procedure reduces the possibility of contamination and degradation of olive oil. Second, the olive oil retains its original scents, vitamins, and antioxidants because no water is used and it is not cooked. Olive oil is both pleasant and beneficial. Last but not least, there is no discharge of black water, therefore no trash is generated for the environment. Nevertheless, there are several disadvantages to two-phase production methods. Initially despite its low efficiency, there is more oil left in the pomace than in three-phase systems. Furthermore, it is more challenging to get rid of pomace. This method is therefore unsuitable for large-scale manufacturing. Because of storage and shipping concerns, many pomace manufacturers decline to buy fresh pomace.

#### **1.14.1.3. Three-Phase Continuous (Sequential) Systems in Olive Oil Production**

With the advancement of machine technology, these systems were created to improve productivity by streamlining the manufacturing process for olive oil, minimising air contact and oxidation, and ultimately producing olive oil that lasts longer. In contrast to the conventional pressing procedure, the most significant characteristic of these systems, which have been in use since the 1960s, is that olive oil is separated using a centrifugal device known as a "decanter." Following washing, the olives are broken with metal crushers in continuous systems, kneaded for a time in kneading tubs, and then the olive dough enters the decanter (centrifuge system), which is the fifth step shown in Figure 1.6.1.3-1. To guarantee separation in the meanwhile, some external water is supplied to the system. Based on the difference in density, this separation mechanism produces three distinct compounds. They are dry pomace, black water, and olive oil, because of this, these systems are

referred to as three-phase. A second centrifuge system is required to separate the olive oil from the water since the oil produced by this system comes out with the olive's black water. Like two-phased systems, three-phased systems offer advantages and disadvantages. Because the system is a sequential manufacturing process, there are several benefits, such as less air contact and no waiting or buildup concerns. The hazards of contamination and oxidation of the olive oil are reduced during the procedure. In addition, it is a rapid and efficient process. Nevertheless, the procedure has drawbacks since it uses a lot of water, which causes some of the water-soluble vitamins, antioxidants, and natural flavours in olive oil to be removed from the oil along with the water. Olive oil loses some of its nutrients. These steps correspond to each procedure and are depicted in Figure 1. Lastly, the procedure has an effect on the environment due to the blackwater generated. It must be disposed of in a way that does not harm the ecosystem. One of the major issues facing our nation and other nations that produce olive oil is environmental degradation. The described transition from olive to oil is illustrated in further detail in Figure 1.6.1.3-1. (Kayahan & Tekin , 2006) (Didin, Zubaroglu Sakarya, Bozdogan Konuskan, & Dogan, 2021) (Gimeno, Castellote, Lamuela-Raventós, López-Sabater, & De la Torre , 2002) (Kiritsakis, 1998) (Mansouri , et al., 2017)



**Figure 1:**Process of Pomace production (Hepsag & Kaya , 2018)

## 1.15. General Production Stages of Olive Oil

### 1.15.1. Pomace Formation

Pomace consists of the fleshy part of the olive fruit and the pulp of the olive seed. Depending on the method used in production, three types of pomace are obtained, with moisture contents ranging from 25% to 75%. From the processing of 1,000 kg of olives, approximately 800 kg of pomace is produced in 2-phase production and 550 kg of pomace in 3-phase production. The content of pomace varies depending on the type of olive, the region where it is grown, the method of cultivation and the olive oil production process. pomace; It can be used for various purposes due to its high organic matter, oil content and high calorific value. Raw pomace is the first product formed after the oils are removed from the olives, and the oil in its structure can be removed by solvent (hexane) extraction or 2nd pressing (pomace oil). Approximately 60-70 kg of dry pomace is obtained from 100 kg of oily pomace. If the pomace is processed without waiting, the resulting oil can be used as food. De-oiled pomace is among the energy sources as it does not contain sulfur and has low ash content. It is thought that 55-60% of pomace in Turkey is utilized by pomace processing facilities. (Ramirez-Tortosa, Granados-Principal, & Quiles, 2006)

### 1.16. Pomace and Pomace Oil Chemical Coverage

There are three types of pomace based on usage artea which. Are pomace, barely seed removed pomace and pulp of pomace. Form those tyes of pomace thereare som physical properties as dry material, ash, cellulose, protein and fat. Those values of pomace may help determination of the usage area. For insatance in biodiesel production generally pulp of pomace and pomace are using because of their fat and dry material amount. Those helps them to interact with both catalysis and other cehmicals suring the bioreactor-based reactions. Additionally, tehre are three types of pomace which are seen on Table 11 are pomace, barely seed removed pomace and pulp of pomace. Those have different values as dry material, ash, cellulose, protein and fat. For instance, dry material value helps to figure out the cosmetic industry, on the other hand fat and cellulose amount give rise to use of biodiesel like applications. For this reason, fat and cellulose amount helps the determination of both catalyst amount and type during the application which directly affects the economical factors of the all pomace based applications.

**Table 11:**Raw nutritional content of pomace (Sansoucy, 1985)

<b>Types of Dry Pomace</b>	<b>Dry material %</b>	<b>Ash %</b>	<b>Cellulose %</b>	<b>Protein %</b>	<b>Fat%</b>
<b>Pomace</b>	75-80	3-5	35-70	5-10	8-15
<b>Barely seed removed pomace</b>	80-95	6-7	20-30	9-12	15-30
<b>Pulp of pomace</b>	35-40	5-8	16-25	9-13	26-33

Another important factor of pomace which used for experiments are chemical compenence of pomace which shown in Table 1.7.2-2. Similar to types of pomace chemical amount into the pomace has direct impact of the system which install for pomace based production process. On the other hand, chemicals of pomace does not show any difference between three pomace types mentioned on the Table 12.

**Table 12:**Chemical compenence of pomace (Alburquerque, González, García, & Cegarra, 2006)

<b>Parameters</b>	<b>Pomace</b>
<b>Moisture</b>	71
<b>pH</b>	5
<b>Electrical conductivity (dS m-1 )</b>	3
<b>Organic matter(g/kg)</b>	952
<b>Lignin (g/kg)</b>	449
<b>Cellulose (g/kg)</b>	207
<b>Hemicellulose (g/kg)</b>	379
<b>Total fats (g/kg)</b>	116
<b>Total organic carbon (g/kg)</b>	539
<b>Total nitrogen (g/kg)</b>	12
<b>C/N</b>	44
<b>P(g/kg)</b>	1
<b>K (g/kg)</b>	16
<b>Ca (g/kg)</b>	4
<b>Mg (g/kg)</b>	2

<b>Fe (ppm)</b>	390
<b>Cu (ppm)</b>	13
<b>Mn (ppm)</b>	12
<b>Zn (ppm)</b>	17

#### 1.16.1.1. Triterpenes

The most commonly found triterpene molecules in olive oil are triterpene alcohols (erythrodiol and uvaol) and triterpenic acids (maslinic acid, oleanolic acid, ursolic acid, betulinic acid). Triterpenic acids, commonly found in plants, are used in the pharmaceutical industry for their anti-tumor and anti-inflammatory activities. Since triterpenes are concentrated in the skin of the olive fruit, they are 10 times higher in pomace olive oil than in other types of olive oil. (Covas, et al., 2006)

#### 1.16.1.2. Sterols

Olive oil contains sterols, which are key components of cell membranes. The sterol content of pomace olive oil (2600 mg/kg) is higher than virgin olive oil (1600 mg/kg). While  $\beta$ -sitosterol constitutes the majority of the sterols in olive oil with a rate of 90-95%, campesterol and stigmasterol constitute 3% and 1%, respectively. (van Rensburg, Daniels, van Zyl, & Taljaard, 2000)

Oil is obtained from pomace by extraction process, but this process should be done without waiting. There are two types of pomaces oil; refined pomace and mixed oil. Refined pomace oil is formed because of refining the oil without changing its natural structure. Mixed pomace oil, on the other hand, is a mixture of virgin olive oil and refined edible oil that can be consumed directly as food. The oil in the structure of pomace is called second quality consumable oil. It is obtained by solvent extraction (usually n-hexane) after the moisture content of the pomace is reduced to 10% by drying. The pomace is dried in rotary dryers at temperatures varying between 40-80°C. Meanwhile, polyaromatic hydrocarbons (PAHs) emerge due to the polymerization of sugars and the effect of combustion fumes. These carcinogenic substances, which can form during the processing of foods at high temperatures, are among the important quality criteria for dried pomace.

Pomace contains up to 4-5% oil and 35-70% moisture, depending on the processing technique. The moisture content of the solid by-product (pomace) formed in two-phase systems (60-70%) is quite

high compared to the moisture content of the solid by-product in three-phase systems (35-40%). While the solid by-product of three-phase systems is considered as a solid with high moisture content, the by-product of two-phase systems is obtained in the form of slurry. (Ramirez-Tortosa, Granados-Principal, & Quiles, 2006)

### **1.17. Pomace usage in food Industry**

In their study where they used phenolic compounds extracted from pomace to enrich virgin olive oil, they found that pomace samples had bad taste and odor due to the ethyl acetate used in extract extraction; However, they reported that the total phenolic substance amount, oxidative stability, bitterness index, chlorophyll and carotenoid amount increased significantly.

