T.R
ERCIYES UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF FOOD ENGINEERING

SUNFLOWER OIL-SOYBEAN WAX OLEOGEL AS A NOVEL FRYING MEDIUM FOR DOUGHNUT

Prepared by
Kurshid ZUBAIREE

Supervisor
Prof. Dr. Hasan YALÇIN

Master's Thesis

January 2023
KAYSERİ

T.R.
ERCIYES UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF FOOD ENGINEERING

SUNFLOWER OIL-SOYBEAN WAX OLEOGEL AS A NOVEL FRYING MEDIUM FOR DOUGHNUT

(Master’s Thesis)

Prepared by
Kurshid ZUBAIREE

Supervisor
Prof. Dr. Hasan YALÇIN

January 2023
KAYSERİ

COMPLIANCE WITH SCIENTIFIC ETHICS

I declare that all information in this study has been obtained in accordance with academic and ethical rules. At the same time, I declare that I have fully cited and referenced all material and results that are not at the core of this work, as required by these rules and conduct

Kurshid ZUBAIREE
Signature:

The masters thesis entitled **“Usage Of Soywax-sunflower Oil Oleogel As A Novel Frying Medium For Doughnuts”** has been prepared in accordance with Erciyes University School of Natural And Applied Sciences Thesis permission and writing guide.

Student:	Supervisor
Kurshid ZUBAIREE	Prof. Dr. Hasan YALÇIN

Chairman of the Department of Food Engineering

ACKNOWLEDGEMENT

Before all, great thanks to Allah, the merciful and the Compassionate.

It is a great pleasure for me to acknowledge a number of people who contributed to the completion of this dissertation.

I wish to express my gratitude to my supervisor Prof. Dr. Hasan YALÇIN for suggesting me the topic of this thesis and for giving me much valuable time and assistance during its preparation. I also wish thank to him immensely for his mentorship and his patience and for providing me all the required instruments and chemicals throughout my research. The training experience has been unique with him. I also wish to thanks Tuğba DURSUN ÇAPAR for helping me throughout my reaserch work.

I would like to thank my friends and family for their love and support of my studies and encouragement.

I would like to thank my friends Ender TURNA and Noman ZAFAR for being helping hand.

Kurshid ZUBAIREE

January 2023, KAYSERI

SUNFLOWER OIL-SOYBEAN WAX OLEOGEL AS A NOVEL FRYING MEDIUM FOR DOUGHNUT

Kurshid ZUBAIREE

Erciyes University Institute of Applied and Natural Sciences,
Theisis of Masters, January, 2023
Supervisor Prof. Dr. Hasan YALÇIN

ABSTRACT

Deep-frying changes the quality of the oil through hydrolysis, oxidation and polymerization, which affects both positive and harmful changes in the oil and donut. The main purpose of this study is to produce donuts with less oil absorption, by converting sunflower oil into Soybean wax-Sunflower Oil Oleogel without changing its nutritional and chemical composition, making the frying medium more durable. Oleogel to be used in frying; It was prepared according to the methods specified in the literature, using sunflower oil and soy wax. Sunflower oil not converted to oleogel was chosen as the control sample. Physical analyzes were performed for the oleogel. The dough was prepared and the donuts were cut and fried in both control and oleogel media. During frying, oil samples were taken from both control and oleogel samples at the end of 5th, 10th, 15th and 20th frying.

In the oil samples taken; free fatty acidity (FFA), peroxide value (POV), p-anisidine value (p-AV), Conjugated diene (CD) and triene value (CT) analyzes were performed. In addition, oil uptake and color analysis in fried donuts and oil binding capacity (OBC), gelation time (GT), viscosity and color analyzes of the produced oleogel were made. The OBC% was 98.55±0.41 and GT was 5.15±0.03 obtained. The oleogels used in frying were compared with sunflower oil used as control. A decreasing trend was determined in the oxidation products formed in the oleogel compared to the control sample. FFA at 20th frying for control sample was 0.55±0.05 and reduced for oleogel sample to the 0.45±0.05. Also POV for control sample at 20th frying was 16.35±0.1 and reduced to the 12.92±0.05 foe oleogel sample. A countable decrease for p-AV was also recorded, for control sample at 20th sample it was 102.3±0.7 and for oleogel it was 90.3±0.6. CD and CT values were also decreased in oleogel sample. The oil absorbed by the doughnuts fried in control sample (17.5±0.34) differed significantly, with the tendency to absorb less oil by the doughnuts fried in oleogel (12.7±0.20). This reduction will provide a significant advantage in terms of consumers consuming less total calories and gaining less weight from fried foods. In the color analysis, the oleogels were found to be brighter (***L**** 45.55±0.60) than the control sample (***L**** 24.9±0.60)**,** and there was no negative effect on the L, a and b* values of the donuts and oleogels.

Key words: Soybeanwax, Sunflower Oil, Oleogel, Doughnuts, Frying

DONUT KIZARTMA ORTAMI OLARAK AYÇİÇEK YAĞI YAĞI-SOY MUMU OLEOJELİNİN KULLANIMI

Erciyes Üniversitesi, Fen Bilimleri Enstitüsü
Yüksek Lisans Tezi, Ağustos 2022
Danışman Prof. Dr. Hasan YALÇIN

ÖZET

Derin yağda kızartma, yağda ve donutta hem olumlu hem de zararlı değişiklikleri etkileyen hidroliz, oksidasyon ve polimerizasyon yoluyla yağın kalitesini değiştirir. Bu çalışmanın temel amacı, ayçiçek yağının besinsel ve kimyasal bileşimini değiştirmeden Soya vaksı-Ayçiçek Yağı Oleojeline dönüştürerek, kızartma ortamını daha dayanıklı hale getirerek, daha az yağ emilimine sahip donut üretimini gerçekleştirmektir. Kızartmada kullanılacak oleogel; ayçiçek yağı ve soya vaksı kullanılarak, literatürde belirtilen yöntemlere göre hazırlanmıştır. Oleojele dönüştürülmeyen ayçiçek yağı, kontrol numunesi olarak seçilmiştir. Oleojel için fiziksel analizler yapılmıştır. Hamur hazırlanıp donutlar kesilmiş, hem kontrol hem de oleojel ortamında kızartılmıştır. Kızartma sırasında, 5, 10, 15 ve 20. kızartma sonunda, hem kontrol hem de oleojel numunelerinden yağ örnekleri alınmıştır.

Alınan yağ örneklerinde; serbest yağ asitliği (FFA), peroksit değeri (POV), p-anisidin değeri (p-AV), Konjuge dien (CD) ve trien değeri (CT) analizleri yapılmıştır. Ayrıca kızartılan donutlarda yağ alımı, renk tayini ile üretilen oleojelde yağ bağlama kapasitesi (OBC), jelleşme süresi (GT), viskozite ve renk analizleri yapılmıştır.OBC %98.55±0.41 ve GT 5.15±0.03 elde edilmıştır. Kızartmada kullanılan oleojeller, kontrol olarak kullanılan ayçiçek yağı ile karşılaştırılmıştır. Oleojelde oluşan oksidasyon ürünlerinde, kontrol numunesine göre azalma eğilimi belirlenmiştir. 20. kızartmada kontrol numunesi için FFA 0,55±0,05 iken oleojel numunesi için 0,45±0,05'e düşürülmüştür. Ayrıca 20. kızartmada kontrol numunesi için POV 16.35±0.1 idi ve oleojel numunesi için 12.92±0.05'e düşürülmüştür. p-AV için de sayılabilir bir düşüş kaydedilmiştir, 20. numunede kontrol numunesi için 102.3±0.7 ve oleojel için 90.3±0.6 idi. Oleojel örneğinde CD ve CT değerleri de azalmıştır. Donutlar tarafından emilen yağ önemli farklılık göstermiş, oleojel içinde kızartılan donutlar tarafından daha az yağ emme eğilimi belirlenmiştir. Bu azalma, tüketicilerin daha az toplam kalori tüketmesi ve kızarmış yiyeceklerden daha az kilo alması açısından önemli avantaj sağlayacak niteliktedir. Yapılan renk analizlerinde, oleojeller kontrol örneğinden daha parlak bulunmuş, donutların ve oleojellerin L, a ve b* değerlerinde olumsuz bir etki bulunmamıştır.

Anahtar kelimeler: Soya mumu, Ayçiçek Yağı, Oleojel, Donuts, Kızartma,

TABLE OF CONTENS

SUNFLOWER OIL-SOYBEAN WAX OLEOGEL AS A NOVEL FRYING MEDIUM FOR DOUGHNUT

SUITABLITY FOR GUIDE iii

APPROVAL iv

ACKNOWLEDGEMENT v

ABSTRACT vi

ÖZET viii

TABLE OF CONTENS x

LIST OF ABBREVIATIONS AND SYMBOLS xiii

LIST OF TABLES xiv

LIST OF FIGURES xv

INTRODUCTION 2

CHPATER 1

GENERAL INFORMATION

1.1. Nutritional and therapeutic benefits of sunflower seeds 4

1.1.1. Benefits of sunflower seed 4

1.2.Sunflower oil 5

1.2.1.Uses of sunflower oil 6

1.3.Fermentation 7

1.4. Fat Structure and Functionality 8

1.4.1.Oil-Structuring Techniques 9

1.4.2. Oleogelation 10

1.5. Oleogelator 10

1.5.1.Types of oleogelator 10

1.5.2.Food Application of Oleogels 11

1.5.3.Future Trend of Oleogels 12

1.6. Frying 12

1.6.1. Properties of Fried Food 14

1.6.2. The Relationship of Frying with Human Health 14

1.7. Oil uptake 15

1.8.Peroxide Value 15

1.9.Acid Value and Free Fatty Acid 15

1.10. Review of literature **16**

CHAPTER 2

MATERIALS AND METHODS

2.1.Materials **22**
2.2.Methods **22**
2.2.1.Preparation of oleogel **22**
2.3.Physical analysis of oleogel **22**
2.3.1. Color analysis **22**
2.3.2.Oil Binding Capacity **23**
2.3.3. Gelation time **24**
2.4. Dough and doughnut formation **24**
2.5.Frying **25**
2.5.1.Colour analysis for doughnuts **25**
2.5.2.Oil Uptake: **26**
2.5.3.Sampling of Oil **26**
2.6.Chemical Analysis **27**
2.6.1.Free Fatty Acid Analysis and Acid Value **27**
2.6.2.Peroxide value (POV) determination **27**
2.6.3. *p*-Anisidine value (p-AV) determination **28**
2.6.4.Conjugated Diene Triene Analysis **28**
2.6.5.Viscosity Analysis **29**
2.7.Statistical Analysis **29**

CHAPTER 3

RESULTS

3.1.Results of analysis applied to the samples **29**

CHAPTER 4

DISCUSSIONS

4.1.The Oil Binding Capacity and Gelation Time **39**
4.2.Oil Uptake **40**
4.3.Colour Measurement of Doughnuts **41**
4.4.Colour Measurement of Oil and Oleogel **41**
4.5.Conjugated Diene and Triene **42**
4.6.Peroxide Value **44**

4.7.Free Fatty Acid....45
4.8.*p*-AV....45
4.9.Viscosity....47
REFRENCES....49
CV....64

LIST OF ABBREVIATIONS AND SYMBOLS

AOCS	: American Oil Chemist Society
CB	: Corn oil based
CHD	: Coronary heart diseases
EO	: Ethyl cellulose
FDA	: Food and Drug Administration
FFA	: Free fatty acid
GRAS	: Generally Recognized As Safe
GT	: Gelation time
MO	: Monoglyceric striate
OBC	: Oil binding capacity
OGC	: oleogel chocolate
p-AV	: p-Anisidine value
POV	: Peroxide value
PUFA	: Polyunsaturated fatty acid
SFA	: Saturated fatty acid
TAGs	: Triacylglycerols
TFA	: Trans fatty acid
WHO	: World health organization
$\omega-3$	: Omega-3

LIST OF TABLES

Table 1.1. Data on production of oil seeds in turkey according to the years. ... 5

Table 1.2. Some specific characters should be present in oil used to be frying ... 13

Table 1.3.Specifications for frying oils in European countries]. ... 14

Table 2.1.Soybeanwax-sunflower oil oleogel and control sample OBC ... 29

Table 2.2. %Oil uptake of doughnuts ... 30

Table 2.3 Colour measurements for doughnuts ... 30

Table 2.4 Colour measurements of control & oleogel samples before frying ... 30

Table 2.5 POV and FFA values of control oil sample and oleogel sample ... 32

Table 2.6 CD & CT of control oil sample and oleogel sample ... 33

Table 2.7 P-AV of control and oleogel samples ... 35

Table 2.8. Viscosity of control and oleogel samples ... 36

LIST OF FIGURES

Figure 1.1. Simple Doughnuts 7

Figure 1.2. Glazed Doughnuts 7

Figure 1.3. Ingredients of dough and physical factors that affect the performance of yeast [1]. 8

Figure 1.4 Types of oleogelators 11

Figure 2.1. Preparation of oleogel 22

Figure 2.2 Oleogel before frying 22

Figure 2.3 Tubes preparation for OBC measurements 23

Figure 2.4 Proofing of doughnuts 24

Figure 2.6 Doughnut fried in oleogel sample 25

Figure 2.5 Doughnut fried in control sample 25

Figure 3.1. Peroxide value (meq/kg) 32

Figure 3.2. Free fatty acid % 33

Figure 3.3 Conjugated diene 34

Figure 3.4 Conjugated triene value 35

Figure 3.5 *p*- Anisidine value 36

Figure 3.6 Viscosity measurements 37

INTRODUCTION

There is need for solid fats in the food industry and to meet their need, food technologists are developing oil structuring strategies like hydrogenation, interesterification, and fractionation to make plastic consistency fat from liquid vegetable oils. A new technology that is called oleogelation has been introduced in the last decade to provide alternative structured fats without enhancements of saturated and trans fatty acids, contrasting to the existing technologies. Formation of these gels are done by adding different oil gelling agents, known as organogelators, to initiate lattices of lipid aggregates organized as liquid crystals, fibrillar lattices, or micellar packages. Structures of these gels are soft and elastic without making any change in the composition or isomeric change in the fatty acids of the starting liquid oil. That is why, they are nutritionally preferable, but structural and sensory properties need to be improved [2].

Plant based natural waxes are the most studied organogelators. They consist of hydrocarbons, wax esters, long-chain fatty acids and alcohols, triterpenoids, and some others. The properties of the oleogels depend on the kinds and proportions of the chemical components in the waxes. Some plant waxes like rice bran wax , sunflower wax , candelilla wax , carnauba wax , beeswax , sugarcane wax , berry wax , and fruit wax are the most widely used waxes for oleogel development. Most of these waxes are listed as GRAS or approved by the FDA as food additives [2, 3].

High consumption of saturated fatty acids (SFA) in the daily diet increases the chance of cardiovascular health risk. Replacement of SFA with polyunsaturated fatty acids (PUFAs) reduces the risk of coronary heart diseases (CHD) incidents. That is why diet with unsaturated fatty acids is recommended[3].

As frying is a popular cooking method in food industry, because of the high demand of ready to eat food. Deep frying is becoming common cooking method in houses and industries across the world[4, 5]. Frying is done by immersing our required food material into the hot oil (150-190^{0}C). Foods are cooked by heat and mass transfer. Foods we get from frying are delicious, crispy, juiciness and other good sensory attributes[5]. The demand of fried food is increasing globally because of the high desirable and unique sensory properties, accessibility, and availability of fried food. But a main issue raised by consumers and stakeholders is its high-fat content[6]. Fried foods are popular among its consumers due to its beautiful golden colour, juiciness and crispy texture[4]. As the high amount of oil in fried food leads to many diseases like diabetes, cardiovascular diseases, obesity etc. Many researches have been conducted to decrease the oil uptake of fried foods. For example pre-frying treatments; blanching, pre-drying, coating, physical modifications of food, ultrasound etc have been commonly used for this aim[7]. Temperature time optimization, oil selection, pressure, sonication are the techniques used while frying the product to decrease oil uptake. Some researchers introduced some new frying techniques like air frying, vacuumed frying, spray frying, microwave frying and ultrasound assisted frying[8]. However, some researchers are focusing on the frying medium. They are trying to modify the frying medium to reduce the oil uptake of fried product[5]. In the market different type of shortenings, oils and mixtures are present for frying[9, 10]. Oleogels are emerging as a new fat source for frying produced by gelation of vegetable oils[11, 12].

During frying, undesirable changes occur in frying medium like oxidation which also affects the taste of product. Also products formed during frying become the reason of serious health issues[5]. But they give less crispy and greasy texture to the fried product and porn to oxidation[13]. It reduces the shelf life of product. That is why oils are converted into solid form by different technologies like hydrogenation. It increases the level of saturated fatty acids in oil. But use of these type of frying media increases the health risks of cardiovascular diseases[4, 5].

Due to the urbanization trend of snack food increases, doughnut is one of those snack foods, made by fermentation of dough followed by deep frying. Main ingredients of doughnut are milk, flour, eggs, sugar, oil and water[13]. Doughnuts are highly demand by people due to its taste pleasant appearance. But due to of deep frying products consumption leads to the risk of cardiovascular disease. In the process of doughnut making high amount of trans fatty acids are used[13]. Due to the all health issues related to the consumption of fried food, which is full of TFA (trans fatty acid) and saturated fatty acids there is need to invent some other technologies which provide same frying attributes to the end fried product, crispiness, juiciness and organoleptic properties. Oleogelation is new and best technique to be used because oleogel is an oil continuous structured oil with macroscopic dimensions that has immobilized networks of self-assembled molecules called organogelators[15]. This thermo-reversible and 3D networks give the advantage of no change in the fatty acids and minor components compositions of the liquid oil. Moreover, it doesn't increase saturated fatty acids and the formation of trans fatty acids. Totally edible, safe, healthy, sensorially acceptable oleogels with various organogelators have been prepared. Oleogels are completely edible, healthy and have good organoleptic properties[5]. As the demand of doughnuts is high and they are prepared by deep frying, this study aims to fry doughnuts with soybeanwax-sunflower oil to provide healthy snack food with the same sensory and rheological properties as fried in transfats. This study also analyzed the oxidative stability of soybeanwax-sunflower oil oleogel.

CHPATER 1

GENERAL INFORMATION

1.1. Nutritional and therapeutic benefits of sunflower seeds

Sunflower is the crucial oil seed crop cultivated all over the world. Addition of sunflower in the diet is increasing due to its healthy chemical composition. Tocopherol, vitamin E, and phenolic compounds present in the seed are responsible for long shelf life of oil and also prevent body from heart diseases[14]. The small seed of sunflower contains unsaturated fats, protein, fiber and vitamin E, selenium, copper, zinc, folate, iron and phytochemicals[15]. Seed of sunflower contains high amount of oil, non volatile composition of oil is 90 percent of unsaturated fats[16]. The seed of Sunflower have high medicinal value. Seeds are used for relaxing the nerves, muscles, and blood vessels. In the seeds, vitamin E is present that is useful as anti-inflammatory agent for asthma, osteoarthritis, and rheumatoid arthritis. Seed contains magnesium that is useful for curing asthma and migraine and lower high blood pressure, and decreases the chances of heart diseases[17].

1.1.1. Benefits of sunflower seed

Sunflower seeds are beneficial because they have

- Antioxidant activity
- Anticancer activity

- Anti-inflammatory activity
- Effect on nervous system
- Dietary and cardiovascular value
- Skin problem curing

Sunflower seeds also have other activities, hypocholesterolemic and analgesic activities. They are also helpful in constipation and urinary problems[18]. Production of sunflower oil seeds and some other seeds in Türkiye was given in the Table 1.1 below.

Table 1.1. Data on production of oil seeds in Türkiye according to the years[19].

SEED TYPE	YEAR(TON)				
	2008	2009	2010	2011	2012
Soya	34	38	87	102	122
Sunflower	900.000	960.000	1.170.000	1.170.000	1.200.000
Canola	84	114	106	91	110
Cotton	1.077.440	1.021.200	1.272.800	1.527.360	1.373.440
Other seeds	124	165	184	172	163

1.2.Sunflower oil

In edible oilseed crop sunflower is an important crop. The botanical name of sunflower is *Helianthus*[20]. Approximately in more than 70 countries it is used as cooking oil and salad dresser[21]. In the list of oil seed crops it is on number fourth and it makes 12% of total world production of edible oil[20, 22]. It is the native crop of the North America so the North Americans were using this crop as medicine for eyesight, worms, worts and snakebite in their ancient time. In 1500s Europeans were using it as an ornamental plant[23]. The former Soviet Union introduced it as a oilseed crop in early 19th century, after that Russian academicians worked on the crop to develop new verities to get higher oil content[24, 25].

Sunflower oil is non-volatile, used in frying and cosmetics. The main components of sunflower oil are linoleic acid that is polyunsaturated fat and oleic acid, mono-saturated fat. The light amber colour and flavour of oil fascinates the consumers. Oil contains vitamins and minerals mainly rich in vitamin E. Oil is liquid at room temperature and have shelf life more than 1 year. The consumption of sunflower oil is helpful in maintaining low-density lipoprotein and cholesterol, could be the treatment of diseases like acne, arthritis, and hair damage. Sunflower oil is the preferred in the of Europe, Mexico, and in mainly South American countries because of its health benefits[26, 27]. Sunflower oil is rich in phenolic antioxidants. Oil has phytosterols, which is important in the changing of cholesterol synthesis, so helping in the reduction of cholesterol level in the blood serum[27, 28].

1.2.1.Uses of sunflower oil

Sunflower oil is used in

- Cooking
- To cure the constipation
- Salad dressings
- Massage
- Curing of skin problems
- Soap making
- Bio diesel
- Lubricants
- Candle making
- Bio fuel

Oil is very important as a dietary supplement[29]. Sunflower oil is effective in infections like bronchial, laryngeal and pulmonary, coughs and cold[18].

1.3. Doughnut

Doughnut is fermented fried food. Doughnut has rich global history. This is known as as street, road, holiday and home food with important cultural and social message. Figure 1.1 and 1.2 shows the different types of doughnuts. They are iconic of American culture and preferred by working people[30]. The dough balls which are deep fried are the part of every culture in the world. It is very difficult to give a definition of doughnut. Some scholars defined it as sweet rings, some disc-shaped pastry. According to the a researcher Edge,(2015) “All doughnuts are fried dough but not all fried doughs are doughnut”[31].

Figure 1.1. Sımple Doughnuts

Figure 1.2. Glazed Doughnuts

It is difficult to tell about the exact beginning of doughnuts but Egyptians and Americans were supposed to eat doughnuts [30]. The history of doughnuts started from 15th century. Doughnut came as a popular food in the market in 1930[31, 32]. Doughnut is a industrial food item made with range of food ingrediants[33]. There are two different ways to produce doughnuts. One is to produce them with the help of yeast and the second is cake based doughnuts[32].

1.3.Fermentation

Fermentation is one of the ancient and cheapest methods of making and increasing the shelf life of food[34]. The scientific name of yeast is *Saccharomyces cerevisiae*. It is also known as baker’s yeast. It is the main source of leavening and known as leavening agent in the production of dough[35]. As the topic of research includes fermented product, doughnuts so it was necessary to knew about the fermentation process. In the process of fermentation yeast uses the sugars of dough and as a result carbon dioxide and ethanol are produced that play important role in the leavening of dough during the fermentation and also in the oven rise. Fermentation not only give rise to the dough, baker's yeast play other roles as well. With the production of 2 main fermentation metabolites or products, other metabolites are produced:

- Organic acids, glycerol
- Aroma compounds

These fermented metabolites show an crucial impact on the making of fermented products process and final quality[36]. The production of all these metabolites in dough strongly regulated by different factors e.g ingredients of dough used , physical and chemical conditions, pre growth factors for yeast, and also the genetics of the yeast used[1]. Ingredients of dough and physical factors that affect the performance of yeast are shown into the Figure 1.3.

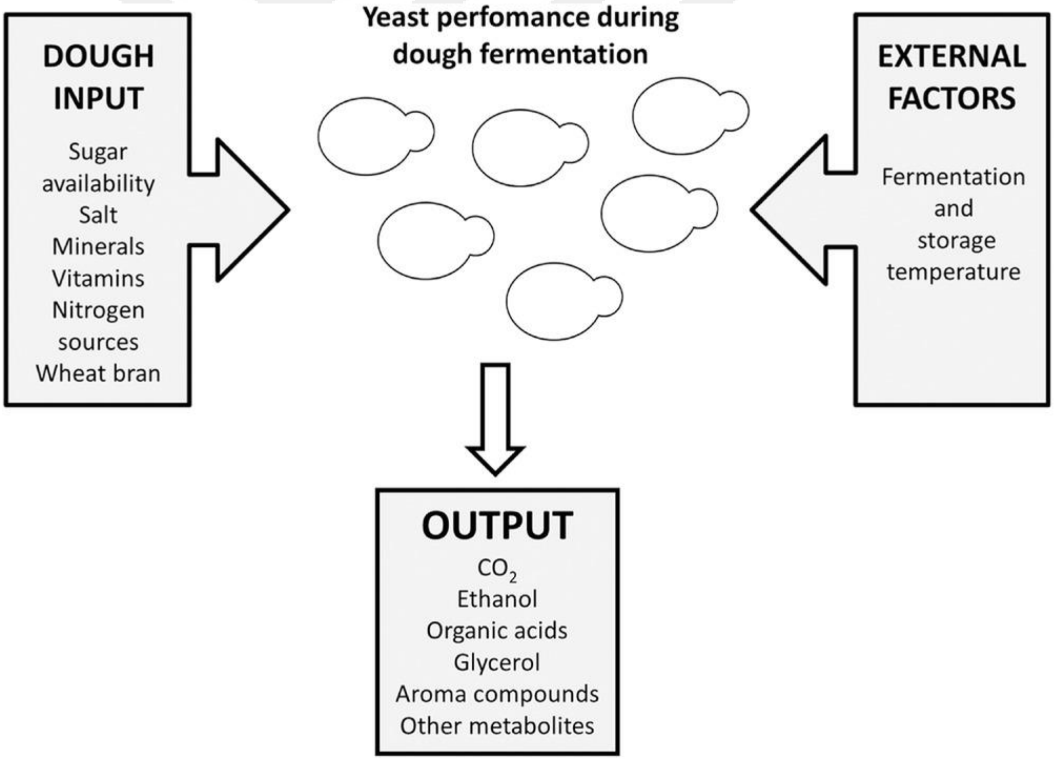

Fig 1.3. Ingredients of dough and physical factors that affect the performance of yeast[1].

1.4. Fat Structure and Functionality

The composition of fat consist of triacylglycerol molecules, commonly(TAGs)[37]. According to the chemical composition TAGs are made of by a glycerol that links with chain of three fatty acids.They are the small but building blocks of the structure of bulk fat[38]. Saturation in the fat depends on the length of longer the fatty acid chain, this is directly related with melting point. Saturated fats due to long chains solid at room temperature and the unsaturated short chain fats are liquid at room temperature. This difference also define saturated and unsaturated fats.

Saturated and unsaturated fats both are part of bulk fat. Saturated fat crystals combines and make a network with which liquid oil is linked, so this type of network known as a colloidal crystal network or colloidal aggregate system[39-41]. The chemical and physical properties of any fat or oil depend on the solid constituent, fat crystal size and their distribution pattern[42].

1.4.1.Oil-Structuring Techniques

It is strenuous to expound the term of gel. According to the Flory, a substance could be describe as a gel as it meets two requirements, its rheological behavior should be solid like and continuous microstructure[43]. Almdal et al. tried to describe a gel in 1992 qualitatively and quantitatively. According to them gel is solid type compound in which liquid fat is in high quantity and the difference between storage and loss modulus should be greater[44].

According to the Terech and Weiss rheology is important to classify a gelled system. Rheology gives information about strong and weak gel. Gel with permanent network will be strong and vice versa[45]. They profess that a rod-like ultrastructure is the systematic way of structuring large volumes of oil[46].

All definitions described above are not wrong but they are not giving a clear definition that can differentiate a gel and solid material. Meanwhile, an inclusive definition can be used for oleogels. Oleogel is a system that have greater volume of liquid oil structured into a gel by using a solid geling agent less than 10% (w/w) that self-build in the process of cooling into a crystal network, and this network should be thermoreversible and three-dimensional and must have capability of entrapping the liquid phase[47]. To solve some of this uncertainty, there are different criteria that explain the good gelator[11]. In the domain of food applications, the gelator should be food grade. The gelator must be cheap, easily available in market, and works best at low concentration. And after using that gelator, gel should have properties same like solid fat.

Beside of all these explanations, lack of knowledge of the mechanisms responsible for oil binding and gelation is present. Another thought or idea is the relationship between gelator and solvent. A gelator could be good if it has moderate solvent solubility. Low solubility is not considered to be good because gelator will precipitate out with low solubility. On the other hand, high rate of solubility is not capable of producing a gelled system[48]. The guidelines‖ described above are helpful while developing an oleogel.

1.4.2. Oleogelation

Oleogelation is a new technique of converting liquid vegetable oils into a semi solid gel type material by using organogelators introduced by researchers to improve the characteristics of oils[11, 49]. It is unconventional method to make substitute of zero trans fats is oleogelation, in the process transformation of the liquid oil into gel type viscoelastic material is produced without any change in its chemical properties[50, 51].

1.5. Oleogelator

There are two main components for the formation of oleogels which are the organic solvent used to dissolve the oleogelator and second one is oleogelator which bring to stand still the organic solvent[52].