Cereal products rank second among the most preferred products in the functional foods industry. To obtain functional bread, enrichment with dietary fiber and polyphenols is generally applied. (Suárez, Romero, & Motilva, 2010)

They examined bread enriched with dried pomace from a sensory perspective. They found that the crumb color of the bread was negatively affected by the enrichment (it became grayer and darker), the inner hardness, crumb and chewiness were higher in pomace breads, and the degree of leavening was lower than the control. In another study conducted to examine the effect of olive oil waste on the sensory and nutritional characteristics of bread, the glycemic response and bioaccessibility of polyphenols in pomace samples were also examined. (Cecchi, et al., 2019)

Since the phenolic content of pomace was found to be stable in vitro, it has been reported that enrichment reduces the glycemic index, affects bread bubble formation, and although there are minor differences with the control sample in terms of taste and color, 10% enriched bread is generally acceptable. (Cedola, Cardinali, Nobile, & Conte, 2019)

They determined that when pomace is used as a functional ingredient in biscuits and bread making due to its composition, enrichment with pomace provides an increase in phenolic content in all products, especially fermented products, and yeast fermentation also increases the tocopherol concentration.

To increase the quality of making gluten-free breadsticks, the effect on textural, sensory and nutritional properties was examined by adding low amounts of olive pulp powder (1%, 2% and 3%) instead of corn flour. As the olive pulp ratio increases in enriched samples, the amount of oil,

ash, moisture and total dietary fiber increases; It was determined that there was a decrease in hardness and an improvement in general liking. (Nunzio, et al., 2019)

In another study, pomace powder was used in pasta production by replacing wheat semolina. Due to the dietary fiber in the pomace content, the cooking time of enriched pasta decreased, and cooking loss and water absorption increased. An increase in stickiness, hardness and redness and a decrease in color value (yellowness) were observed. (Gimeno, Castellote, Lamuela-Raventós, López-Sabater, & De la Torre , 2002)

The presence of pomace also positively affected the digestibility of the starch fractions of the samples.

In another study on pasta, the effects of pomace on the chemical composition, cooking and sensory quality of pasta were examined by adding pomace to the dough in certain proportions by weight after drying, grinding and turning it into flour. It was determined that pomace-added samples were richer in fiber, tocopherol and carotenoids, and pomace-added pasta was more acceptable.

Later, the addition of different concentrations of transglutaminase was tried to increase the quality. It was found that the addition of transglutaminase improved the overall quality of pasta in terms of elasticity, stickiness and bulkiness.

In another study where dried pomace was added to egg pasta and examined in terms of its sensory properties, it was determined that the enriched pasta differed from the control pasta with an increase in color, color stability, olive oil and wheat flour flavor. (Padalino, et al., 2018)

In their study on the use of pomace in meat products in Spain, they examined the changes in the oxidative stability and sensory properties of lamb meatballs enriched with Omega 3 fatty acids during 9 days of storage under refrigerator conditions. According to the results obtained, it was seen that pomace extract had the potential to be used as a natural antioxidant in meatballs. With the addition of extract, fat and protein oxidation of meatballs decreased and their acceptable color stability was prolonged. (Simonato B. , Trevisan , Tolve, Favati, & Pasini, 2019)

When dry pomace flour was added to fish burgers for the purpose of enrichment and increasing quality properties, it increased the phenolic content and antioxidant activity, and caused deterioration in color, texture, odor and taste (due to polyphenols), especially in cooked burgers.

There are also studies on the recovery of pectin, a complex polysaccharide used as a gelling and thickening agent in foods, from pomace. In a study, pectin was obtained from heat-treated pomace by ethyl acetate extraction and was compared with commercial ones. It has been determined that

pomace pectin is similar to apple pectin in terms of emulsion stability with its low water retention and high oil retention capacity, and in in vitro experiments it has been determined that it may contribute to lowering serum cholesterol levels and reducing the risk of bowel cancer. (Difonzo, Troilo, Squeo, Pasqualone, & Caponio, 2020) (Difonzo, et al., 2018)

Studies are being conducted to evaluate the feasibility of creating natural fragrance compounds from pomace by microbial fermentation.

Active packaging is defined as adding qualities to the packaging material that operate as a barrier to protect the goods from external pressures. Today, scientists have resorted to inventing environmentally friendly packaging that might reduce food waste. (Muiño, et al., 2017)

Since pomace has high antioxidant properties, trials are being carried out for its use in the packaging industry. After lyophilizing pomace at  $-40^{\circ}\text{C}$ , grinding and sieving it (to separate particles smaller than 500 nm), they investigated its antioxidant, optical, barrier and mechanical properties by adding it to chitosan films at different concentrations (10%, 20% and 30%). (Cardinali, Cedola, Nobile, & Conte, 2017)

It was observed that with the addition of pomace, the antioxidant property improved, the chitosan film became rougher, and the tensile strength increased. It is stated that films containing pomace flour are effective for one month in protecting hazelnuts against oxidation. (Rubio-Senent, Rodríguez-Gutiérrez, Lama-Muñoz, & Fernandez-Bolanos, 2015) In a similar study, pomace-added chitosan coating was used on cold-stored strawberries and compared with commercial coating, while uncoated fruits served as the control sample. It was observed that the amount of malondialdehyde, which is an indicator of decay area and lipid peroxidation, increased significantly in control fruits compared to samples coated with pomace-added films. (Crizel, et al., 2018) (Lammi, Moigne, Djenane, Gontard, & Angellier-Coussy, 2018)

### **1.18. Pomace usage in animal Feeding**

Considering the number of cattle and sheep in Turkey and the average amount of roughage required to feed them, it is thought that there is a serious roughage deficit and the use of some by-products such as pomace, which can reduce feed costs, will be an important alternative in order to close this gap.

However, as it is known, olive harvest and therefore pomace production is done once a year and in certain months. For this reason, for pomace to be used as a roughage source for animal feeding

throughout the year, it must be silaged or stored using appropriate ensiling techniques after its oil is removed in a short time.

The use of pomace in animal nutrition is more common compared to other by-products of olive oil production, but its chemical composition affects its use in animal nutrition.

The fiber content of pomace is high and the amount of crude protein is low. The majority of pomace consists of organic matter. Since 2-phase pomace does not oxidize in a short time, it has a higher potential to be used as animal feed. In the study conducted to determine the effects of feeding dried pomace (10%) on the properties of milk and cheese in dairy cattle; It has been reported that pomace feeding is better in terms of fatty acid composition, total tocopherol and hydroxytyrosol content, there is an increase in mono- and polyunsaturated fatty acids and a decrease in saturated fatty acids, there is no sensory difference with the control sample and even better quality milk is obtained. (Castellani, et al., 2017)

The use of olive pomace in feeding small ruminants that can better utilize low-quality feed is more suitable than in productive dairy cows, whose requirements are higher.

They tried to determine the effect of pomace on milk yield, milk composition, fatty acid composition and coagulation properties by using pomace alone and in combination with vitamin E in the feeding of milk rations. According to the analysis results of the samples taken in two-week periods; The highest protein and casein percentages were found in control samples. In addition to milk yield, the addition of pomace increased the amount and quality of fat content in milk, the coagulation time of the vitamin E-containing pomace group decreased, and thus, a waste product was recovered and the ration cost was reduced. (Chiofalo, Luigi, Zumbo, & Chiofalo, 2004)

In another study, it was reported that polyunsaturated fatty acids and vitamin E levels, as well as oxidative stability and shelf life of the meat, increased in the meat of lambs fed for about one and a half months with the addition of seeded pomace to concentrated feed. (Luciano, et al., 2013)

When the effect of pomace on the live weight, carcass characteristics and chemical structure of the meat of lambs fed for approximately two months with feed containing two different concentrations of pomace was investigated, it was seen that pomace did not have a negative effect on daily live weight gain and carcass weight.

In a study on the use of pomace in chicken feeding, the growth rates of chicken groups fed three different diets: control diet, low dose and high dose pomace increased in parallel with the increasing pomace concentration. The highest level of pomace processing increased the level of antioxidants

and oxidative stability of protein. Consumers perceived no sensory difference between chicken meats. (Branciari, et al., 2017)

According to another study, when laying hens were fed pomace-fortified feed, the cholesterol level in the yolk was found to be lower than in control eggs. A good silage quality was obtained by silage of pomace with a certain amount of molasses, and it was stated that it could be used more easily in ruminant feeding as it reduced the polyphenol content, which limits protein use and microbial protein synthesis in ruminants, by approximately half. (Difonzo, Troilo, Squeo, Pasqualone, & Caponio, 2020)

### **1.19. Pomace Usage in Biodiesel Production**

Although pomace oil has similar properties to olive oil, it is understood at first sight that it is different from olive oil with its strong smell and green color. Consuming it as cooking oil without any processing is dangerous for health. Some procedures must be carried out when using oils with high fatty acid values as cooking oil. These processes cause high-cost input. For this reason, oils containing high fatty acids are preferred to be used in biodiesel production, soap industry or cosmetics industry. The acidity of pomace oil depends on the type of olive, the soil where the olive is planted, the processing technology of the olive, and the time the olive pulp is kept for processing. To produce biodiesel from pomace oil, which is a by-product of the olive industry, the value of free fatty acids must be reduced, and optimum values must be determined. The improvement of the amount of free fatty acids is done by reacting pomace oil with different alcohol ratios by volume and different H<sub>2</sub>SO<sub>4</sub> catalysts by mass. Thus, after reducing the amount of free fatty acids, pomace oil can be used in biodiesel production and can provide economic return for the olive industry.

The effects of reaction temperature, reaction time, the amount of H<sub>2</sub>SO<sub>4</sub> added by mass and the amount of alcohol added by volume, which affect the yield in reducing the amount of free fatty acids, should be examined. (Franklin, Sarantopoulos, Tsoutsos, & Gekas, 2012)

### **1.20. Industrial Usage of Pomace**

Olive Oil – 2022/23 Harvest Year Olive oil and pomace oil trade, 2022/23 harvest year (October 2022-November 2022) is indicated with numerical data in the first 8 market countries in the table below. When compared to the same harvest period in the previous year, imports; While it increased by 2% in Australia, 26% in Brazil, 54% in Canada, 22% in China and 23% in the USA, it decreased

by -21% in Japan. When the first two months of the harvest year (2022/2023) are compared with the last harvest year; While there was a 6% increase in intra-EU purchases; EU imports also decreased by -29%. (National Horticulture Board )

## 1.21. Pomace in Turkiye

### 1.21.1. Olive Groves and Grain Olive Production

According to TÜİK data; A total of 9 million decares of olive grove area was recorded in Turkey in 2022. For 2022, 74% of the total olive grove areas will be oil olive areas and 26% will be table olive areas. There was a 9.1% increase in the area of grain olives between 2013 and 2022. When we examine the increase in olive groves as oil olive areas and table olive areas, it is seen that there is a 12.4% increase in oil olive areas and a 0.7% increase in table olive areas.

When the number of olive trees in Turkey is examined, there will be approximately 194.5 million olive trees in 2022. Of the total number of trees, 163 million are fruit-bearing olive trees and 31.5 million are non-fruiting olive trees. In other words, 84% of olive trees consist of fruit bearing trees and 16% of them do not bear fruit. Between 2013 and 2022, the total number of fruit-bearing olive trees increased by 26%, while the total number of non-fruiting trees decreased by 17%. Between 2013 and 2022, there was a 14% increase in the number of fruit-bearing table olive trees and a 33% increase in the number of fruit-bearing oil olive trees. The data taken from TUIK was shown in Table 13, addition to Table 13 in Table 14 olive oil production in tons for both table olive and oil olive was shown.

**Table 13:** Olive areas, number of trees , production and efficiency status in Turkey( $10^3$  tons) (<https://arastirma.tarimorman.gov.tr/tepge>, n.d.)

Types of olive	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Table olive	2309	2200	2236	2263	2265	2100	2341	2335	2303	2326
Olive for oil	5949	6060	6133	6193	6196	6545	6450	6536	6589	6685
Total	8258	8261	8369	8455	8461	8644	8792	8871	8892	9011

**Table 14:** Olive Oil Production in Turkiye ( $10^3$  tons) (<https://arastirma.tarimorman.gov.tr/tepge>, n.d.)

Production	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Table olive	390	438	400	430	460	427	415	513	556	938

<b>Oil olive</b>	1286	1330	1300	1300	1640	1073	1110	803	1183	2038
<b>Total</b>	1676	1768	1700	1730	2100	1500	1525	1317	1739	2976

Periodic olive production in the olive tree varies from year to year, and depending on the production, one year the product is low and the other year it is high. In 2022, as in Türkiye in general, in most provinces, a higher yield was achieved compared to the average of 2013-2022. This high yield will impact the 2022/23 marketing year.

A total of 2.98 million tons of olives were produced in 2022, of which 2 million tons are oil olives (68.5%) and 98 thousand tons are table olives (31.5%). Although production fluctuates over the years, grain olive production tends to increase in parallel with the increase in olive areas. (TUIK 2023)

Oil olive production is concentrated in the Aegean Region. Turkey's top five provinces for oil olive output are Aydın, İzmir, Muğla, Balıkesir, and Manisa, based on a ten-year average. In 2022, the shares of provinces in oil olive production were 20.1% in Izmir, 12.2% in Aydın, 11% in Muğla, 10.7% in Balıkesir and 10.1% in Manisa.

### 1.22. Turkey's Olive Oil Production and Consumption

According to UZZK (National Olive and Olive Oil) data, approximately 1,200 olive pressing facilities in Turkey have an average capacity of 70,000 tons/day. Capacity utilization rates in olive oil factories, which have difficulties in supplying raw materials due to the periodicity of olives, are around 40-50% on average. Aydın, Muğla and İzmir provinces produce approximately half of Türkiye's olive oil production.

According to 2020/21 season data, olive oil per capita in producing countries such as IOC and EU members Spain (11.4 kg), Greece (10.3 kg), Italy (7.1 kg) and Portugal (5.8 kg). consumption was over 5 kg. In other IOC member countries, per capita olive oil consumption is 5.2 kg in Algeria, 3.7 kg in Morocco, 2.5 kg in Tunisia and 1.8 kg in Turkey. Syria, which is not a member of the IOC, stands out with per capita consumption of 6.8 kg and Australia with 2.2 kg. Turkey's per capita olive oil consumption remains below the global average. However, the high consumer prices of olive oil in Turkey compared to other vegetable oils affect domestic olive oil consumption. Since sunflower and corn oils, which are mostly consumed as edible oils in Turkey, are more affordable, domestic olive oil consumption remains under pressure, although there is sufficient production to meet domestic demand. When the prices of competing products are examined; The prices of

sunflower, corn and margarine oils are approximately half of the price of olive oil. Butter is much more expensive than olive oil.

Year by year olive oil production and consumption were change all mediterranean countries. In Turkiye this values were increasing yearly as well shown in Table 15.

**Table 15:**Turkiye's olive oil production and consumption amount( $10^3$  tons)

<b>Years</b>	<b>Produce</b>	<b>Consumption</b>
<b>2012/13</b>	195	150
<b>2013/14</b>	135	105
<b>2014/15</b>	160	125
<b>2015/16</b>	150	116
<b>2016/17</b>	178	150
<b>2017/18</b>	263	177
<b>2018/19</b>	194	163
<b>2019/20</b>	230	170
<b>2020/21</b>	194	150
<b>2021/22*</b>	235	170

### **1.23. Contribution of Olives and Olive Products to Turkish Economy**

#### **1.23.1. Olive Oil Export**

When we look at the amount of olive oil exports between 2013 and 2022, we can say that although it fluctuates over the years, it tends to increase. Of the 93,265 tons of exports in 2022, 68% was pure olive oil and 32% was other olive oil (refined and riviera).

The countries to which Turkey exports the most are Spain, the United States, Saudi Arabia, Japan and the United Arab Emirates, nevertheless exports a vast variety of goods.Export operations are carried out in accordance with the "Issuance of Health Certificate in the Export of Herbal Food and Feed and the Implementation Regulation for the Products Returned from Export" and the "Issuance of the Health Certificate in the Export of Herbal Food and Feed and the Implementation Instruction for the Products Returned from Export". In exports, the criteria of the recipient country are taken into account first, and if the recipient country does not have a special request, Turkey's legislation is taken into account as hown in table 16.

**Table 16:** Turkiye's export amount(tons) and value(thousand tons)by years  
(<https://arastirma.tarimorman.gov.tr/tepge>, n.d.)

Years	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Pure olive oil (150910, 2022 yılından sonra 150920, 150930 ve 150940)</b>										
<b>Amount</b>	42336	15771	11403	19030	33554	41897	31261	31056	38243	63869
<b>Value</b>	140888	62878	52557	67271	133406	157441	90905	81186	116795	230721
<b>Other olive oil (150990)</b>										
<b>Amount</b>	49844	7382	5098	10033	22934	29851	22668	22628	16958	29396
<b>Value</b>	153992	26708	20504	35452	89758	103533	52292	48110	53363	107721
<b>Total</b>										
<b>Amount</b>	92180	23153	16501	29063	56488	71748	53929	53684	55201	93265
<b>Other</b>	294780	89586	73062	102723	223164	260974	143197	129296	170158	338442

Although Turkey is among the top four countries in olive oil exports, it remains far behind the leading country, Spain, in terms of export value. A significant part of olive oil production in Turkey is subject to international trade, but olive oil exports in Turkey are mostly made in the form of crude oil with low added value. Exported oil is sold in packaged form in the foreign market in insufficient quantities. It should be aimed to promote exports as packaged Turkish olive oil and to export more of them in this way. It is important to support the olive oil sector within the framework of long-term programs in all areas from production to consumption.

Unregistered trade in olive oil also emerges as a big problem. Although the profile of branded, packaged and registered producers and traders in the sector in accordance with the rules required by trade has increased in recent years, there is a significant segment that is unregistered, unbranded and operates under inappropriate packaging and storage conditions. There are occasional increases in the sales of contaminated oil. The fact that the Export Refund Support for agricultural products in Turkey is low compared to exporting countries reduces our competition in world markets. This support should be close to the level in EU countries. (Tarımsal Ekonomi ve Politika Gelistirme Enstitüsü, 2022) (<https://arastirma.tarimorman.gov.tr/tepge>, n.d.)

SuperPro Designer is a process simulation, modelling, and optimisation program that is widely used in industries such as biotechnology, pharmaceuticals, food, chemicals, and water treatment.