1.5.1.Types of oleogelator

The main two types are low molecular weighed oleogelators and high molecular weighed oleogelators as shown in the fig 1.4. The low molecular weighed oleogelators includes:

- Waxes and shellac
- Phytosterols based oleogelators

High molecular weighed oleogelatos are :

- Polysaccharide based oleogelators
- Protein based oleogelators[52]

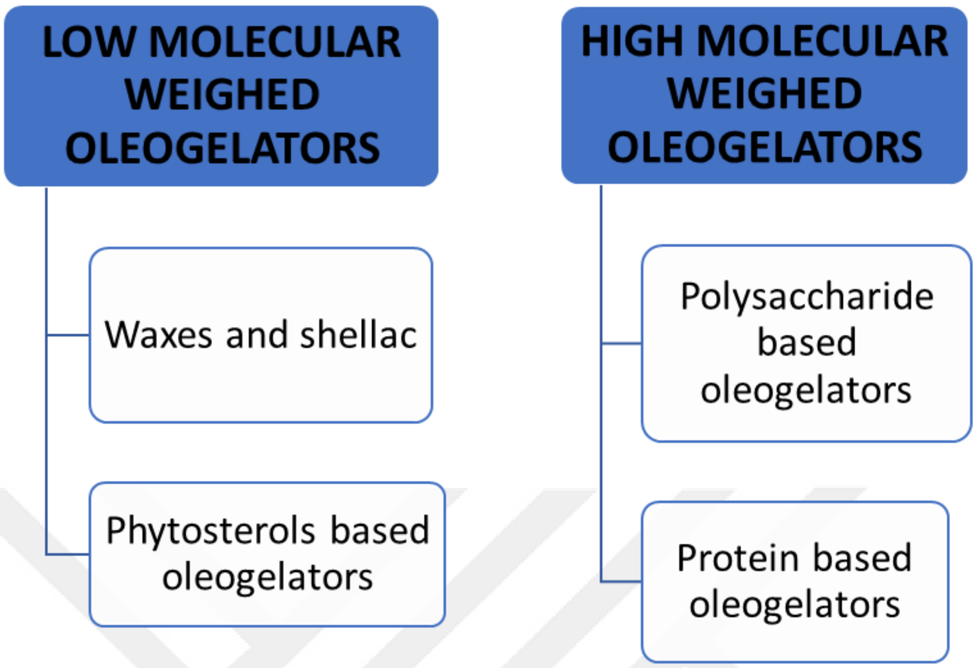

Fig 1.4 types of oleogelators

1.5.2.Food Application of Oleogels

Nowadays oleogles are used in different foods to give them structure in the place of trans fats:

- Breakfast spreads
- Confectionary
- Chocolate and chocolate pastes
- Pralines
- Fillings
- Pastry
- Cookies and biscuits
- Cakes and baked goods
- Bread
- Meat products
- Frankfurters and Sausages
- Meat patties

- Dairy
- Ice cream
- Cream cheese[51]

1.5.3.Future Trend of Oleogels

Due to of oleogelation release of controlled nutraceuticals and pharmaceuticals could be added in foods. Many fat-based molecules for example -carotene, lycopene, co-enzyme Q10, docosahexaenoic acid, eicosapentaenoic acid, conjugated linoleic acid. Using of it gives medical benefits. Because of it encapsulation or delivering by means of oleogels is needed, also will be incorporated in functional foods[53].

The transfer of fat-soluble substances from oleogel depends on some characteristics of the oleogel, for example texture and structure of oleogel and it depends on the type and quantity of oleogelators used in the process[53].

1.6. Frying

Plant and animal-based eating commodities are cooked before eating by mean of baking, roasting, or frying, to make them digestible and delicious. To cook the food with heat transfer there are different medium could be used like air, water, or oil[54]. The range of temperatures can be used for frying is 150–200°C. Due to the high range of temperature reactions between food components are take place, like proteins and carbohydrates and dehydration of the crust and oil uptake. On the other hand method of boiling in hot water provides also a good color, crispness and aroma[55].

Frying is a more effective method than other cooking methods and got high popularity in restaurants and in industry due to of its rapid cooking and operational simplicity[56]. Frying is very ancient way of food processing. It is very easy and quick way to cook delicious food[57]. Frying is cheap and effective way of cooking because of high temperature rapid heat transfer is done[58]. Oil in which frying is done act as a heat transfer medium. In the frying process due to the heating at high temperature microorganism are killed, enzymes are destroyed and water is removed, frying process also adds preservation to the food[59]. The origin of frying is Mediterranean area. Fried food has great contribution in a countries economy[60]. During the frying process different changes occurred in food and oil due to the continuous exchange of heat, nutrients and moisture between oil and food. So the state of oil is getting changed during frying. For example due to the exchange of moisture hydrolysis of oil take place in the presence of oxygen[61]. Due to the heating oxygen reacts with oil and oxidation take place[62]. Table 1.2 shows some specifications for the oil used for frying.

Table 1.2. some specific characters should be present in oil used to be frying[63]

CHARACTER	SPECIFICATION
Heating temperature of oil	≤ 180°C
Polar substances	≤ %25
Number of acid (mg KOH/g fat)	≤ 2.5

The food commodity contain holes and pores, pores are occupied by water and air. After dipping into the hot oil medium, water holding the pores of food commodity starts to evaporate quickly produces bubbling and make the surface dry[64]. The evaporation of water causes cooling in the external area of the food, so that the food is not burnt or charred in this way. The water inside the food is heated to boiling causes gelatinization of starch and denaturation of proteins. The starting upper layer vaporization also in depth vaporization create a crust that is porous, dried and overheated region. The size of pores can be varied, can be small voids, molecular interstices. The pores interconnected or non-connected and are just like a pipelines network. The water should move properly through this network. So to achieve the aim, it is necessary not to overheat the food when food is dipped into the hot oil. Because overheating can destroy the network of pores developed during frying. Resultant a good structured crust retards the loss of moisture. When the porosity of the food is small in amount, this increases in pressure that reduces the drying rate[56]. Advantages of frying are:

- Quick and easy cooking;
- Add value to the economy
- Consistency of cooked product;
- Gives good colour, flavor and crispy texture
- Preserves micro-nutrients

1.6.1. Properties of Fried Food

In food products there is a major functional and sensory part of lipid. They are responsible for the development of sensory qualities like mouth-feel. Fats and oils give flavor to the fried product[65]. The basic objective of frying process is to develop more demand of food. Lipids are the natural appetizing agents. While frying lipid or fat perforated into the food at the place of water, hence make the food more tasty[66]. The perforated lipid tenderized the crust and wet the food, hence increases the popularity of deep fried food[67].

The optimum temperature is important in frying process and time also, food fried at optimum temperature and time has golden brown color, cooked well, crispy and has proper oil absorption. In contrast foods fried at low temperature for short time develop white or brown color and starch remained ungelatinized[68].

1.6.2. The Relationship of Frying with Human Health

As the western consumer is being aware of food and its relation with nutrition ultimately, effect on their health. So they want to decrease the consumption of fat in their daily life. Most important unsaturated fats are dangerous for health as they could be reason for diabetes, high blood pressure, cancer and heart diseases. So consumption of unsaturated fats should be decreased. The negative health effects of fried foods depend on high oil uptake, degradation of oil and hazardous chemical compounds formed. Specifications for the oil to be used as frying medium are shown in table 1.3.

Table 1.3.Specifications for frying oils in European countries[69].

CHARACTERS	VALUES
It will not impart bad taste and odor to the product.	_
Free fatty acid	< %4.5
smoke point	>170°C
polar compound charge	<%27

1.7. Oil uptake

To understand frying and its effects on food, the mechanism of frying and oil absorption should be reviewed first. Frying is the process of immersing food in hot oil and cooking, and it is a mechanism in which there are many interactions between the food and the oil environment, including heat and mass transfer. The purpose of frying is rapid cooking, giving colour, aroma, texture and crust to the fried food. The frying process is complex and depends on many factors, some depending on the process and some depending on the food and the oil used. Basically, frying is a dehydration process with 3 different properties[70, 71].

- Its high temperature (160-180°C) allows rapid heat transfer and short cooking time.
- The temperature of the product (except for the crust region) does not exceed 100°C.
- The loss of water-soluble compounds is minimal.

To control the oil absorption we have to understand the mechanism of frying. There are different factors like during frying process constant exchange of oil and evaporated water, oil absorption when frying process is completed effets the oil absorption. My study focused on the type, oil or oleogel fried doughnut which one abosorbed the less fat.

1.8.Peroxide Value

For the determination of initial stage oxidation in lipids POV is the most commonly and popular way to be used[72]. Different data is present for POV of different vegetable oils that contains soybean, sunflower and canola, ranges from lowest 3–5, medium 10–12, and 16–18 for higher oxidation levels. The benefit of the POV analysis is, it gives direct measurements of the lipid peroxides, known as the primary lipid oxidation products[73].

1.9.Acid Value and Free Fatty Acid

The acid value (AV) is a volumetric way to find or analyses free fatty acid (FFA) level in lipids. The process held through the titration along with KOH (potassium hydro oxide) solution and phenolphthalein as an indicator [74].

In lipids and oils FFAs increases mostly due to the hydrolysis of triacylglycerides (TAG's) when oils and lipids are produced, stored or during handling of raw material.

Moreover, their production reason is deterioration processes in lipids. This secondary oxidation of unsaturated fatty acids leads to the production of short chain FFAs. Waxes shows part of FFAs, so, the acid value of waxes is the base for identity [75].

1.10. Review of literature

As the fats and oils are primary source of calories or energy in human body they also have many nutritional values. Fats and oils are main component of human body cells and their cell membrane. As they are the single source of essential fatty acids, they are necessary to prostaglandin formation. They are responsible to control the lipid blood level, and are transporters for lipid soluble vitamins and other important substances, for example carotenoid pigments and sterols[82].

The composition o fatty acids TAGs are the responsible for the physical condition of fats and oils. If a fat contains higher number of double bonds it will be liquid at room temperature but higher concentration of saturated fatty acids with long chain hydrocarbons linked to a solid or semi-solid state[83, 84]. High intake of saturated SFAs increases the impair risk for cardiovascular diseases. Replacement of saturated fatty acids with PUFA's can be reduces risk of heart diseases[85, 86]. So the diet which is rich in mono- or poly-unsaturated fatty acids is recommended than saturated fatty acids[87]. Facts shows that people in United States are not adding enough quantity of ω-3-PUFAs to meet the recommendations of WHO and FAO, serious action should be taken to add them in food products[88, 89]. Unluckly, oils from plant source are rich in mono (MUFA's) and polyunsaturated fatty acids (PUFA's) are not able to give the structure, necessary for different food products because they are liquid in nature at room temperature. Moreover, saturated fats satisfy the structural requirements of the individual food product. As a result, saturated fatty acids from functional fat ingredients such as shortenings or confectionary fats are desirable but stay as a challenge for the food industry.

Triacylglycerols are used from palm oil and other hydrogenated plant oils. In short, hydrogenation was done of these plant based oils but hydrogenated fats have countable amount of trans fatty acids (TFA)[90]. But high the consumption of trans fatty acids higher the risk to cardiovascular diseases. So institutes like Public Health Authorities recommends the TFA intake less than 1% of the total nutritional energy[91, 92]. The hard fats are more important in food industry due to of their vital roles than liquid soft oils, they have role in the modification of the texture of the food to give crispiness and tenderness[93]. This is the reason of hydrogenation, interesterification, and fractionation of vegetable oils to make plastic fats to obtain desirable texture and taste. Plastic fats are made by mixing solid and liquid fat. They are commonly used in confection and baking industry. They are also used in whipped creams and spreads. But plastic fats put negative effects on human health due to the presence of trans fatty acids[94]. Epidemiological research shows that higher the consumption of TFA and also saturated fats, higher the risk of cardiovascular diseases, weight gain, high blood gulucose, and high blood pressure[95]. Further, glycidyl fatty acid esters, constituent of plastic fat recognized as possible human carcinogen[96]. WHO suggested replacing the TFAs with traditional healthy solid fats in in may 2018[87]. Hence, researchers are working to to develop novel substitutes to structure huge amount of oil without saturated fats[97].

If we talk about margarines and shortenings, they are rich in saturated and trans fatty acids. Structure of fat based products is due to the triacylglycerols having saturated and trans fatty acids. If we study the microstructurel of solid fats they show continuous three-dimensional network of TAG crystals. Formation of TAG crystals take place when transition is occurring from liquid to solid state[98]. Functions of the structure of fats, they provide high-melting characteristic ultimately is gives functionality, sensory and textural properties to the fats[99]. The high amount of saturation makes a fat more stable for oxidative degradation. Mostly functional fat products are used in industries, produced by the hydrogenation of vegetable oils. As the trans fats are unhealthy, elimination of them from food products is difficult for the food manufacturers. If they reduce the level of such trans fatty acids, food product will be the healthier, but it puts negative effects on the textural quality of the food product. So there is need to find alternative fats with no trans fats and good in terms of functionality. It is challenging to find such alternative fats. There is a new emerging technology to produce a fat-like substance known as the gelation of liquid oils by using an organogelator. This material shows properties like solid fat with high amounts of unsaturated fatty acids[100].

It is difficult to define gels, definition of a gel has been discussed controversially. It is however generally acknowledged that a gel shows a solid-like rheological behavior and have immobilized liquid phase. The structure or network is due to of gelling agent. This shows the complex nature of gels. Same views or discussions are present for oleo- or organogels[3]. In the field of fats and oils oleogels are emerging as a new research field. Replacement of oleogels with other plastic fats reduces the consumption of saturated fatty acids as well as TFAs. Research of the oleogelation field shows that there are many vegetable or plant-based waxes that can be used for structuring large volumes of vegetable oils, hence, producing edible oleogels with same functional properties as *trans* and saturated fats have[101] .There are different ways to turn liquid oil into a gel. By the production of colloidal crystalline network by the crystallization of triacylglycerols, diacylglycerols, monoacylglycerols and fatty acids[47]. Esters of plant waxes are known as the organogelators that are used for gelation of liquid oil successfully. As these plant waxes are cheap and easily available, also they have ability to make gel at lower concentration. Chemical properties of wax affects the properties of gel network. Some major plant waxes are rice bran wax, candelilla wax, carnauba wax, sunflower wax and sugarcane wax[102-105]. Oleogels are able to contain up to 99% (w/w) oil, hence they have high oil binding capacities to protect from the leakage of oil.

In producing physical properties, texture, spreadability, snap, shelf life, and mouth-feel of foods hard fats are important, which primarily consist of trans- and saturated fats. To eliminate harmful trans-fats and to decrease saturated fats in foods, the oleogel technology is developed.[2, 106]. The US Food and FDA removed trans fats from GRAS list in 2015 and completely banned the use of partially hydrogenated oils in foods from January 2020[106]. From the last several years' negative health effects of trans and saturated fatty acids are under discussion on human health. Numerous researches have done that shows high intake of trans fatty acids, leads to the increase of the risk of cardiovascular disease in a way that lowers serum levels of high density lipoprotein and increasing the low density lipoprotein in blood serum. A high daily consumption of saturated and trans fatty acids also increases risk of other diseases, coronary heart disease, diabetes, weight gain , brain or heart stroke, metabolic syndrome and other cholesterol maladie. Due to all these facts, the American Heart Association decided that do not eat more than 2 g of trans fats in daily routine, amount is equal to 1 % of the average daily caloric consumption[107]. 2]. Governments also passed laws to decrease the amounts of trans fatty acids that can be present in food products commercially present in the markets. In 2003 Denmark limited the consumption of trans fatty acids in food products to 2 % of, then in 2008 by Switzerland[108].