\*\*Intelligen, Inc.\*\* created a complete framework for designing, analysing, and optimising

manufacturing processes. There are several important features that relate to the SuperPro Designer program, including process modelling, cost analysis, environmental impact assessment, scalability and technology transfer, resource management, and regulatory compliance. First, process modelling and simulation allow for the modelling of whole production processes, including material and energy balances, as well as the simulation of batch and continuous processes in a variety of sectors. Second, cost analysis is used to undertake extensive cost evaluations, such as capital expenditures (CapEx) and operating expenditures (OpEx), as well as to find cost-saving options and evaluate profitability. Then, environmental impact assessments, which examine the environmental footprint of operations such as waste creation, energy consumption, and emissions, help to build more sustainable and eco-friendly processes. Another application area is scalability and technology transfer, which aids in the transition of processes from laboratory or pilot-scale to full-scale production and facilitates technology transfer by giving a clear depiction of process needs. Furthermore, resource management is a critical application of SuperPro designer, which optimises the utilisation of raw materials, utilities, and labour to improve efficiency and aid in inventory and supply chain management by integrating production schedules. Finally, regulatory compliance, which includes industry standards to guarantee that processes fulfil regulatory criteria, aids in the documentation of regulatory filings and audits. SuperPro is used for a variety of reasons, including process optimisation, economic feasibility, time and cost savings, improved decision making, support for innovation, sustainability and environmental compliance, and cross-team communication. First, one of the most common applications is process optimisation, which identifies bottlenecks and inefficiencies in a process, allowing for the optimisation of production throughput and cost. Second, by giving specific cost breakdowns and profitability data, economic feasibility analysis aids in determining whether a method is financially viable. Then, by enabling virtual testing and scenario analysis, RD departments can save time and money on experimental trials. Improved decision-making provides a data-driven approach to decision-making, which aids investment and operational decisions. Support for innovation promotes the development and scaling of new technologies and processes, assuring their technical and economic viability. Furthermore, sustainability and environmental compliance assist firms in developing greener operations that comply with environmental rules and reduce waste. Finally, collaboration across teams gives a shared platform for engineers, scientists, and business analysts to work together on process design and improvement. In addition to its ease of use, SuperPro Designer is applicable in

a variety of industries, including biotechnology and pharmaceuticals, food and beverage, chemical, water and waste management, and renewable energy.

As mentioned before SuperPro designer is using for technological optimisation and economical analysis, moreover, system found in the application give rise to examine both technologies as techno-economical analysis.

Techno-economic analysis (TEA) is a systematic assessment of a project's technical and economic characteristics. It integrates technical, scientific, and economic approaches to evaluate the feasibility, cost-effectiveness, and scalability of a technology or procedure. Techno-economic analysis has three subtitles: technical assessment, economic assessment, and the integration of technical and economic elements. First, technical assessment is used to determine the technical feasibility of a process or technology, which includes design parameters, material needs, energy consumption, and process efficiency. Additionally, it reveals potential technical issues and bottlenecks. Second, techno-economical analysis is used for economic assessment by estimating expenses such as capital expenditures (CapEx) and operational expenditures (OpEx) to analyse revenue potential, market trends, and competitive positioning. Furthermore, economic assessments include financial indicators like net present value (NPV), internal rate of return (IRR), and payback period. Finally, techno-economical analyses integrate technical and economic elements, linking process performance (e.g., yield, efficiency) to economic results to examine trade-offs between technical performance and costs. The reasons why production systems require techno-economic assessments are divided into numerous categories, including decision making, risk management, technological development, scalability and market entry, regulatory and policy assistance, and sustainability assessment. First and foremost, decision making assists stakeholders in determining whether to proceed with, invest in, or quit a project or technology to uncover the most cost-effective choices. Then, risk management identifies potential risks and uncertainties, allowing for more informed decisions that lower the possibility of unexpected costs or technical failures. As the next generation of technology develops, techno-economical studies are required to drive R&D activities by identifying essential performance indicators that effect economic viability, ensuring that new technologies correspond with market expectations and cost restrictions. Furthermore, scalability and market entrance assist in determining if a technology or process can be profitably scaled up, as well as evaluating market circumstances and potential entry obstacles. Regulatory and policy assistance offers policymakers or regulatory authorities with proof of a technology's economic and

technical benefits to support grant applications and funding proposals by demonstrating economic and technical feasibility through techno-economical analysis. Finally, through sustainability assessments, which are frequently combined with environmental impact evaluations, TEA can analyse the economic viability of sustainable technologies to aid decision-making in fields such as renewable energy, carbon capture, and green chemistry. Techno-economical analysis systems can be used to evaluate the cost-effectiveness of renewable energy systems (e.g., solar, wind, hydrogen), assess biofuel production processes for scalability and profitability, analyse the feasibility of carbon capture and storage (CCS) technologies, develop cost estimates for manufacturing new materials or products, and compare the economics of different wastewater treatment technologies. By combining with required systems.

Olive pomace, commonly known as olive cake, is made up of remaining olive components like olive seeds, husks, leaves, and pulp. The most prevalent method of producing or getting olive pomace occurs in olive oil facilities. (Zeytinyagi, 2019) Additionally, olive farmers and collectors acquire olive pomace. In addition to olive oil manufacturers, farmers gather olive pomace to feed animals (Meclisi, 2020). Approximately 20% of the olive pomace is lost during the early stage. This loss comes as a result of farmers' uninformed usage. To prevent this loss, farmers and olive collectors must be educated and trained early on. However, when examined on a project basis, this education and awareness will never be sufficient and efficient enough, thus all calculations performed or to be made take into account the large amount of waste occurring in the first stage. When olive pomace is regarded as industrial waste, the traditional pressing of olive oil during olive oil production is the first significant step in obtaining olive pomace (Akbas , 2022). Furthermore, traditional pressing processes are mostly responsible for the leftover olive oil in olive pomace. Stone mills or similar instruments and equipment are used to perform this pressing procedure. The following level is the three-phase process. During this stage, the uniform mixture formed after pressing olives is divided into three portions. This is known as the three-phase process approach. Due to the acidity of the olives or soil in various producing zones, this process may be repeated one or more times. Finally, a two-phase separation procedure is used to refine the resulting olive oil. As with the preceding stage, this step can be repeated numerous times. Every time this process is repeated, the olive oil's purity rises. In addition to raising the sales price, the two-phase and three-phase separation techniques are thought to improve the vitamin and mineral content of olive oil (Elibol, Yasa, Karacanci, Coban , & Ozsoy, 2017) Black water and olive pomace are the waste

products produced by all of these processes. The project's goal is to recycle purified olive pomace and make it accessible to the general population in addition to the high-value olive oil that is produced. Consequently, the SuperPro application will be used in a digital setting to optimise the processing of olive pomace and boost its production. The project can proceed with execution if this thesis, which was carried out only to show the techno-economic appraisal of olive pomace without the requirement for any practical application, succeeds in its objective. The most efficient techno-economic aspect is the recovery of black water as process water, which also adds value as olive pomace. With each iteration of these procedures, the amount of olive pomace produced will decrease as the sales cost rises. The waste management procedures that must be followed are impacted by the decline in olive pomace. Olive pomace is a major biomass resource that is especially prevalent in Mediterranean nations like ours. The generation of biogas and biodiesel is the most well-known application for olive pomace. The quantity and quality of biomass can influence the order of subsequent stages in collaborative agricultural-industrial research. It also has an impact on a lot of things, such the work force, equipment capacity, and the chemicals that will be used in the operations. Every alteration to these variables eventually affects the system's relevance and cost. (Ilay, Erarslan, & Kavdir , 2019)

Relevance is crucial in these kinds of systems since the more modern the system, the less maintenance it needs. The system will be similarly autonomous to optimise and advance throughout the process, rather than only considering maintenance requirements. (Hocaoglu , 2015)

Olive oil production, which is particularly important in Mediterranean nations, is a year-round operation, but olive picking is a seasonal task. Olive oil manufacturers only function a few times a year, for around three months, leaving the other nine months idle since farmers can only harvest olives once a year. Our idle industries will run for extended periods of time given the techno-economic contribution of olive pomace. By creating job possibilities, this would not only boost the local economy but also lower unemployment rates. In addition to creating jobs in the area, the same business will be able to handle olive pomace. At the moment, processing firms get olive pomace from oil producers, which leads to substantial operational and transportation losses. By overcoming this loss and additional expense, the system that will be built aims to prevent these identified losses. (Elibol, Yasa, Karacanci, Coban , & Ozsoy, 2017) (Hocaoglu , 2015)

## **2. Materials And Method**

### **2.1. Materials**

#### **2.1.1. SuperPro Design Program**

Three distinct applications were developed using the SuperPro Designer software, each designed as a batch process.

The first application focused on the production of olive oil and pomace through a two-phase process. Initially, the required chemicals for this application were defined and introduced into the system. Subsequently, the operational mechanism was configured, and the chemical inputs were systematically incorporated. Once the system was confirmed to be fully functional, it was recorded to enable the extraction of techno-economic data for analysis.

In the second application, the focus shifted to converting olive pomace into a biodiesel additive. For comparative analysis, two distinct biodiesel application procedures were selected, both implemented as batch processes. Variations in catalytic agents were introduced during the biodiesel production processes to evaluate their impact.

These applications were designed to investigate the techno-economic feasibility and optimization of the outlined processes.

### **2.2. Method**

The SuperPro Design program has created three systems focused on the processes of converting olive oil to pomace and pomace to biodiesel. Based on the economic analyses performed in SuperPro Design, olive pomace production from olive oil was integrated with two different biodiesel production systems. The data obtained from these systems were compared to determine the most suitable production line for transitioning from olive oil to biodiesel.

The process of obtaining olive oil from olives follows several key steps. First, olives gathered from the field are washed. After washing, the olives are crushed to prepare them for subsequent processes. They are then passed through grinders that separate them into smaller pieces. Following this separation, the first water extracted from the olives is added to a tank heated to 400 degrees, which is calibrated to the appropriate amount of water based on the crushing process. This mixture is then squeezed to separate the oil from the solids. Through the decanter separation process, the

extracted essence is divided into olive oil and pomace, with pomace representing approximately 80 percent of the initial weight of the olives.

In the initial application trial, we utilized four bioreactors, four decanters, three distillation/separation columns, and two small-scale mixers. These reactors facilitated sequential processes for oil separation, water separation, glycerin production, and biodiesel production.

In the first reactor, a mixture of pomace and olive oil was combined with alcohol and a catalyst. This combination triggered the reaction that produced impure glycerin and water vapor. The glycerin generated in this reactor is then processed through a series of purification steps to separate it from the water content. These purification steps include separating alcohol and water, followed by salt separation.

In the second phase of the process, the glycerin solution—which contains pomace, salt, and alcohol—is mixed with additional water and alcohol, resulting in a mixture of glycerin and biodiesel. This mixture is first processed in mixer P11, where it undergoes reactions for the formation and purification of methyl esters, after passing through reactor P2 and decanter P6 for glycerin separation.

Next, the mixture is reacted with a catalyst in reactor P4 to separate the methyl esters. After this reaction, the biodiesel-glycerin solution is transferred to decanter P8 for further glycerin separation. The biodiesel is then subjected to distillation in column P12 to remove any remaining water. The final distillation process yields biodiesel with 80% purity, achieved by evaporating residual gases and separating the methyl esters.

Second biodiesel application has done in SuperPro design program includes two reactors, four distillation columns two decanting reagent and two mixing blending machine. First, pure water and purified water are combined and prepared for the reaction in the P2 reactor. The mixture is then heated and reacted with catalysts in the P2 reactor. After this process, a mixture containing water, methanol, sodium hydroxide, methoxide, and glycerol is produced and directed to the P3 separation unit. After waiting for approximately four hours, the mixture is sent to the decanter to separate the glycerin.

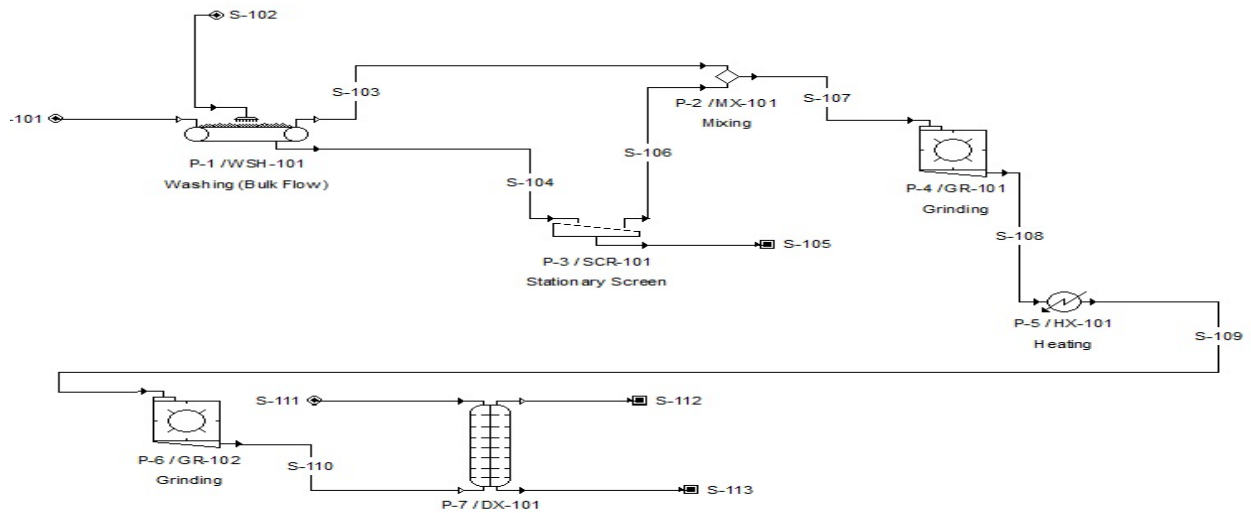
Some of the glycerin sent to the decanter is forwarded to the P11 distillation unit to be converted into biodiesel. The impure portion is sent to the P5 mixing unit, where it is combined with water and chemical mixtures and reacted at a temperature of 120 degrees Celsius. As a result of this reaction, a mixture of biodiesel, glycerin, and alcohol is obtained.

This mixture first passes through the P7, P8, and P10 processes for the separation of alcohol and then glycerin, respectively. The remaining semi-pure biodiesel is then transmitted to the P9 mixing unit. In the P9 unit, the mixture undergoes further processing in the P11 distillation to obtain 80% pure biodiesel and glycerol, resulting in complete purification from glycerin.

Following the application of two distinct biodiesel treatments, each was separately integrated into a two-phase continuous system made especially for processing olive pomace, which is a byproduct of the manufacturing of olive oil.

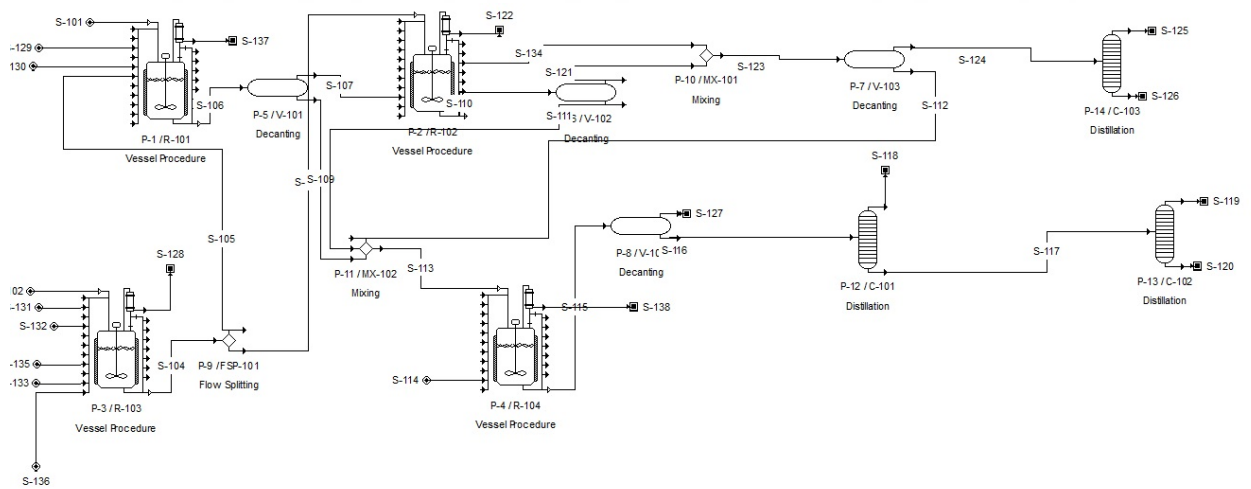
### **3. Results**

In the SuperPro program, various techno-economic analyses were conducted using data from systems designed to examine the production of two-phase olive pomace and the utilization of the resulting pomace for biodiesel production. There are two different application type in Supoerpro, batch process and continuous process. In batch process, basically process does not repeat itself and may add other processes, however, in continuous process It is easier to repeat process itself, additionally, combine process with other processes by the help of programme. Not only to adding other processes easier but also to determine optimization of the process from olive oil to pomace process determined as continuous process. The other reason why continuous process was selected is machine determination. The last step of the process which is shown in Fig.1 is decantor. This step is crucial step of the process because the last unit will add to the other processes shown in Fig 2 and Fig 3.



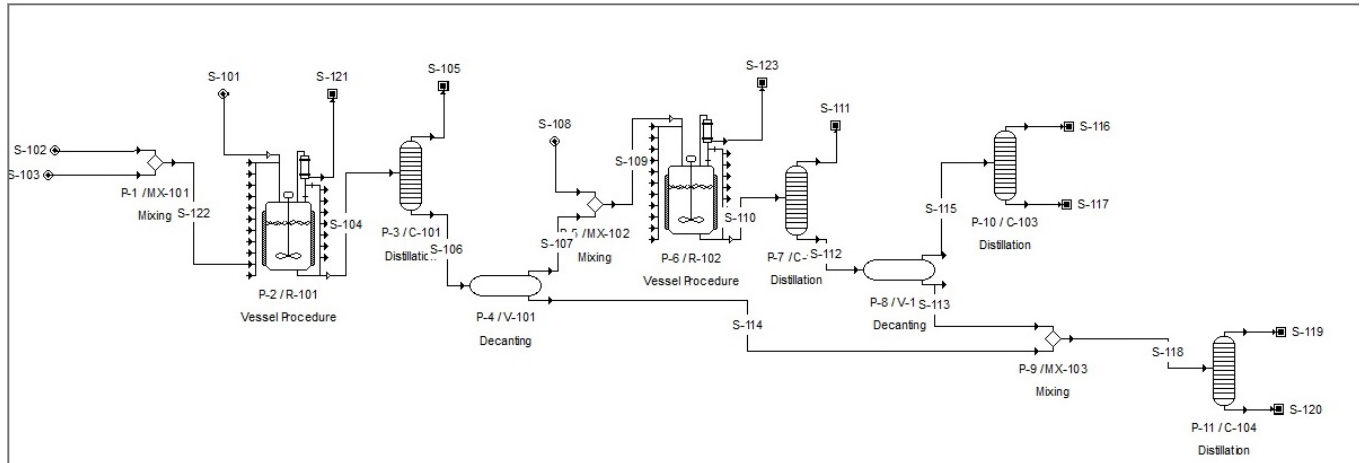
**Figure 2:** Two phase diagram from olive to pomace

The first application of biodiesel process includes four vessel procedure bioreactors and decanters, three distillation columns. This system was obtained using the steps mentioned in the method part.



**Figure 3:** Biodiesel application 1 from pomace

Similar to other applications last application was taken from the SuperPro design program by the help of steps mentioned in the method part.



**Figure 4:**Biodiesel application 2 from pomace

After taking optimum systems of olive oil to pomace and pomace to biodiesel applications, optimum economical results were taken as shown in Table 17.