According to Limpimwong et al. (2017) rice bran oil-rice bran wax oleogel decreased the amount of adipose accumulation, cholesterol and triglycerol in rats fed on this oleogel. Applications of oleogels in foods are limited because of the difficulty in identifying food grade, inexpensive gelators. Even with this limitation research has increased exponentially, illustrating the vast interest garnered by oleogels. Oleogels can be applicable in many food products where conventional solid fats are added. Oleogels used as spreadable products. Firmness, stickiness, oxidative stability, spreadability, and other sensory properties including grassy, milky, rancid, fatty, sweet, salty, waxy, grittiness, and mouth coating were compared with conventional spreads. Bakery products such as , muffins and biscuits were prepared with oleogels. The substitution of shortening with carnauba wax-canola oil oleogels at up to 50% effectively maintained the ability to hold air cells into the cake. The replacement of commercial margarine with the monoglycerides-high oleic sunflower oil oleogels in muffin formulation provided greater spreadability, higher specific volume, similar hardness values, and a more connected and homogeneous crumb structure than those with commercial margarine[106, 109].

Moghtadaei, Soltanizadeh and Hossein Goli, (2018) worked on beef burger to replace partially animal fat with sesame oil-beeswax oleogel. burgers. Results indicated that acid value and thermal properties of the oleogels were affected by the BW concentration; however, peroxide value and fatty acid profile of the oleogels did not change as a function of the variables. The oleogels had less hardness than the animal fats which in turn decreased the hardness, gumminess and chewiness of the raw burgers to<50% of control sample. This is while cooked burger colour did not significantly change ($p<0.05$). The 11% reduction of cooking loss and 1.6% reduction of fat absorption was considered as pros aspects of the oleogel incorporation to beef burger. However, cooking shrinkage and lipid oxidation increased significantly[110].

Rapeseed oil-beeswax oleogel used in beef heart paties to replace animal fat. In conclusion, the oleogel addition improved fatty acid profiles and nutritional index of beef heart patties, but the texture and oxidative stability of patties still need further improvement [111]. Canola oil-carnauba wax oleogel used to replace solid fat in cheese. The application of canola oil-carnauba wax oleogels could successfully produce imitation cheese high in unsaturated fat and low in saturated fat. This study thus demonstrated that the health-functional properties of imitation cheese could be enhanced by using oleogels[112]. Oleogels structured by monoglyceric stearate (MO), β-sitosterol/lecithin (SO) and ethyl cellulose (EO) with different gelation mechanisms were evaluated to prepare oleogel-based chocolate (OGC) with 50% or 100% replacement of cocoa butter. The microstructure characterization verified that three kinds of oleogels-CB (corn oil based) mixtures exhibited different crystalline structure. These findings demonstrate that highly unsaturated oleogels could be promising candidates for reducing use of CB in chocolate[113].

There are fairly limited number of studies involving the use of oleogels in food frying. Soybean oil carnauba wax oleogel was used for noodle frying, and it was shown that noodles fried in oleogel had 16% less fat absorbed without any detrimental effect on noddle texture. Saturated fat content was also decreased significantly. In the other study, rapeseed oil– sunflower wax oleogel was used for French fries. Results indicated that oleogel fried potatoes had a little less oil absorbed, and a little higher firmness values, but these differences were not statistically significant. Also, the sensory evaluation indicated no significant difference against the control sample[4, 5]. As the demand of doughnuts is high and they are prepared by deep frying this study aimed to fry doughnuts with sunflower oil-soywax oleogel to provide healthy snack food with the same sensory and rheological properties as fried in trans fats. This study also analyzed the oxidative stability of sunflower oil-soywax oleogel.

CHAPTER 2

MATERIALS AND METHODS

2.1.Materials

Refined sunflower oil (Yudum Ayçiçek yağı oil company, Istanbul, Turkey) was purchased from a local store. The organagelator soy bean wax was purchased from Öz Yaldız Kimyevi Maddeler company, Istanbul, Turkey**).**

Material used for doughnut making such as wheat flour, sugar, yeast, eggs, baking powder and salt were purchased from a local market in Kayseri. All the chemicals used in the experiments were provided by Erciyes University, Food Engineering Department.

2.2.Methods

2.2.1.Preparation of oleogel

Soybeanwax-sunflower oil oleogel was prepared with soybean-wax. Quantity was used 100:10 w/w as described by Maryam, Nafiseh Soltanizadeh & Sayed Amir, 2018 (Referans Listesinde yok?). Oleogel was prepared according to the method described by Jung et al.[114]. 10 liter sunflower oil with 1000g wax was heated to make oleogel with soy wax in 1 kg beakers at 90°C as shown in the Figure 2.1. Agitation was done at 200 rpm continuously. Process of melting and blending took 1 hour and 13 minutes. Afterwards, prepared oleogel was cooled to the room temperature and stored in refrigerator at 4^0C as shown in the Figure 2.2.

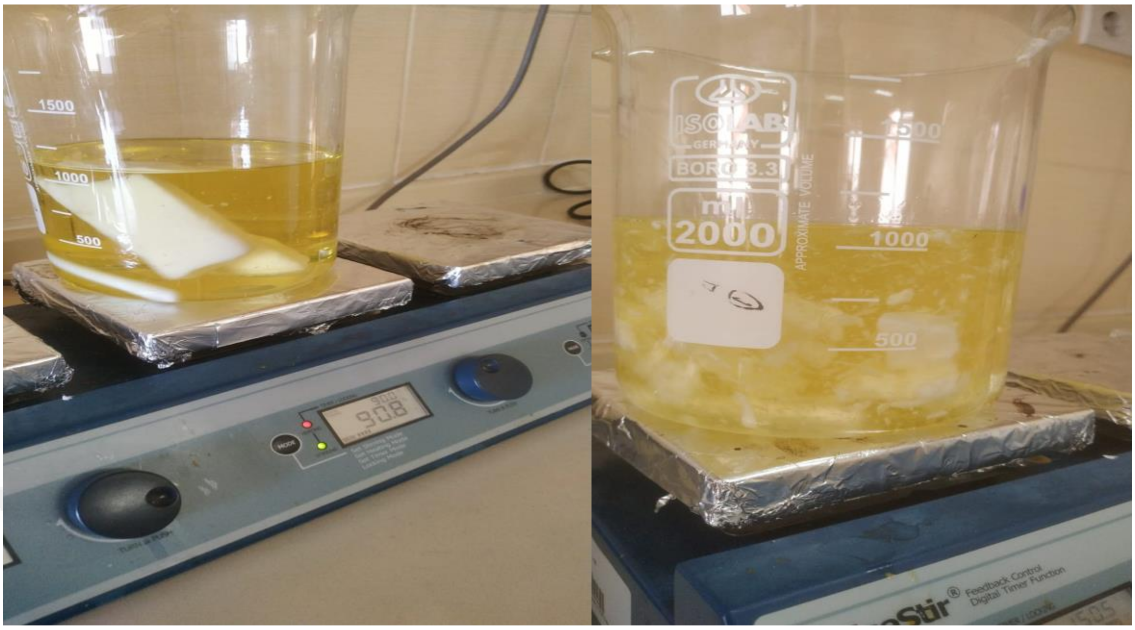

Figure 2.1. Preparation of oleogel

Figure 2.2 Oleogel before frying

2.3.Physical analysis of oleogel

After preparation of oleogel, it was analyzed for physical properties. Color measurement, gelation time and oil binding capacity were analyzed with 3 replicates.

2.3.1. Color analysis

Color analysis was performed on oleogel sample as well as for control (sunflower oil) sample. Experiment was carried out with Konica Minolta Chroma Meter CR-5, Konica Minolta Optics Inc., Japan, colour determination device. The measurements were scanned 5 times for both oil and oleogel and averaged, and the results were obtained in (*L*a*b*)* format.

2.3.2.Oil Binding Capacity

The method was used described by Da Pieve et al.[115] At start, 2 mL of oleogel was melted and put into already weighed (A1), (B1) and (C1) Eppendorf tubes (for three replicates) and stored in a refrigerator for 1 h. Then the tube were weighed (A2), (B2) and (C2)again. Then, the centrifugation was done at 9167 g for 15 min at ambient temperature. Tubes were turned onto a paper cloth to remove the excess liquid oil. After that, the weight of tubes measured again accordingly (A3), (B3) and (C3). Oil binding capacity (OBC) values were calculated by the following formula:

%Released oil= **[**(B1-A1)-(C1-A1)/B1-A1x100]

%OBC= 100-%Released oil

Fig 2.3 Tubes preparation for OBC measurements

2.3.3. Gelation time

5 mL oleogel was melted in a water bath at 90^{0}C and filled in glass tubes and rested for 2 h in isothermal setting. Afterwards, the tubes were removed from the water bath into room temperature, and a timer was turned on. Then the tubes were tilted and no flow was seen, the time was recorded, known as the crystal formation time or gelation time[105].

2.4. Dough and doughnut formation

Dough formulation was made according to the method described by Aggelousis, G., & Lalas, S. (1997) and Ayo-Omogie, H. N., & Odekunle, O. Y. (2017) with slight modification[116, 117]. In the recipe 210 mL water, 400g flour, 48g yeast, one egg, 4g salt, 60g sugar, 8g baking powder and 20 mL sunflower oil was used to make dough. Then the prepared dough was proofed for 20 minutes at 30 ^{0}C. After that doughnut were made with hand with central hole shape and proofed again for 20 minutes as shown in the Figure 2.4.

Figure 2.4 Proofing of doughnuts

2.5.Frying

5 liter oleogel was used in an electric fryer and heated to 175^{0}C. Frying of doughnuts was carried out for 2 minutes, 1 minute for each side[116]. The frying was conducted parallel with another 5 liter oleogel with the same parameters.

Same process was repeated in 5 liter control sample (sunflower oil). In control sample the same parallel frying was also done in 5 liter sunflower oil.

2.5.1.Colour analysis for doughnuts

Colour analysis was performed on fried doughnuts (both fried in oleogel and in sunflower oil for comparison). Experiment was done with Konica Minolta Chroma Meter CR-5, Konica Minolta Optics Inc., Japan, colour determination device. The measurements were scanned 5 times for doughnuts fried both in control and oleogel and averaged, and the results were obtained in (*L*a*b**) format.

For the visual difference photographs were taken as shown below in Figure 2.5 and 2.6.

Fig 2.5 Doughnut fried in control sample

Fig 2.6 Doughnut fried in oleogel sample

2.5.2.Oil Uptake:

The total oil content of the doughnuts fried in control and oleogel samples were determined by soxhelet extraction apparatus. For this purpose, glass balloons with a volume of 500 mL were kept in an oven at 105±2 ºC for two hours to achieve constant weight. The samples were ground to obtain the smallest possible particles in order to ensure the best possible penetration of the solvent into the oil in the body. The ground samples were weighed 10 g and placed first on coarse filter paper and coarse filter paper in the cartridge. The top of the cartridge was covered with oil-free cotton to prevent the solvent from carrying the sample out. The cartridge was placed in the assembly and the heating plates were adjusted to 60 ºC by adding solvent. Hexane was used as solvent. The analysis was continued for 6 hours and at the end of this period the analysis was completed, the solvent was distilled back and the balloons were kept in an oven at 105 ºC for 1 hour to ensure that the remaining solvent was completely removed from the oil. The balloons in the oven were cooled to room temperature in the desiccator and final weighed[118]. Experiment was repeated twice for both samples. Then, the calculation of the total amount of oil in the samples was calculated with the following formula.

Crude Fat %= $[(W_2\text{-}W_1/W_S)]x100$

W2= weight of flask with fat

W1= weight of flask

Ws= weight of sample

2.5.3.Sampling of Oil

In frying process during each frying (both for control and oleogel samples) 10 doughnuts were fried in one turn. After 5 turns of frying first sampling of oil was done to do further experiments to check the stability of oil and oleogel. After that with the same frying interval gape of five fryings sampling was done at 10^{th}, 15^{th} and at 20^{th} frying. These samples were used to do further analysis.

2.6.Chemical Analysis

2.6.1.Free Fatty Acid Analysis and Acid Value

FFAs was determined by using the direct titration method of AOCS (2000). At the start, the oil/oleogel sample to be analyzed, 5g was taken to the 250 mL volume flask. The weight of sample was taken in grams. Then, 50 mL of ethanol diethylether mixture was added to the weighed sample, shaking was done for 1 minute to dissolve the oil and fatty acids for the well the mixing process. After that 3-4 drops of phenolphthalein were added. Titration was done with 0.1 N NaOH in the burette till a permanent pink colour was attained. Utilized amount or the burrete reading was noted. Calculations were made according to the following formulas:

FFA= V/M x2.82 (with the referance of oleic acid)

FFA= Free fatty acid analysis

V= volume of NaOH used

m= weight of sample

2.6.2.Peroxide value (POV) determination

The peroxide number of control and oleogel sample was measured before frying and also for the samples taken out at different frying levels (5^{th},10^{th}, 15^{th}, 20^{th}). The method was used as described AOCS official method Cd 8-53[81]. As described in method, 1.5 g of the oil/oleogel weighed and mixed with 10 mL of chloroform (Merck, Darmstadt, Germany) shaking was done to dissolve the oil. After that, 15 mL of acetic acid (Merck, Darmstadt, Germany) and 1 mL of saturated KI (Sigma St. Louis, MO, USA) were added into it, again shaking was done for 1 minute, and flask was kept in the dark place for 5 minutes. After that period, addition of 75 mL of distilled water was added and titrated with 0.01 N sodium thiosulfate (Merck, Darmstadt, Germany) and 1% starch (Merck, Darmstadt, Germany) solution indicator. The formula used to calculate the peroxide value was:

Peroxide Number (meq O_2/kg oil) = [(V_1-V_0) x N x 1000]/m (2)

V_0 = Volume of sodium thiosulfate solution spent for the blank test (mL)

V_1 =Volume of sodium thiosulfate solution spent for the sample (mL)

N = Normality of sodium thiosulfate solution

m = Sample weight (g)

2.6.3. *p*-Anisidine value (p-AV) determination

The *p*-anisidine test, which is used to determine secondary oxidation products, which are high molecular carbonyl compounds in aldehyde structure, in the oxidation of oils was carried out with the method given in IUPAC 2.504[119]. For this purpose, 0.5 g of oil was weighed into a 25 mL volumetric flask and completed with hexane (Merck, Darmstadt, Germany) solution. 5 mL of this mixture was taken and 1 mL of p-anisidine (Sigma) solution (0.25 g/100 mL of glacial acetic acid) was added to it and kept in the dark for 10 minutes. At the end of the time, the absorbance value against the hexane solution at 350 nm was determined and the p-anisidine value of the samples was calculated using the formula below.

p- anisidine value = $25*(1.2\,A_2-A_1)/m$

A_1: absorbance value of the solution prepared with hexane

A_2: absorbance value of the solution prepared with *p*-anisidine

m: Sample weight (g)

2.6.4.Conjugated Diene Triene Analysis

Specific absorption values were determined in order to determine the primary and secondary oxidation products released as a result of the oxidation of oils during the storage process. For this purpose, 0.1 g of the oil/oleogel sample was weighed and completed with 10 mL of cyclohexane (Sigma). Conjugates as primary oxidation products were measured against hexane in a spectrophotometer (Shimadzu UV-VIS 1800, Kyoto-Japan) at a wavelength of 232 nm, and secondary oxidation products, especially aldehydes and ketones, at 270 nm[120]. The calculation was made according to the formula below.