**Table 17:**2 phase olive oil to pomace application, Biodiesel 1 and Biodiesel 2 application economical results

	2	phase	Biodiesel 1	Biodiesel 2
	continuous			
<b>Total Captive Investment</b>	2084000	21617000	11084000	
<b>Capital Investment</b>	2084000	21617000	11084000	
<b>Operating Cost</b>	1433000	6978000	6921000	
<b>Revenues</b>	0	0	0	
<b>Gross Margin</b>	-1%	-1%	-1%	
<b>Return On Investment</b>	-60%	-23,33%	-53,72%	
<b>Payback Time</b>	0	1	1	
<b>IRR( After Taxes)</b>	0	1	1	
<b>NPV( at 7.0% Interest)</b>	0	0	0	
<b>Major Equipment Specification</b>	306000	3425000	1713000	
<b>Fixed Capital Estimate</b>				
<b>Total Plant Direct Cost</b>				
<b>Equipment Purchase Cost</b>	306000	3425000	1713000	

<b>Installation</b>	153000	1197000	598000
<b>Process Piping</b>	107000	1199000	599000
<b>Instrumentation</b>	122000	1370000	685000
<b>Insulation</b>	9000	103000	51000
<b>Electrical</b>	31000	343000	171000
<b>Buildings</b>	138000	1541000	771000
<b>Yard Improvement</b>	46000	514000	257000
<b>Auxiliary Facilities</b>	122000	1370000	685000
<b>TPDC</b>	1033000	11061000	5530000
<b>Total Plant Indirect Cost</b>			
<b>Engineering</b>	258000	2765000	1383000
<b>Construction</b>	362000	3871000	1936000
<b>TPIC</b>	620000	6636000	3318000
<b>Total Plant Cost</b>	1653000	17697000	8848000
<b>Contractor's Fee and Contingency</b>			
<b>Contractor's Fee</b>	83000	885000	442000
<b>Contingency</b>	165000	1770000	885000
<b>CFC</b>	248000	2655000	1327000
<b>Direct Fixed Capital Cost</b>	1901000	20351000	10176000
<b>Labor Cost</b>	699166	3358575	4048000
<b>Bulk Cost</b>	264000	0	
<b>Utilities Cost</b>	8279	0	
<b>Material Cost</b>	0	0	348480
<b>Annual Operating Cost</b>			
<b>Raw Materials</b>	264000	0	348000
<b>Labor-Dependent</b>	699000	2732000	4048000
<b>Facility-Dependent</b>	357000	3835000	1918000

<b>Laboratory/QC/QA</b>	105000	410000	607000
<b>Consumables</b>	0	0	0
<b>Waste Treatment</b>	0	0	0
<b>Utilities</b>	8000	0	0
<b>Transportation</b>	0	0	0
<b>Miscellaneous</b>	0	0	0
<b>Advertising/Selling</b>	0	0	0
<b>Running Royalties</b>	0	0	0
<b>Failed Product Disposal</b>	0	0	0
<b>Total</b>	1433000	6978000	6921000

One of the key findings indicated that the required investment for the olive pomace production process amounts to 2,084,000 liras. However, this investment could potentially be reduced through industrial collaborations in Turkey, or in some cases, eliminated altogether on a project basis, with a probability exceeding 50%.

The operating cost was calculated as 1,433,000 liras, representing a necessary expense for establishing new factories. Given that the business will be situated in an industrial zone, it is assumed to benefit from tax exemptions. The general factory direct cost, which encompasses equipment and labor-related expenses, is a cost framework applicable both in Turkey and globally. Specifically, the equipment cost was identified as a shared expense across systems.

The total cost for processes such as washing, mixing, cutting, and boiling, which are integral to the system, was calculated as 306,000 liras. This is a one-time cost that can be recouped through the sale of products derived from the system. The equipment purchase cost, required for the initial setup of the devices, was calculated as 153,000 liras. All factory-related costs are one-time expenses and can be offset by profits generated from production as operations progress.

Additional factory costs were detailed as follows: 107,000 liras for piping, 122,000 liras for instrumentation, 9,000 liras for insulation, 31,000 liras for electrical system installation, 138,000 liras for construction works, 46,000 liras for area development, 122,000 liras for auxiliary facilities, and 1,033,000 liras for TPDC (Total Product Direct Cost). These costs collectively outline the financial requirements for establishing the production infrastructure.

The other step of the two phased olive oil to pomace production economical step is total plant indirect cost which means salaries of workers and engineers. They were calculated as engineering, construction and TPIC which are orderly 25800,36200, and 620000 liras as total 1653000liras. Another economic factor of the system is construction fee and contingency which are contractor's fee, contingency and as total CFC is calculated as 248000 liras. The last fixed capital cost is calculation of total plant cost and contractor's fee and contingency cost which is calculated as 1901000 liras. Another affected cost in the created simulation is the labor cost which is caculated as 69 liras per hour of average cost of worker's annually caculated as a699166 liras.

To begin of the system olives has to taken from farmers by kilos as 0,80 liras for annual 330000kilos as totalis 264000 liras per year. Total utilities cost is calculated by the help of system as industrial area discount of turkey to 8279 liras for standard power and steam of the system.

The last factor of the system is annual operating cost which includes raw materials, labor-dependent, facility-dependent, laboratory, consumables, waste treatment, utilities, transportation, miscellaneous, advertising, running royalties and failed product disposal. As beginning raw materials costs 264000 liras, then labor-dependent cost is 699000 liras. Then the facility dependent cost is calculated as 357000 liras.Laboratory cost is the second lowest cost between all annual operating costs which is 105000 liras. Consumables and waste treatment has zero liras because the simulation includes both waste treatment and recycle of the olive oil waste, for this reason, failed product disposal is calculated as zero as well. Lastly utilities cost 8000 liras because of the government support of waste treatment law, in addition to this support advertising and running royalties are calculated as zero.

The next stage in the olive pomace production process, developed in the initial SuperPro application, involved integrating the pomace into the biodiesel production process. This integration was tested using two distinct approaches. The results of the first approach are illustrated in Figure 3-2, while the corresponding economic analysis is detailed in Table 17.

In terms of economic performance, the total cost of the first biodiesel production system was calculated to be 21,617,000 liras, with an annual operating cost of 6,978,000 liras. The return on investment (ROI) was determined to be -23.33%, and the profit margin was calculated at -1%. The total cost of all equipment used in the system amounted to 3,425,000 liras.

The physical costs of the system, including previously examined factors, were estimated at 11,061,000 liras, while the indirect costs were calculated at 6,636 liras. The combined total of these

costs was 17,697,000 liras. Contractor fees and contingency fees were assessed at 855,000 liras and 1,770,000 liras, respectively, resulting in a total of 2,655,000 liras. The fixed capital cost for the system was calculated to be 20,351,000 liras.

Regarding labor expenses, the cost per worker per hour was estimated at 48,675 liras, which corresponds to an annual labor cost of 3,358,575 liras. The confirmed annual operating cost of the system remained at 6,978,000 liras.

An analysis of the economic performance of the third and final system for biodiesel production indicates a total economic cost of 11,084,000 liras, with an annual operating cost of 6,921,000 liras. The return on investment (ROI) is calculated to be -53.72%, and the profit margin stands at -1%. The total cost of all equipment utilized in the system amounts to 1,713,000 liras.

The physical cost of the system, which includes previously examined factors, is calculated at 553,000 liras, while the indirect costs are estimated at 3,318,000 liras. Together, these amounts to a total of 8,848,000 liras. The contractor and contingency fees are calculated at 442,000 liras and 885,000 liras, respectively, summing up to 1,327,000 liras. The total fixed capital cost for the system is determined to be 10,176,000 liras.

Labor expenses for this system are notably high, with an hourly wage of 58,667 liras, leading to an annual cost of 4,048,000 liras. This system also requires external procurement of raw materials, specifically olive oil and pomace. The annual costs for these materials are calculated at 343,200 liras for olive oil and 5,280 liras for pomace. The total annual operating cost for the system has been confirmed to be 6,921,000 liras. Those analysis are more visible on table 18.

**Table 18:**Economical Analysis from SuperPro

	<b>2 Phase and Biodiesel 1</b>	<b>2 Phase and Biodiesel 2</b>
<b>Total Captive Investment</b>	23701000	13168000
<b>Capital Investment</b>	23701000	13168000
<b>Operation Cost</b>	8411000	8354000
<b>Revenues</b>	0	0
<b>Gross Margin</b>	-0,02	-0,02
<b>Return On Investment</b>	-0,8344	-1,1383
<b>Payback Time</b>	1	1
<b>IRR( After Taxes)</b>	1	1

<b>NPV( at 7.0% Interest)</b>	0	0
<b>Major Equipment</b>	3731000	2019000
<b>Specification</b>		
<b>Fixed Capital Estimate</b>	0	0
<b>Total Plant Direct Cost</b>	0	0
<b>Equipment Purchase Cost</b>	3731000	2019000
<b>Installation</b>	1350000	751000
<b>Process Piping</b>	1306000	706000
<b>Instrumentation</b>	1492000	807000
<b>Insulation</b>	112000	60000
<b>Electrical</b>	374000	202000
<b>Buildings</b>	1679000	909000
<b>Yard Improvement</b>	560000	303000
<b>Auxiliary Facilities</b>	1492000	807000
<b>TPDC</b>	12094000	6563000
<b>Total Plant Indirect Cost</b>	0	0
<b>Engineering</b>	3023000	1641000
<b>Construction</b>	4233000	2298000
<b>TPIC</b>	7256000	3938000
<b>Total Plant Cost</b>	19350000	10501000
<b>Contractor's Fee and</b>	0	0
<b>Contingency</b>		
<b>Contractor's Fee</b>	968000	525000
<b>Contingency</b>	1935000	1050000
<b>CFC</b>	2903000	1575000
<b>Direct Fixed Capital Cost</b>	22252000	12077000
<b>Labor Cost</b>	4057741	4747166
<b>Bulk Cost</b>	264000	264000

<b>Utilities Cost</b>	8279	8279
<b>Material Cost</b>	0	348480
<b>Annual Operating Cost</b>	0	0
<b>Raw Materials</b>	264000	612000
<b>Labor-Dependent</b>	3431000	4747000
<b>Facility-Dependent</b>	4192000	2275000
<b>Laboratory/QC/QA</b>	515000	712000
<b>Consumables</b>	0	0
<b>Waste Treatment</b>	0	0
<b>Utilities</b>	8000	8000
<b>Transportation</b>	0	0
<b>Miscellaneous</b>	0	0
<b>Advertising/Selling</b>	0	0
<b>Running Royalties</b>	0	0
<b>Failed Product Disposal</b>	0	0
<b>Total</b>	8411000	8354000

The production of olive pomace was evaluated using two different approaches based on earlier stages involving biodiesel 1 and biodiesel 2 applications. The first approach combined a two-phase application with biodiesel 1, while the second combined it with biodiesel 2. These combinations resulted in two sets of economic data. By analyzing this data, we aim to determine which application is the most economically viable and feasible.