Absorption at wavelength = A/(c x l) (4)

A : absorbance measured at 232 or 270 nm wavelength

c : Solution concentration (g/100 mL)

l : Light path in the tub (1 cm)

2.6.5.Viscosity Analysis

The investigation of viscosity was carried out (Vibro Viscometer, A&D Company Limited, Japan) at 24°C, or room temperature at 60 rpm for 2 minutes[121].The results of each sample measurements were averaged after being performed three times.

2.7.Statistical Analysis

The statistical evaluation of the data acquired as a consequence of the analysis was carried out using the Windows-based IBM SPSS 25.0 statistical software. One factor and two factor analyses of variance were used to examine the impact of making oleogel on the oxidative stability of sunflower oil and some other analysis like oil absorption etc. For the purpose of comparing the samples' differences, the Tukey multiple comparison with the significance level of 95%.

CHAPTER 3

RESULTS

3.1.Results of analysis applied to the samples

Gelation time (GT) and oil binding capacity (OBC) of soybean-wax-sunflower oil oleogel are given into the Table 2.1

Table 2.1. OBC and GT of Soybeanwax-sunflower oil oleogel

Sample	Oleogel
GT	5.15 ± 0.03^a
OBC	98.85 ± 0.41^a

$^{a-a}$Means in each column does not represent significant differences ($p > 0.05$).

Gelation time (GT) is the time that a gel needed to be solid at a given temperature. OBC is a scale of determining the percent contributation of liquid oil ensnare with an oleogelator or wax[122]. According to the Table 2.1 gelation time for soybeanwax-sunflower oil oleogel is good, 5.15 min for gelation time showed that soybeanwax-sunflower oil oleogel is a strong gel. Oil binding capacity is also higher(98.85%).

Table 2.2 shows the difference of oil absorption between doughnuts fried in control sample and oleogel. According to the Table 2.2 there is a significant difference ($p < 0.05$) is present between the oil absorption in both samples. Doughnuts fried in oleogel sample absorbed less amount of oil than control sample.

Table 2.2. %Oil uptake of doughnuts

Doughnut type	**Doughnuts fried in control sample**	**Doughnuts fried in oleogel sample**
Oil uptake %	17.5±0.34^a	12.7±0.20^b

$^{a-b}$Means in each column represent significant difference according to the Tukey multi veriate test ($p < 0.05$).

The main characteristic of fried food is its colour that attracts the consumer first. Lets understand how this colour is produced during frying. It develops due to the reactions occurred during frying process on the food surface. The time and temperature of frying process is also important in development of colour[123].

Values for colour of doughnuts fried in control sample and oleogel are given into the Table 2.3. According to the *L** values brightness of fried doughnuts both for control and oleogel was almot same. For green tone, (*a**) oleogel fried doughnut less greenish values showed. Yellow colour values according to the Table 2.3 are also good for oleogel fried douhghnut.

Table 2.3 Colour measurements for doughnuts

Type of doughnut fried	**Doughnut fried in control sample**	**Doughnuts fried in oleogel**
L*	87.72±0.08^a	87.73±0.08^b
a*	0.37±0.03^a	0.33±0.025^b
b*	1.54±0.15^a	1.52±0.19^b

$^{a-b}$Means in each row represent significant difference according to
the Tukey multi veriate test ($p < 0.05$).

Table 2.4 contains colour difference of oleogel and control sample before frying. *L** value or brightness shows clear significant difference ($p < 0.05$). Soybeanwax-sunflower oil oleogel is more brighter than control sample. Redness or *a** values for both samples shows significant difference ($p < 0.05$). Control sample showed higher redness than oleogel as value was positive 0.62 and for oleogel value was negative -1.89. For yellowness or *b** value, oleogel was more yellow than control sample according to the values of Table 2.4 and there was significant difference ($p < 0.05$) present between both control and oleogel samples for *b** value.

Table 2.4 Colour measurements of control & oleogel samples before frying

Type of oil/oleogel	Control sample	Oleogel sample
L*	24.91 ± 0.01^{a}	45.55 ± 0.60^{b}
a*	0.62 ± 0.01^{a}	-1.89 ± 0.25^{b}
b*	1.76 ± 0.03^{a}	3.05 ± 0.04^{b}

$^{a\text{-}b}$Means in each row represent significant difference according to the Tukey multi veriate test ($p < 0.05$).

POV is commonly used to calculate the oxidation rate in the oils. Limit of POV set to the 10–15 meq O_2 kg^{-1} for oils by the Codex of Alimentarius Commision[124]. But in the different countries value is 10 meq O_2 kg^{-1} oil for frying oils and fats[125]. According to the Table 2.5, initial value of POV(peroxide value) was less than oleogel. But after frying decreasing trend in oleogel samle was found than control sample. There is a significant difference ($p < 0.05$) present between control and oleogel samples for POV. The increase in POV value for both control and oleogel sample was not in a linear manner as shown in the Figure 3.1. POV of control sample before frying was 5.12±0.15 but after frying it started increasing. It was 11.9±0.1 at 5th frying but at 20th frying it became 16.35±0.1. according to the table 2.5 oleogel showed higher POV than control sample 6.43±0.07. But after different frying periods the POV was less than control sample. As it was 9.8±0.1 at 5th frying and became 12.92±0.05 at 20th frying that is less than control sample POV. The fig 3.1 also presents the difference between POV of control and oleogel sample.

Table 2.5 POV and FFA values of control oil sample and Oleogel sample

Frying interval	**0**	**5**	**10**	**15**	**20**
POV of control sample	5.12±0.15[a]	11.90±0.1[a]	13.38±0.25[a]	15.63±0.18[a]	16.35±0.1[a]
POV of Oleogel sample	6.43±0.07[b]	9.80±0.1[b]	10.63±0.14[b]	11.21±0.09[b]	12.92±0.05[b]
FFA of control sample	0.29±0.01[c]	0.38±0.05[c]	0.46±0.01[c]	0.51.1±0.01[c]	0.55±0.05[c]
FFA of oleogel sample	0.35±0.005[d]	0.37±0.005[d]	0.41±0.01[d]	0.43±0.01[d]	0.45±0.05[d]

[a-b]Means and [c-d]means in each row represent significant difference according to the Tukey multi veriate test ($p < 0.05$).

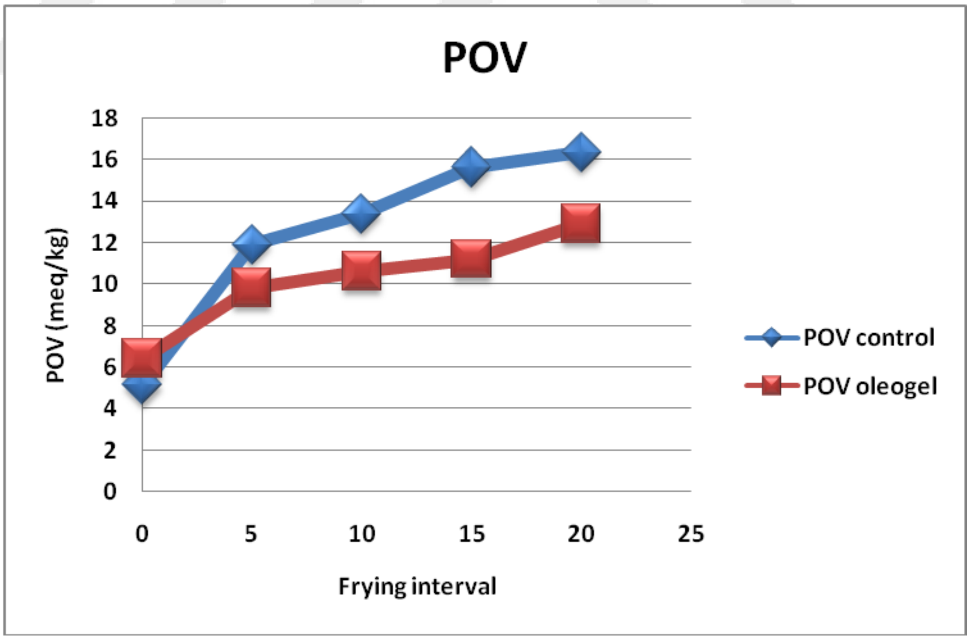

Fig 3.1. Peroxide value (meq/kg)

Table 2.5 also contain free fatty acid values for control and oleogel sample. There is a significant difference ($p < 0.05$) present between the FFA % of both samples. As the Figure 3.2 and Table 5.2 shows the FFA level increased after addition of wax in the oil. Before frying, control sample's FFA was 0.29±0.01 and oleogel's was 0.35±0.005.

There was not big difference was noted at 5th frying in FFA value in both control and oleogel sample as shown in the fig 3.2 graph lines are closer to each other for both control and oleogel sample at 5th frying. Regardless of this value of FFA was less for oleogel than control sample. And this decreasing trend was found with the increase in frying period and became obvious at the 20th frying.

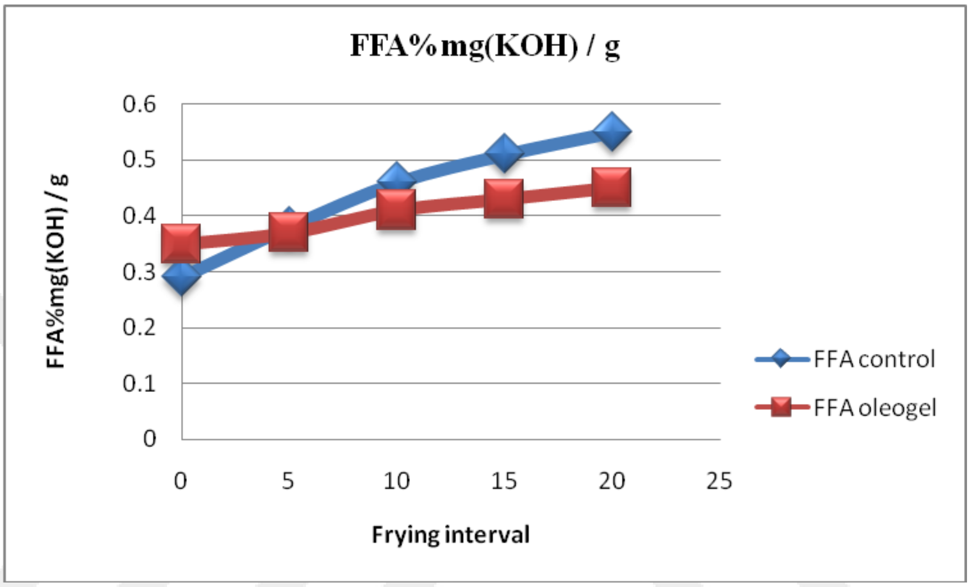

Fig 3.2. free fatty acid %

To calculate the deterioration or oxidation of fats, UV coefficient (k) at 232 and 270 nm is the best way to use. For the calculation of primary oxidation products K_{232} is used an indicator, these primary oxidation products are: hydroperoxides and CD (conjugated dienes). So the while K_{270} is used to calculate CT (conjugated trienes) include ketones, aldehydes[126]. According to the Table 2.6 there is a significant difference ($p < 0.05$) present between control and oleogel sample for conjugated diene and triene tests. For CD(conjugated diene) value there was higher increasing trend noticed in control sample as compare to the oleogel sample as shown in Figure 3.3 that is the 3D graphical representation of CD tes data and Table 2.6. CD was increased at every frying period at 5th, 10th, 15th and 20th but for oleogel sample was less prone to secondary oxidation. Same trend was noted in the case of CT (conjugated tiene) that control sample showed high CT value than oleogel and at different frying period CT increased but oleogel showed less increase than control sample. Figure 3.4 is the 3D graphical representation of CT value, how it increased during frying and difference of this increase between control and oleogel sample.

Table 2.6 Conjugated Diene & Conjugated Triene of control oil sample and Oleogel sample

Frying no	0	5	10	15	20
CD of control sample	4.5±0.24[a]	23.05±0.23[a]	27.7±0.74[a]	33.4±0.42[a]	36.07±0.1[a]
CD of oleogel sample	3.85±0.09[b]	15.2±0.27[b]	17.1±0.04[b]	23.1±0.83[b]	25.1±0.17[b]
CT of control sample	3.06±0.09[c]	11.2±0.25[c]	16.06±0.16[c]	19.9±0.57[c]	22.6±0.55[c]
CT of oleogel	2.9±0.01[d]	7.1±0.28[d]	10.1±0.27[d]	13.1±0.11[d]	16.1±0.20[d]

[a-b]Means and [c-d]means in each column represent significant difference according to the Tukey multi veriate test ($p < 0.05$).

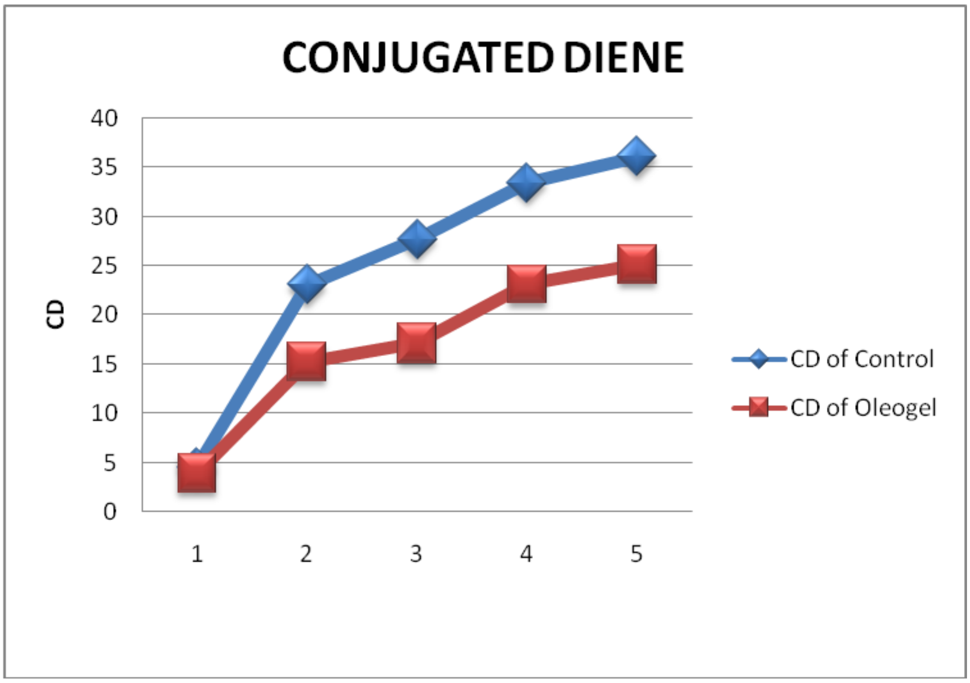

Figure 3.3 Conjugated diene

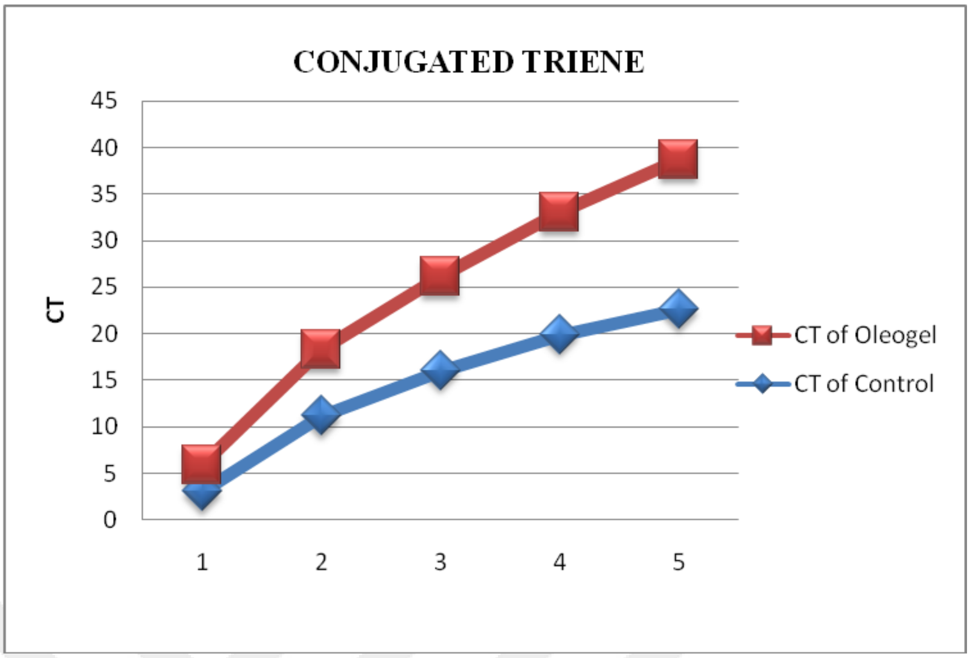

Fig 3.4 conjugated triene value

The *p*-Anisidine is also known as the test for secondary oxidative products. According to the Table 2.7, control sample showed higher value for this test than oleogel. Overall during all frying periods *p*-AV value was high than oleogel sample. Figure 3.5 is 3D graphical representation of Table 2.7 which shows that there was a clear significant difference was present between oleogel and control sample. Frying affected the both control and oleogel sample *p*- AV value increased with increase in frying period but oleogel was less pron to the secondary oxidation.

Table 2.7 *P*-AV of control and oleogel samples

Frying interval	***0***	**5**	**10**	**15**	**20**
***p*-AV of control sample**	6.2±0.33^{a}	31.5±1.1^{a}	63.3±1.7^{a}	78.9±1.3^{a}	102.3±2.7^{a}
***p*-AV of oleogel sample**	5.70±0.1^{b}	23.43±0.11^{b}	50.26±0.05^{b}	69.5±0.4^{b}	90.3±0.6^{b}

$^{a\text{-}b}$Means in each column represent significant difference according to the Tukey multi veriate test ($p < 0.05$).

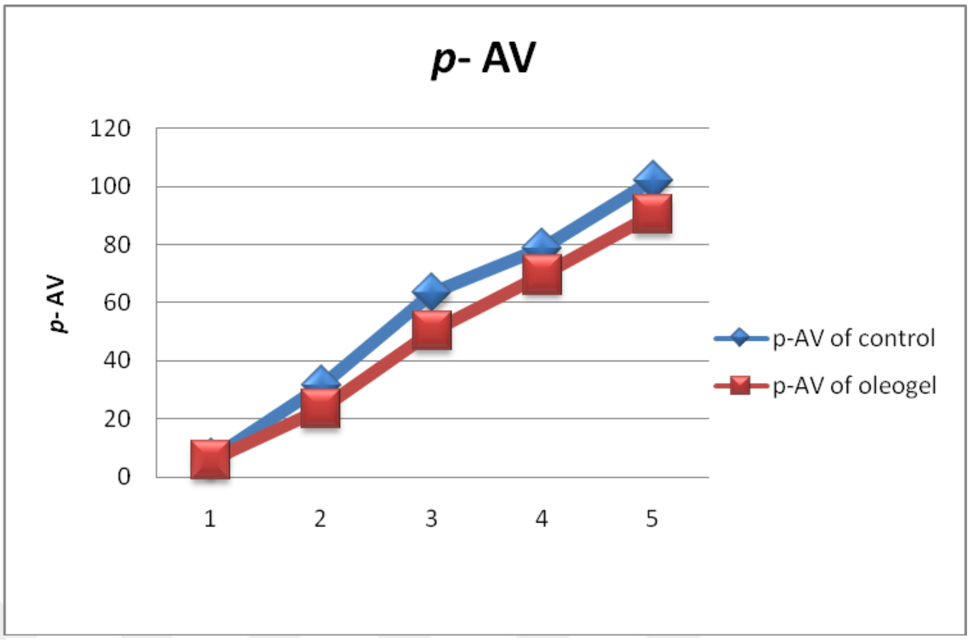

Figure 3.5 p- Anisidine value

Viscosity:

Viscosity of control and oleogel samples was effected during different frying turns or cycles($p < 0.05$). According to the Table 2.8, viscosity of control sample increased with the increase of frying period. For oleogel, viscosity also increased at the 5th frying cycle and decreased at 10th cycle after that it increased again at 15th frying cycle and decreased again at 20th cycle. Figure 3.6 is the graphical representation of the this increasing and decreasing trend of viscosity for both control and oleogel samples.

Table 2.8. Viscosity of control and oleogel samples

Frying interval	***0***	**5**	**10**	**15**	**20**
Viscosity of control sample	92.5±4.7^{a}	153.03±2.24^{a}	166.0±2.83^{a}	172.1±1.75^{a}	191.7±1.96^{a}
Viscosity of oleogel	253.2±6.33^{b}	348.3±7.39^{b}	265.96±6.21^{b}	323.20±5.93^{b}	284.57±4.57^{b}

$^{a-b}$Means in each row represent significant difference according to the Tukey multi veriate test ($p < 0.05$).

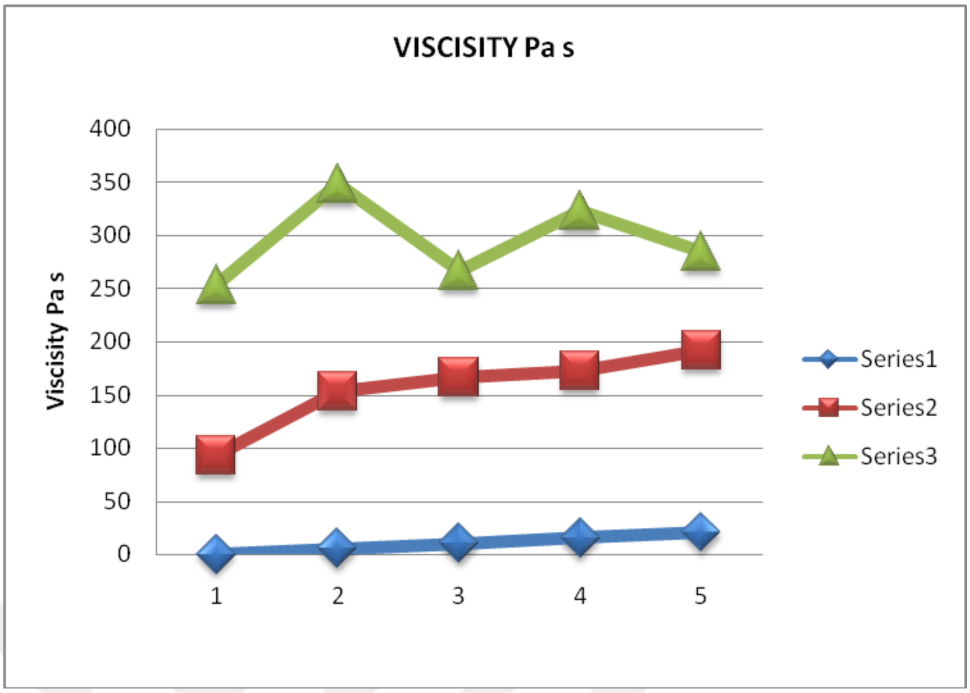

Figure 3.6 Viscosity measurements

CHAPTER 4

DISCUSSIONS

4.1.The Oil Binding Capacity and Gelation Time

Gelation time (GT) and oil binding capacity (OBC) of oleogel was analyzed, and the results are shown in Table 2.1. In the process of gel formation structuring of a continuous 3-D network take place which entraps the liquid oil. Gelation time（GT）is dependent on the balance of the concentration of the soluble and insoluble entities and it is the time that a gel needed to be solid at a given temperature[11, 127]. Guneser and . Yilmaz (2022) reported in their study that gelation time of an oleogel decreases with increase of concentration of gelator. They used 3-8% gelator in the oleogel formation. Gelation time with 3% concentration was 21.30 minutes and for 8% it decreased to 12.17 min. As in present study, 10% soya wax was used and according to the Table 2.1 mean value for oleogel sample was 5.15±0.03 minutes. The gelation time of soybeanwax- sunflower oil oleogel is lesser, so it is a strong gel and low GT value is helpful to save time while using real conditions[127, 128].

Finding the functionality of oleogels can be achieved by OBC. The oil binding capacity may be defined as the ability of a system to retain its liquid oil phase[80]. Oleogels with High OBC results are required for preparation of oleogels. High the OBC, lesser the concentration of the oleogelators will be used[129, 130].

According to Guneser and Yilmaz (2022) “All oleogel samples formulated, exhibited OBC values above 99％”. Some other studies also agreed with their results[104, 129].

The oil binding capacity (OBC) of soyabeabwax-sunflower oil oleogel was 98%, according to the results obtained through the analysis shown into the Table 2.1. These results are close to the results of previous researches done for the wax based oleogels[12, 131]. The oil binding capacity is the indicator of the strength and capacity of a gel under specific mechanical treatment conditions. According to the Table 2.1 the OBC value for oleogel sample was 98.85± 0.4. Results for both OBC and GT proved that soybeanwax-sunflower oil oleogel is a good or strong gel.

4.2.Oil Uptake

The taste, aroma, and texture of the fried food depend on the oil uptake of that fried food. There is need to minimize the oil uptake in the deep fried food to make it healthier. The process of absorption of oil in deep frying is the aggregation of oil inside the food during frying through the pores and capillaries present in the surface of food from where moisture evaporates rapidly. As the moisture leaves rapidly, builds turbulent and the pores that increases the oil uptake[132]. Frying process in the oleogels makes smooth surface as compared to the foods fried in control oil. Studies shows that if the structure of fried food smoother and with reduced pore size that can be obtained by frying food in oleogel leads to lower fat content[4].

In a research which was done for the frying of potatoes it was reported that the oil uptake percentage of Potato strips fried in oleogels showed less absorbed oil content, 11.97% and 12.07%. On the other hand potato strips fried in the control or simple oil sample showed high oil uptake percentage,15.20%[5]. In parallel, Lim et al.[4] fried noodles in carnauba wax oleogel that showed less oil absorbance, 16% than noodles fried in simple oil. Another study showed significant decrease in the content of oil uptake by the onion rings fried in the oleogel approximately 35% decrease was reported as compared to the control sample[122]. Researchers are doing efforts to decrease the oil absorption of fried foods[4, 9, 133-135]. In the present study doughnuts were analyzed for oil uptake fried in the control sample and comparison was made with soybeanwax-sunflower oil oleogel sample and their results were given into the Table 2.2. According to the Table 2.2, results doughnuts fried in sunflower oil or control sample showed high oil absorption 17.5±0.34. However, the fat absorption was reduced in the oleogel samples to the12.7±0.20. The significant difference was present between the doughnuts fried in control and oleogel samples ($p < 0.05$).. Hence, result shows that soybeanwax-sunflower oil oleogel can be counted as good to achieve low fat fried food expectations and can be the promising frying medium for doughnuts with respect to the oil uptake.

4.3.Colour Measurement of Doughnuts

The main characteristic of fried food is its colour that attracts the consumer first. Let's understand how this colour is produced during frying. It develops due to the reactions occurred during frying process on the food surface. The time and temperature of frying process is also important in development of colour[123].

A study on fried potato strips reported that the brightness that is indicated by $L*$ values showed slight changed from control to the oleogel fried potato strips. $L*$ value for control sample was 77.84 and for oleogel fried sample was 77.69. Also there was no significant change in $a*$ value. The $a*$ indicates the green tone. The $b*$ value show the yellow colour. There was also slight change in oleogel fried sample as compared to the control sample. In the another study of Matthäus et al [135] quite matching results were present to the previously discussed study. According to the Table 2.3 there is slight or no difference in the brightness of control and oleogel fried samples. It is due to the brown colour requirement of fried doughnuts. According to the Table 2.3 $a*$ values are in the positive number so they shows the red colour of doughnut that was the requirement of fried doughnuts, $a*$ value for control was 0.37 and for oleogel fried doughnuts decreased to the 0.33. These values indicate that doughnut fried in control samples had dark brown colour and doughnut from oleogel samples had nice golden brown colour. According to the Table 2.3 $b*$ values for control sample was 1.54, more yellowish colour and for oleogel based samples this value showed slight change 1.52. As a result, colour values of oleogel fried doughnuts were parallel to the control sample and also similar to the other studies discussed above and are acceptable. Doughnuts fried in soybeanwax-sunflower oil oleogel will be acceptable by the consumer according to the colour aspects.

4.4.Colour Measurement of Oil and Oleogel

Colour is the primary character of any food that attracts to the consumer first. Colour of edible oils is due to the pigments and their derivatives naturally present in that oil[136].

In a study similar to the present work, they fried potato strips in the sunflower oil and oleogel. In one part they analysed colour of sunflower oil and oleogels with different concentration of waxes made by researcher. Results showed that the prepared oleogel samples showed higher values of *L** than sunflower oil, *L** value for sunflower oil was 30.50 and oleogel with 3% wax concentration showed 42.40 and 8% wax containing sample showed 55.02 *L** value[5, 137]. It means more the addition of wax increases the brightness of oleogel. As in the present work soy-wax concentration was 10%. According to the Table 2.4 mean of *L** value for sunflower oil before frying was 24.91±0.0. After addition of soya wax (10%) its increased to the 45.55±0.60 for sample of oleogel [7,19]. In the same potato strips frying research, difference was present for *a** values among oleogel sample and sunflower oil. Results of that study showed that green colour was more in oleogel sample than sunflower oil[5]. In the present study same results were obtained shown in the Table 2.4. For control sample before frying a* value was 0.62±0.01 and for oleogel sample turned to the -1.89±0.25 (Tabla 2.4).