The total investment required for the first application was 23,701,000 liras, while the investment for the second application amounted to 13,168,000 liras. The estimated operating costs were 8,411,000 liras for the first application and 8,354,000 liras for the second application. Additionally, both systems were found to have a gross margin of -0.02%. The return on investment (ROI) was calculated to be -0.8344 for the first application and -1.1383 for the second application.

The next step was to examine the costs of primary production equipment. For the first application, these costs were calculated to be 3,731,000 liras, while for the second application, they amounted to 2,019,000 liras. Following this, the total direct factory costs were categorized into three

subheadings: equipment purchase costs; installation, piping, instrumentation, and insulation; and expenses for electricity, buildings, landscaping, and auxiliary facilities.

For the first application, the respective costs were calculated as follows (in liras): 3,731,000 (equipment purchase cost), 1,350,000 (installation), 1,306,000 (piping instrumentation), 1,492,000 (insulation), 112,000 (electricity), 374,000 (buildings), 1,679,000 (gardening), 560,000 (auxiliary facilities), 1,492,000, and a total of 12,094,000. In the second application, these costs were: 2,019,000 (equipment purchase cost), 751,000 (installation), 706,000 (piping instrumentation), 807,000 (insulation), 60,000 (electricity), 202,000 (buildings), 909,000 (gardening), 303,000 (auxiliary facilities), 807,000, and a total of 6,563,000.

Non-direct costs were also evaluated, which included engineering, construction, Total Plant Investment (TPIC), and Total Facility Cost. In the first application, these costs were as follows: 3,023,000 liras for engineering, 4,233,000 liras for construction, 7,256,000 liras for Total Plant Investment, and 19,350,000 liras for Total Facility Cost. In the second application, the corresponding costs were 1,641,000 liras for engineering, 2,298,000 liras for construction, 3,938,000 liras for Total Plant Investment, and 10,501,000 liras for Total Facility Cost.

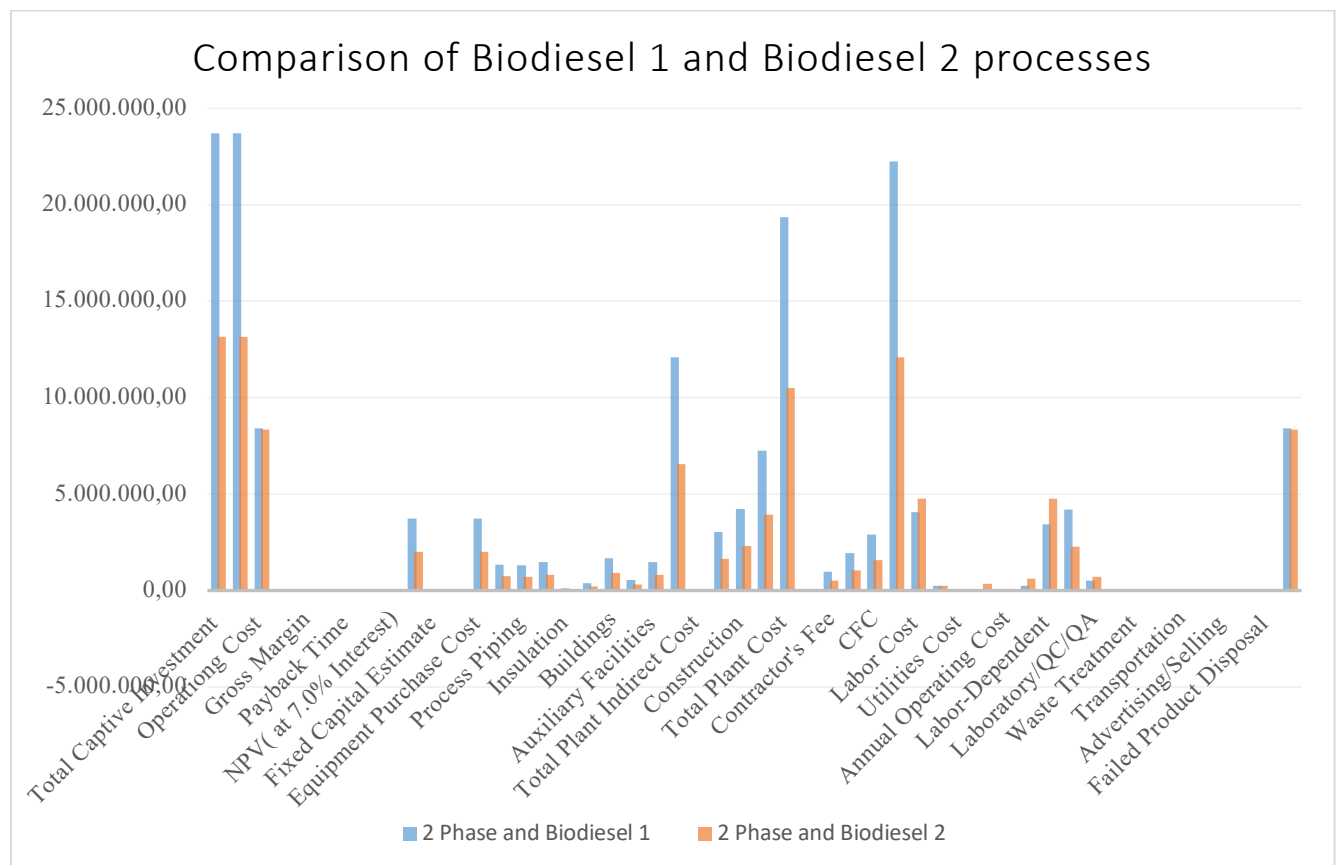
Additionally, contractor fees and contingency costs were assessed. For the first application, these fees amounted to 2,903,000 liras, while in the second application, they were 1,575,000 liras.

The total indirect costs were analyzed under two subcategories: engineering and construction works. For these categories, the costs for the two applications were calculated as 3,023,000 and 4,233,000 liras for the first application, and 1,641,000 and 2,298,000 liras for the second application, respectively. When combined with the total factory costs of 7,256,000 liras and 3,938,000 liras, the total indirect costs were determined to be 19,350,000 liras for the first application and 10,501,000 liras for the second application.

Contractor and contingency costs were 2,903,000 liras for the first application and 1,575,000 liras for the second application. The direct main costs were 22,252,000 liras and 12,077,000 liras for the two applications, respectively. Annual employee costs were calculated at 4,057,741 liras for the first application and 4,747,166 liras for the second application. Material costs were not observed in the first application but were recorded as 348,480 liras in the second application.

Raw material costs were determined as 264,000 liras and 612,000 liras for the first and second applications, respectively. Additionally, production-related costs were calculated as 3,431,000 liras for the first application and 4,747,000 liras for the second application. Facility-based production

costs were estimated at 4,192,000 liras and 2,275,000 liras, respectively. Labor costs were calculated as 515,000 liras for the first application and 712,000 liras for the second application. No costs were identified for consumables and waste processing, and similarly, costs for transportation, miscellaneous expenses, advertising/sales, copyright enforcement, and disposal of unsuccessful products were all calculated as zero. Public utility costs were 8,000 liras for both applications. As a result, the total costs were determined to be 8,411,000 liras for the first application and 8,354,000 liras for the second application.



**Figure 5:** Comparison of economical analysis of biodiesel applications

The graphical analysis of the applications is presented in Figures 4. Upon examination, it is evident from the figures that the biodiesel 1 application is significantly more expensive than the biodiesel 2 application across several financial parameters.

#### 4. Discussion

The olive tree and its fruit hold significant importance not only in Turkey but also globally. This prominence is primarily attributed to the numerous benefits olives provide, both as a tree and as a fruit. Beyond their direct consumption as food, olive oil derived from olives offers considerable advantages, both when used in culinary applications and as a healthy solvent in the cosmetics industry. Among these benefits, the use of olive oil stands out prominently.