These values shows that oleogel samples were more green than sunflower oil as showed in previous study. According to the table 2.4 b* value for oleogel was increased to 3.05±0.04 than oil sample (1.76±0.03). These values are also simlar to the previous study done for potato strips frying in oleogel and oil, yellowness of oleogels was higher than sunflower oil because *b** of oleogels were high than oil sample[5]. So the colour results showed that soywax- sunflower oil oleogel is good according to the colour aspect.

4.5.Conjugated Diene and Triene

To calculate the deterioration or oxidation of fats, UV coefficient (K) at 232 and 270 nm is the best way to use. For the calculation of primary oxidation products K_{232} is used an indicator, these primary oxidation products are: hydroperoxides and CD (conjugated dienes). So while K_{270} is used to calculate CT (conjugated trienes) include ketones and aldehydes[126].

The quality of oils can be measured by checking their absorbance at 200 and 300 nm. These are frequencies used to analyze the quality of oils, known as conjugated diene (K232) and triene (K270). The hydroperoxides shows the initial stage of oxidation, at 232 nm [138]. PUFA oxidized due to the formation of hydroperoxides. As the peroxides formed the non-conjugated double bonds affects the regeneration of conjugated dienes. Secondary oxidation or conjugated trienes production increases the absorbance at 270 nm. When in the PUFA (polyunsaturated fatty acids) having three or more double bonds started to be oxidized, the conjugation process sustained to another double bond caused by the formation of conjugated trienes (K270). These absorbance values used as quantification of oxidation[139]. In the frying fats presence of K232 and K270 is a good oxidation measurement [140]. During heating production level of CD and CT depends on the level of polyunsaturated fatty acids present in the oil.

The initial value of CD for the control sample before frying was 4.5±0.24 and for oleogel it was 3.85±0.09 (Table 2.5). Bascuas et al (2020) reported similar values for sunflower oil for conjugated dienes and they reported similar initial values for the oleogel made with sunflower oil as compared to the present study. Their value of CD for oleogel was 3.9 and the present study shows the quite similar values[141, 142]. According to the Table 2.5 CT values for control sample was 3.06±0.09 similar to the Bascuas et al (2020) results. For oleogel sample CT values was 2.9±0.01. According to the results, CD and CT values were less in the oleogel before frying. As primary and secondary oxidation depends on the presence of polyunsaturated fatty acids, addition of waxes into the edible oil decreases the unsaturation level[143]. So it could be the reason of the decrease of oxidation in oleogel.

In another study for the deep frying process CD value started from 19 and with the passage of time and reached to 60. CT values in the same study started from 5 and at the end of the process peak value was 12[144]. In the present research CD and CT values checked after the 5 intervals of frying at 5th frying CD was for control sample found as 23.05±0.23, at 10th frying it turned to the 27.7±0.74 and at the 20th frying the final value was 36.07±0. CT value according to the Table 2.5, of control sample for 5th frying 11.2±0.25 and increase to the 22.6±0.55 at 20th frying. In the case of oleogel absorbance at K_{232} and $K2_{70}$ was decreased . CD value at 5th frying was 15.2±0.27 and ended at 20th with 25.1±0.17. CT values was 7.1±0.28 and reached to the 16.1±0.20 at the 20th frying. As compared to the control samplw oleogel shows low level of oxidation according to the results. As there was no data present on the CD and CT for the frying of oleogels, results could be defended by the study for the oleogels and oil during the storage time period. The research conducted to check oxidation difference of oil and oleogels during storage time, oleogels shows less values for CD and CT than oil[141]. These results could be sorted by the statement, higher the amount of PUFA higher the oxidation level of CD and CT[143]. If any fat or oil shows the decreased or less level of conjugated dienes and trienes, oxidative stability of that oil or fat is good[141]. Hence, soywax-sunflower oil oleogel is more stable for oxidation than sunflower oil during heating or frying.

4.6.Peroxide Value

POV is commonly used to calculate the oxidation rate in the oils. Limit of POV set to the 10–15 meq O_2 kg^{-1} for oils by the Codex of Alimentarius Commision[124]. But in the different countries value is 10 meq O_2 kg^{-1} oil for frying oils and fats[125]. In a study the peroxide value increased when oleogel prepared with the combination of sunflower oil and beeswax. Addition of wax was 3% and 8%. Fresh sunflower oil had POV 6.3 meq O_2 kg^{-1} and increased to the 17 meq O_2 kg^{-1} after the frying of 7 hr frying. For the sample of oleogels 3% and 8% initial values were 14.12 and 9.35 meq O_2 kg^{-1} respectively. Level of POV was increased after frying, POVs for oleogel 3% concentration of wax sample it reached to the 17.84 and for 8% sample it was 15.41 meq O_2 kg^{-1} [5]. In the present study according to the Table 2.6 POV of control sample before frying was 5.12±0.15. Addition of saoywax increased the POV level of prepared oleogel as shown in the Table 2.6. As in the previous study oleogel with high wax concentration showed less increase in POV, it could be defend here that soya-wax concentration was 10% so that is why less increase of POV in the oleogel happened. As in this study POV measured with the gap difference of frying not with respect to the time, increase was also less due to the less time interval present among the frying stages than 7 hrs. But the change was in the same manner for oil for control samples POV increased in a linear manner at every 5 frying interval. Same increase was happened in the oleogel samples as shown in to the Table 2.6 but the increase in POV was less than control sample. Hence, oleogel showed more resistance in increase of POV during frying process than the control samples. There is a possibility that reason of less POV in oleogel was due to the their solid structure that may not penetration of oxygen into the oil after the completion of frying and when the temperature of oleogels reached to ambient temperature and the become solid again. In other studies the same trend was shown [12, 131]. Furthermore, in A study of Lim et al. same stabilizing effect were encountered[4]. In another study, It has been reported that oleogels could cease or decrease the rate of fats oxidation. This property could be related less permeability of O_2 into the oleogels network[106]. According to the present research result of POV soywax-sunflower oil oleogel is good replacement of sunflower oil for frying.

4.7.Free Fatty Acid

According to the Table 2.6, free fatty acid value for control samples was low, 0.29. However after making soywax-sunflower oil oleogel free fatty acid value increased to the 0.35 in the oleogel sample. During frying process or at the end of frying higher values of FFA were shown by the control sample of sunflower oil. Oleogel sample showed less value of FFA. A study of onion frying in sunflower oil polyglycerol stearate oleogel reported the same results with present research result[122].

Another study compares the fresh samples with the oleogels prepared showed that FFA values were increased after addition of wax[145, 146]. The reason of increase in FFA was the availability of some long-chain saturated free fatty acids[145, 146]. In that study control and oleogel with 8% concentration showed not significant diference after 7 hr frying($P<0.05$). Oleogel with 3% concentration showed increased FFA.

But the time period of 7 h of frying was not sufficient to create significant changes in the FFA values[5]. In the present study, as the frying was done for long period (20 fryings), before frying oleogel showed higher amount of FFA but at 5th frying there was no significant difference present between control and oleogel samples. However, at 10th, 15th and 20th stage of frying of oleogel sample showed slight increasese in FFA percentage.

The FFA value that permitted level is 0.9–2.5% in some European countries[125]. The Table 2.6 shows that even after 20 frying oleogels did not cross the limit of permitted FFA value, so soywax-sunflower oil oleogel is good medium for frying of doughnuts.

4.8.*p*-AV

A rise in peroxide value is insufficient to evaluate the frying process. Together with the peroxide value, the value of *p*-anisidine alue should be taken into account because it is another highly reliable and important test. Hydroperoxides and secondary oxidation products are produced during the oxidation of unsaturated fatty acids. Peroxide value (POV) and anisidine value measurements are used to determine the generation of hydroperoxide and the secondary oxidation products, respectively (.*p*-AV Value) When heated or deep-fried, hydroperoxides lose their stability and rapidly split apart into mixes of volatile aldehyde molecules. As a result, the observed is regarded *p*-AV Value as a measurement of the non-volatile aldehydes (2-alkenal and 2,4-dienal), which are byproducts of oil decomposition. In light of this, secondary oxidation products that are more stable than hydroperoxides have a strong link with the anisidine value[144, 147-150].

In a study researcher checked the increasing trend of p-AV value in refined oleic/linoleic sunflower seed oil and olive oil during deep frying. There was an increasing trend was found in *p*-AV value with the increase in frying hours[144]. The result of present study are related to the results of refined oleic sunflower oil frying. Before frying *p*-AV for control sample was 6.2±0.33 that is same with the results of study discussed abve[144]. For oleogel value was almost same 5.70±0.1.There was no data or research present for the *p*-AV test for oleogels after fryings. Same trend like the study described above was found in the present study[144]. The *p*- AV gradually increased with the period of frying in control sample as well as in oleogel sample. As shown in the Table 2.7 *p*-AV was increased from 6.2 to the 31.5 at 5th frying and at 20th frying it reached to the 102.3±2.7· for control sample. However at 5th frying th *p*-AV increased to the 23.43 and became 90.3 at 20th frying for oleogel sample. According to the results of Askın & Kaya (2020) increased value were seen samples of oil contain less amount of PUFA were more porne to the oxidation. In the present study oleogel showed decreased trend for *p*-AV than control sample. We can defend it by the hard structure of oleogel, that was harder for oxygen to penetrate and high amount of PUFA because addition of wax into oil does not affect the saturation of oil [10, 128]. Figure 3.5 illustrate the graphical representation of the *p*-AV. Results showed that soywax-sunflower oil oleogel was less prone to the secondary oxidation. So it could be the replacement of trans fats in industry.

4.9.Viscosity

The viscosity of the oil changes during deep fat frying processes according to the frying time and temperature[121]. In the present study the viscosity of oleogel was much higher than oil before frying because addition of wax increased the viscosity of oleogel (Table 2.8). In the control sample the normal trend of increased of viscosity was observed with the increase of frying temperature[121]. However, in oleogel viscosity increased at 5^{th} frying and again decreased after 10^{th} frying cycle. The increasing trend was observed after 15^{th} frying cycle and again decreased after 20^{th} frying cycle. Air (autoxidation) and water have a degrading effect on regularly used oils (hydrolytic degradation). Oil breakdown products have a significant impact on viscosity, and the creation of dimers, trimers, polymers, epoxides, alcohols, and hydrocarbons increases viscosity[67, 151]. Oil serves as a heat transmission medium while frying food. The oil may thicken and become more viscous as the temperature rises. The amount of time it takes for food to cook and develop its fried colour increases as oil becomes thicker because it slows down the rate at which heat is transferred or exchange take place between food and frying medium.

4.10.Conclusions

Soybean–wax Sunflower oil oleogel prepared with 10% soywax addition was used as frying medium against the control (sunflower oil) for doyghnut frying. Oleogel analyses showed that oleogel was true stable gel with good gelation time and Oil binding capacity. Oleogel was solid at ambient temperature and turns into liquid in the frying process. Moreover, starting FFA, POV, *p*-AV, CD and CT values were within the acceptable range. However, with the increase of frying period, results of all the fat analyses proved that oleogel have higher oxidative stability than the control sample. Doughnuts fried in oleogel suck up less oil than those fried in the control sample. Further, doughnuts fried in oleogel were of nice golden colour than that of control sample. Furthermore, colour of oleogel was more brighter than control sample. Moreover, viscosity of oleogel was also less after frying than control sample. In fact, overall acceptability of the oleogel sample and doughnut fried in oleogel sample was the highest than control. As a result, this study proved that doughnuts fried in Soybean–wax

Sunflower oil oleogel had less oil uptake with improved oxidative stability, viscosity and colour.

4.11.Future studies

It is recommended to fry oleogels with other types of oleogels prepared at different solidity levels over a long period of time for various kinds of foods. To assess the effectiveness of oleogels as a frying medium, studies comparing the short-term storage of fried foods cooked in oleogels to those cooked in other fats/oils could be useful. This study will offer creative suggestions and opportunities for the creation of low-calorie fried goods and oleogel-based frying medium. Findings from this study can improve understanding of oleogels' frying stability, as well as increasing the frying time and frying cycles of oleogel-based frying medium. Characterizing the aromatic profile, testing the storage stability of fried goods, and keeping an eye on the formation of trans fatty acids in frying oils are some potential research directions for oleogel-based frying mediums.

REFRENCES

1. Struyf, N., E. Van der Maelen, S. Hemdane, J. Verspreet, K.J. Verstrepen, and C.M. Courtin, 2017. Bread dough and baker's yeast: An uplifting synergy. **Comprehensive Reviews in Food Science and Food Safety. 16**, (5): 850-867.
2. Yilmaz, E., E. Keskin Uslu, and C. Öz, 2021. Oleogels of some plant waxes: Characterization and comparison with sunflower wax oleogel. **Journal of the American Oil Chemists' Society. 98**, (6): 643-655.
3. Scharfe, M. and E. Flöter, 2020. Oleogelation: From scientific feasibility to applicability in food products. **European journal of lipid science and technology. 122**, (12): 2000213.
4. Lim, J., S. Jeong, and S. Lee, 2017. Evaluation of soybean oil-carnauba wax oleogels as an alternative to high saturated fat frying media for instant fried noodles. **LWT. 84**: 788-794.
5. Aydeniz Guneser, B., E. Yılmaz, and E.K. Uslu, 2021. Sunflower Oil–Beeswax Oleogels Are Promising Frying Medium for Potato Strips. **European Journal of Lipid Science and Technology. 123**, (10): 2100063.
6. Adrah, K., S.C. Adegoke, and R. Tahergorabi, 2022. Physicochemical and microbial quality of coated raw and oleogel-fried chicken. **LWT. 154**: 112589.
7. Wiege, B., E. Fehling, B. Matthäus, and M. Schmidt, 2020. Changes in physical and chemical properties of thermally and oxidatively degraded sunflower oil and palm fat. **Foods. 9**, (9): 1273.
8. Yi, J., M. Qiu, N. Liu, L. Tian, X. Zhu, E.A. Decker, and D.J. McClements, 2020. Inhibition of lipid and protein oxidation in whey-protein-stabilized emulsions using a natural antioxidant: Black rice anthocyanins. **Journal of Agricultural and Food Chemistry. 68**, (37): 10149-10156.
9. Aladedunye, F., R. Przybylski, and B. Matthaus, 2017. Performance of antioxidative compounds under frying conditions: A review. **Critical Reviews in Food Science and Nutrition. 57**, (8): 1539-1561.
10. Asokapandian, S., G.J. Swamy, and H. Hajjul, 2020. Deep fat frying of foods: A critical review on process and product parameters. **Critical Reviews in Food Science and Nutrition. 60**, (20): 3400-3413.

11. Marangoni, A.G., 2012. Organogels: An alternative edible oil-structuring method. **Journal of the American Oil Chemists' Society. 89**, (5): 749-780.

12. Patel, A.R., *Edible oil structuring, food chemistry, function and analysis (p. 336)*. 2018, Cambridge, UK: Royal Society of Chemistry.

13. Oke, E.K., A.O. Tijani, O.T. Abiola, A.K. Adeoye, and B.O. Odumosu, 2018. Effects of partial substitution of wheat flour with breadfruit flour on quality attributes of fried doughnut. **Journal of Agricultural Sciences-Sri Lanka. 13**, (1): 72-80.