Furthermore, by-products generated during the olive oil production process, particularly the chemical residue known as olive pomace, have been demonstrated in numerous studies and articles to have applications beyond cosmetics, including as a potential source for biodiesel production. Despite this, biodiesel consumption remains minimal both in Turkey and globally, although it plays a crucial role in recycling and maintaining carbon balance. Currently, most commercial and agricultural vehicles primarily utilize either gasoline or electricity, leading to a greater demand for gasoline compared to biodiesel. (Hocaoglu , 2015)

Olive pomace is mostly produced during the conventional pressing of olives using stone mills or comparable machinery. It is frequently seen as an industrial waste byproduct of the manufacturing of olive oil. The pomace contains leftover olive oil from this procedure. In further steps, the olive mixture is separated into oil, water, and solid residues using a three-phase process. The olive oil is then further refined using a two-phase separation. These stages, which are frequently repeated to increase purity, also raise the olive oil's vitamin and mineral content, which raises its market value. Waste items like olive pomace and black water are produced by the procedures. The main objective of pomace to biodiesel application to maximise its processing utilising the SuperPro Designer software while recycling purified olive pomace for public consumption. The objective of this computer simulation is to evaluate and improve the techno-economic viability of processing olive pomace. Recovering and reusing black water as process water is one of the suggested innovations that offers a lot of value. Iterative processing increases the refined olive oil's sales value while reducing the amount of olive pomace. Since the decreased pomace yield affects operational operations such as personnel, equipment capacity, and chemical consumption, it is imperative that waste be managed effectively. This has a direct influence on system costs and relevance. For the production of biogas and biodiesel, olive pomace—a significant biomass resource in Mediterranean nations—is essential. Its quantity and quality have a major impact on the efficiency of following processes as well as agricultural-industrial cooperation. Modern, self-sufficient systems improve

operational optimisation and lower maintenance needs. The manufacturing of olive oil is a seasonal activity in Mediterranean countries, with companies running for around three months each year during the olive harvest. In addition to eliminating transportation and operational inefficiencies, the techno-economic use of olive pomace might increase local economies, provide jobs, and prolong the operating spans of these companies. The suggested solution seeks to maximise the economic and environmental advantages by processing olive pomace locally in order to reduce losses and additional expenses. (Elibol, Yasa, Karacanci, Coban , & Ozsoy, 2017)

In terms of bioprocesses and bioengineering utilising the SuperPro software, no systematic optimisation has been found for the reintegration or valorisation of olive pomace into the system. The SuperPro program's use of olive pomace aims to educate a larger audience about the technology and social applications of olive pomace. (Simonato B. , Trevisan, Tolve, Favati , & Pasini, 2019) Applications in the bioengineering, computer engineering, and pharmaceutical sectors are currently undergoing fast changes that are impacted by all external factors while maintaining an unbreakable integrity. Emphasising the use of SuperPro on olive pomace, demonstrate the connections between industry, biotechnology, computer science, and environmental impacts. (Elibol, Yasa, Karacanci, Coban , & Ozsoy, 2017) (Ilay, Erarslan, & Kavdir , 2019) In order to give economic and environmental added value, the olive tree, olive plant, and olive by-products (such as olive leaves and olive pomace), which are not easily classified as therapeutic aromatic plants, are intended to be assessed all year long. Theoretically, applying bioprocesses with the SuperPro software is appropriate. This application can provide an alternative viewpoint on bioprocess and bioreactor applications with the use of experimental data.

Although there are some other research as Elnasr et.al. they researched on dried olive pulp's Sulfonated Carbon (SC) increases the effectiveness of transesterification (Elnasr, et al., 2024) . On the other hand they reached 94% of efficiency on biodiesel production which in our application 80% of efficiency was done. The differences between Elnasr and our research is primarily, our research is more digital than their research and rather than using sulfonated catalyst our research we prefer more ecological catalyst. There are some research aimed to maximize the factors as bio-yield and using lower temperature as 65°C, as a result of this research, higher temperature was used to maximize the yield to 80%. (Ikhlass, S, & Tabet, 2023). Although created system may permit to higher degrees or yields, optimum material simulation wdetermined as 80% in economically. On

the other hand there are some research papers emphasize the importance of the biodiesel production rather than petroleum fuels (Rajaeifar, et al., 2016). However, not only improvement technology but also ecological recycling does not support petroleum fuel production hypothesis, for this reason, as Rajaeifar et.al mentioned using free fatty acids as used in our thesis and environmental usage of chemicals have some significant factors.

Given the ongoing depletion of global oil reserves, it is evident that the demand for gasoline will continue to rise in the coming years. Addressing this increasing demand can be achieved through two potential approaches. The first involves the expanded adoption of electric or hybrid vehicles, which are not yet widely used in agriculture. The second involves the broader use of biodiesel as an alternative fuel, particularly in vehicles with diesel engines.

In the context of the second approach, an economic analysis of production lines—whether newly established or rented near agricultural lands—was conducted using SuperPro design, as detailed in the results and methods section. This analysis highlights the feasibility and potential benefits of scaling biodiesel production to meet future energy needs.

The contribution of olives to biodiesel production has been examined through three distinct approaches, organized into two primary stages. The first stage involves producing olive pomace in quantities and with properties suitable for biodiesel production. A continuous production method was selected for this application. This decision was based on the limitations observed in a batch system, where the separation and decanter components must operate in a time-sensitive manner, leading to increased costs. Additionally, the batch system requires equipment to function on a larger scale, further contributing to inefficiency. Consequently, a batch system was deemed unsuitable for this purpose.

As a result of the selection of the batch application allowed for the optimization and establishment of a system on SuperPro design that enabled both increased pomace production and reduced costs. Among the three approaches examined, the two-phase continuous olive pomace production method was identified as the most cost-effective. The return cost for the technological optimization of this application, as calculated using SuperPro, was determined to be the lowest compared to the other methods. Moreover, the system was designed to be as autonomous and labor-independent as possible, following modifications made during the optimization process. The reduced costs associated with equipment and labor have further enhanced the system's practicality and adaptability across various applications.

Additionally, the first and the second application of biodiesel process give rise to some significant feed backs of process which begins with olive ends with biodiesel production.

Biodiesel applications were designed as continuous processes, similar to the approach taken for pomace processing. When a batch process was selected, errors—particularly in the reactor sections—prevented the collection of the necessary data, rendering the system inefficient. A significant advantage of the continuous approach is the ability to process a large volume of product simultaneously. As detailed in the methods section, while 300 kilograms of pomace (or multiples there of) are introduced into the system, approximately 150 liters of biodiesel with 80% purity are produced. Another key reason for selecting the continuous process is its cost-effectiveness. Beyond cost reduction, the integration of systems streamlined operations, leading to a decrease in labor requirements and associated expenses across both processes.

Despite these advantages, notable differences between the systems were identified. The most significant of these differences lies in the type and quantity of chemicals used. This aspect can be analyzed under two subcategories: chemical composition and chemical usage. In the first system, four different reactors and reaction-enzyme compounds are utilized, making it comparatively more toxic. Conversely, the second system employs only two bioreactors, thereby reducing the extent of reactions within the system. This reduction not only decreases toxicity but also lowers costs.

Another critical distinction between the systems is the cost of equipment. While both systems were optimized to minimize expenses, such as transportation and transfer costs, the first system remains more expensive due to the inability to further downscale the required devices. In contrast, many components in the first system are replaced in the second system by larger but more efficient decanters. This modification, however, results in slower production speeds and slightly reduced efficiency due to the diminished use of chemicals. Nonetheless, this trade-off ensures a more sustainable and cost-effective contribution to biodiesel production.

As a result of the economic comparison of the production lines, it is clearly seen that the xecon production line is more economical than the first production line. Another significant cost difference between the two systems lies in factory costs. A comparative analysis reveals that the factory cost of the first system is nearly double that of the second system. However, despite the higher device costs, the first system benefits from a lower labor cost due to its more automated and self-sustaining design.

When each system is integrated separately with the olive pomace production process from olive oil, the resulting financial changes are presented in Table 3.2. Based on the data in the table, it is evident that the second system has a larger volume than the first, requiring more raw material—namely olives—which affects cost calculations. While the second system appears more profitable in terms of return on investment, the first system proves more advantageous for build-operate-transfer procedures and yields greater profitability within a five-year period.

Another notable difference emerges during the installation phase. Due to its larger scale, the installation cost of the second system exceeds that of the first by approximately 52,000 liras. Additionally, the total cost of the second system is around 70,000 liras higher than that of the first system. Although this additional cost can be offset through other components of the system, the second system offers greater potential for research and development, making it more adaptable to future advancements.

Both systems have a one-year recovery period, resulting in negative profit returns within this timeframe. However, if costs are analyzed over a longer period, the systems may require further optimization. Overall, despite its higher initial costs, the second system reduces costs by approximately 60,000 liras when evaluated comprehensively, balancing its disadvantages in cost and operation with long-term savings.

SuperPro Designer is an effective solution for industries that focus on process innovation and optimisation. By combining technical, economic, and environmental considerations, businesses can streamline production, reduce costs, and improve sustainability, maintaining competitiveness in today's dynamic markets. SuperPro, a techno-economic analysis tool, has facilitated the evaluation of these systems, enabling the identification of their respective advantages and limitations. When assessing the viability, cost-effectiveness, and scalability of technologies, initiatives, or procedures, techno-economic analysis (TEA) is crucial. Through the integration of technical and economic evaluations, TEA offers a thorough framework for well-informed choices. In order to make sure that projects and technologies are both technically sound and economically feasible, industry and governments rely heavily on techno-economic analysis. TEA helps optimise procedures, reduce risks, and increase the likelihood of success in cutthroat and dynamic markets by fusing technical precision with economic understanding. This analysis, which is applicable not only in Turkey but also in other olive-growing regions worldwide, highlights how the suitability and improvement strategies for each system vary depending on the country and region. The

findings confirm that these systems are feasible for implementation in Turkey, albeit with minimal economic contributions. Both systems are adaptable and reversible, allowing for modifications based on technological advancements and regional requirements.



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