14. Anjum, F.M., M. Nadeem, M.I. Khan, and S. Hussain, 2012. Nutritional and therapeutic potential of sunflower seeds: a review. **British Food Journal**.

15. Stat, F.A.O., *Online agricultural statistics. http*. 2008.

16. Osorio, J., J. Fernández-Martínez, M. Mancha, and R. Garcés, 1995. Mutant sunflowers with high concentration of saturated fatty acids in the oil. **Crop Science. 35**, (3): 739-742.

17. Mashelkar, R.A., 1998. The Wealth of India: A Dictionary in Indian Raw Material and Industrial Products. **Vol 2B, Publication and Information Directorate, CSIR, New Delhi, India**: 174-176.

18. Pal, D., *Sunflower (Helianthus annuus L.) Seeds in health and nutrition*, in *Nuts and seeds in health and disease prevention*. 2011, Elsevier. pp. 1097-1105.

19. Kurt, G. and I. Tepe, 2014. Van'da Küçük Tohumlu Yonca Küskütü (Cuscuta approximata Bab.)'nün Yayılma Yolları. **Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi. 24**, (1): 51-59.

20. Gunstone, F., 2011. Vegetable oils in food technology: composition, properties and uses. John Wiley & Sons.

21. Rauf, S., M. Shahzad, J.A. Teixeira da Silva, and I.R. Noorka, 2012. Biomass partitioning and genetic analyses of salinity tolerance in sunflower (Helianthus annuus L.). **Journal of Crop Science and Biotechnology. 15**, (3): 205-217.

22. Ye, Y., M. Barange, M. Beveridge, L. Garibaldi, N. Gutierrez, A. Anganuzzi, and M. Taconet, 2017. FAO's statistic data and sustainability of fisheries and aquaculture: Comments on Pauly and Zeller (2017). **Marine Policy. 81**: 401-405.

23. Lazarević, J.M., J.Ž. Luković, S.Z. Terzić, M.Đ. Jocković, L.N. Zorić, D.S. Karanović, S.B. Jocić, and D.M. Miladinović, 2016. Micro-morphological features of achene of wild annual sunflowers. **Zbornik Matice srpske za prirodne nauke**, (131): 73-80.

24. Kaya, Y., I. Balalic, and V. Milic, *Eastern Europe perspectives on sunflower production and processing*, in *Sunflower*. 2015, Elsevier. pp. 575-637.

25. Rauf, S., N. Jamil, S.A. Tariq, M. Khan, M. Kausar, and Y. Kaya, 2017. Progress in modification of sunflower oil to expand its industrial value. **Journal of the Science of Food and Agriculture. 97**, (7): 1997-2006.

26. Adeleke, B.S. and O.O. Babalola, 2020. Oilseed crop sunflower (Helianthus annuus) as a source of food: Nutritional and health benefits. **Food Science & Nutrition. 8**, (9): 4666-4684.

27. Adeleke, B.S. and O.O. Babalola, *Oilseed crop sunflower (Helianthus annuus) as a source of food: nutritional and health benefits. Food Sci Nutr 8: 4666–4684*. 1783.

28. Kollia, E., P. Markaki, P. Zoumpoulakis, and C. Proestos, 2017. Antioxidant activity of Cynara scolymus L. and Cynara cardunculus L. extracts obtained by different extraction techniques. **Natural product research. 31**, (10): 1163-1167.

29. Paarakh, P.M., 2009. Ficus racemosa Linn.–an overview.

30. Mullins, P., 2008. Glazed America.

31. Hunwick, H.D., 2015. Doughnut: A global history. Reaktion Books.

32. Qin, Z., Improvement in the Making of the All-Time American Treat: Deep-Fried Doughnut.

33. Dailey, E.W., 2019. Contemplating a Doughnut: Analyzing Current Food Theologies through a Fellowship Hour Treat. **Theology Today. 75**, (4): 482-493.

34. Manickavasagan, A., S.K. Chandini, A. Sivakumar, and R. Pratibha, 2014. Effect of dates on fermentation of appam batter. **Journal of Pure and Applied Microbiology. 8**, (SPEC. ISS. 1): 305-311.

35. Keentok, M., M.P. Newberry, P. Gras, F. Bekes, and R.I. Tanner, 2002. The rheology of bread dough made from four commercial flours. **Rheologica Acta. 41**, (1): 173-179.

36. Jayaram, V.B., S. Cuyvers, B. Lagrain, K.J. Verstrepen, J.A. Delcour, and C.M. Courtin, 2013. Mapping of Saccharomyces cerevisiae metabolites in fermenting wheat straight-dough reveals succinic acid as pH-determining factor. **Food Chemistry. 136**, (2): 301-308.

37. Robertson, G.L., 2009. Food packaging. **Textbook of Food Science and Technology**: 279-298.

38. Himawan, C., V.M. Starov, and A.G.F. Stapley, 2006. Thermodynamic and kinetic aspects of fat crystallization. **Advances in colloid and interface science. 122**, (1-3): 3-33.

39. Maleky, F. and A. Marangoni, 2011. Nanoscale effects on oil migration through triacylglycerol polycrystalline colloidal networks. **Soft Matter. 7**, (13): 6012-6024.

40. Marangoni, A.G. and D. Rousseau, 1996. Is plastic fat rheology governed by the fractal nature of the fat crystal network? **Journal of the American Oil Chemists' Society. 73**, (8): 991-994.

41. Rogers, M.A., 2009. Novel structuring strategies for unsaturated fats–Meeting the zero-trans, zero-saturated fat challenge: A review. **Food Research International. 42**, (7): 747-753.

42. Marangoni, A.G., N. Acevedo, F. Maleky, F. Peyronel, G. Mazzanti, B. Quinn, and D. Pink, 2012. Structure and functionality of edible fats. **Soft Matter. 8**, (5): 1275-1300.

43. Flory, P.J., 1953. Principles of polymer chemistry. Cornell university press.

44. Almdal, K., J. Dyre, S. Hvidt, and O. Kramer, 1993. Towards a phenomenological definition of the term ‘gel’. **Polymer gels and networks. 1**, (1): 5-17.

45. Terech, P. and R.G. Weiss, 1997. Low molecular mass gelators of organic liquids and the properties of their gels. **Chemical reviews. 97**, (8): 3133-3160.

46. Pernetti, M., K.F. van Malssen, E. Flöter, and A. Bot, 2007. Structuring of edible oils by alternatives to crystalline fat. **Current Opinion in Colloid & Interface Science. 12**, (4-5): 221-231.

47. Zetzl, A.K. and A.G. Marangoni, *Novel strategies for nanostructuring liquid oils into functional fats*, in *Edible Oleogels*. 2011, Elsevier. pp. 19-47.

48. Wright, A.J. and A.G. Marangoni, *Vegetable Oil-Based Ricinelaidic Acid Organogels; Phase Behavior, Microstructure, and Rheology*, in *Edible Oleogels*. 2018, Elsevier. pp. 65-83.

49. Gandolfo, F.G., A. Bot, and E. Flöter, 2004. Structuring of edible oils by long-chain FA, fatty alcohols, and their mixtures. **Journal of the American Oil Chemists' Society. 81**, (1): 1-6.

50. Patel, A.R. and K. Dewettinck, 2016. Edible oil structuring: an overview and recent updates. **Food & function. 7**, (1): 20-29.

51. Puşcaş, A., V. Mureșan, C. Socaciu, and S. Muste, 2020. Oleogels in food: A review of current and potential applications. **Foods. 9**, (1): 70.

52. Manzoor, S., F.A. Masoodi, F. Naqash, and R. Rashid, 2022. Oleogels: Promising alternatives to solid fats for food applications. **Food Hydrocolloids for Health**: 100058.

53. O'Sullivan, C.M., S. Barbut, and A.G. Marangoni, 2016. Edible oleogels for the oral delivery of lipid soluble molecules: Composition and structural design considerations. **Trends in Food Science & Technology. 57**: 59-73.

54. Vitrac, O., G. Trystram, and A.L. Raoult-Wack, 2000. Deep-fat frying of food: Heat and mass transfer, transformations and reactions inside the frying material. **European Journal of Lipid Science and Technology. 102**, (8-9): 529-538.

55. Perkins, E.G. and M.D. Erickson, *Deep fryingChemistry, nutrition and practical applications*. 1996, AOCS.

56. Gertz, C., 2014. Fundamentals of the frying process. **European Journal of Lipid Science and Technology. 116**, (6): 669-674.

57. Xue, J. and M. Ngadi, 2009. Effects of methylcellulose, xanthan gum and carboxymethylcellulose on thermal properties of batter systems formulated with different flour combinations. **Food hydrocolloids. 23**, (2): 286-295.

58. Sanibal, E.A.A. and J. Mancini Filho, 2002. Alterações físicas, químicas e nutricionais de óleos submetidos ao processo de fritura. **Food Ingr South Am. 1**, (3): 64-71.

59. Oke, E.K., M.A. Idowu, O.P. Sobukola, S.A.O. Adeyeye, and A.O. Akinsola, 2018. Frying of food: a critical review. **Journal of Culinary Science & Technology. 16**, (2): 107-127.

60. Moreira, R.G., M.E. Castell-Perez, and M.A. Barrufet, 1999. Deep fat frying: fundamentals and applications.

61. Chung, M.-K., H. Lee, A. Mizuno, M. Suzuki, and M.J. Caterina, 2004. 2-aminoethoxydiphenyl borate activates and sensitizes the heat-gated ion channel TRPOV3. **Journal of Neuroscience. 24**, (22): 5177-5182.

62. Sumnu, S.G. and S. Sahin, 2008. Advances in deep-fat frying of foods. CRC Press.

63. Kaplan, H., 2020. Atmosferik ve basınçlı kızartmanın hindi nuggetlarının bazı kalite özellikleri ile kızartma yağı kalitesine etkisi.

64. Costa, R.M., F.A.R. Oliveira, O. Delaney, and V. Gekas, 1999. Analysis of the heat transfer coefficient during potato frying. **Journal of Food Engineering. 39**, (3): 293-299.

65. Giese, J., 1996. Fats, oils, and fat replacers. **Food technology (USA)**.

66. Guillaumin, R., 1988. Kinetics of fat penetration in food. **Frying of food**: 82-90.

67. Stevenson, S.G., M. Vaisey-Genser, and N.A.M. Eskin, 1984. Quality control in the use of deep frying oils. **Journal of the American Oil Chemists Society. 61**, (6): 1102-1108.

68. Choe, E. and D.B. Min, 2007. Chemistry of deep-fat frying oils. **Journal of food science. 72**, (5): R77-R86.

69. Kayahan, M., 2002. Modifiye yağlar ve üretim teknolojileri. Odtü Geliştirme Vakfı Yayıncılık.

70. Saguy, I.S., 1995. Oil uptake during deep-fat frying: factors and mechanism. **Food Technol. 49**: 142-145.

71. Saguy, I.S., G. Ufheil, and S. Livings, 1998. Oil uptake in deep-fat frying. **Oleagineux Corps Gras Lipides (France)**.

72. Warner, K., E.N. Frankel, and T.L. Mounts, 1989. Flavor and oxidative stability of soybean, sunflower and low erucic acid rapeseed oils. **Journal of the American Oil Chemists' Society. 66**, (4): 558-564.

73. Løvaas, E., 1992. A sensitive spectrophotometric method for lipid hydroperoxide determination. **Journal of the American Oil Chemists Society. 69**, (8): 777-783.

74. Skiera, C., P. Steliopoulos, T. Kuballa, B. Diehl, and U. Holzgrabe, 2014. Determination of free fatty acids in pharmaceutical lipids by 1H NMR and comparison with the classical acid value. **Journal of Pharmaceutical and Biomedical Analysis. 93**: 43-50.

75. Pokorny, J., 2005. Volumetric analysis of oxidized lipids. **Analysis of lipid oxidation. Champaign: AOCS Publishing**.

76. Pink, D.A., B. Quinn, F. Peyronel, and A.G. Marangoni, 2013. Edible oil structures at low and intermediate concentrations. I. Modeling, computer simulation, and predictions for X ray scattering. **Journal of Applied Physics. 114**, (23): 234901.

77. Velasco, J., S. Marmesat, and M.C. Dobarganes, 2009. Chemistry of frying. **Advances in deep-fat frying of foods**: 33-57.

78. Alvarez-Pérez, O.B., J. Montañez, C.N. Aguilar, and R. Rojas, 2021. Pectin–Candelilla wax: An alternative mixture for edible films. **Journal of Microbiology, Biotechnology and Food Sciences. 2021**: 167-171.

79. Autio, K. and T. Laurikainen, 1997. Relationships between flour/dough microstructure and dough handling and baking properties. **Trends in Food Science & Technology. 6**, (8): 181-185.

80. MacDougall, C.J., M.S. Razul, E. Papp-Szabo, F. Peyronel, C.B. Hanna, A.G. Marangoni, and D.A. Pink, 2012. Nanoscale characteristics of triacylglycerol oils: phase separation and binding energies of two-component oils to crystalline nanoplatelets. **Faraday Discussions. 158**, (1): 425-433.

81. Yildiz, G., R.L. Wehling, and S.L. Cuppett, 2003. Comparison of four analytical methods for the determination of peroxide value in oxidized soybean oils. **Journal of the American Oil Chemists' Society. 80**, (2): 103-107.

82. Masson, L., 1981. Relative nutritional value of various dietary fats and oils. **Journal of the American Oil Chemists' Society. 58**, (3): 249-255.

83. Hamm, W., R.J. Hamilton, and G. Calliauw, 2013. Edible oil processing. Wiley Online Library.

84. Kloek, W., P. Walstra, and T. van Vliet, 2000. Crystallization kinetics of fully hydrogenated palm oil in sunflower oil mixtures. **Journal of the American Oil Chemists' Society. 77**, (4): 389-398.

85. Nettleton, J.A., I.A. Brouwer, J.M. Geleijnse, and G. Hornstra, 2017. Saturated fat consumption and risk of coronary heart disease and ischemic stroke: a science update. **Annals of Nutrition and Metabolism. 70**, (1): 26-33.

86. Mensink, R.P., P.L. Zock, A.D.M. Kester, and M.B. Katan, 2003. Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: a meta-analysis of 60 controlled trials. **The American journal of clinical nutrition. 77**, (5): 1146-1155.

87. Ghebreyesus, T.A. and T.R. Frieden, 2018. REPLACE: a roadmap to make the world trans fat free by 2023. **The Lancet. 391**, (10134): 1978-1980.

88. Papanikolaou, Y., J. Brooks, C. Reider, and V.L. Fulgoni, 2014. US adults are not meeting recommended levels for fish and omega-3 fatty acid intake: results of an analysis using observational data from NHANES 2003–2008. **Nutrition journal. 13**, (1): 1-6.

89. Zhang, Z., V.L. Fulgoni, P.M. Kris-Etherton, and S.H. Mitmesser, 2018. Dietary intakes of EPA and DHA omega-3 fatty acids among US childbearing-age and pregnant women: an analysis of NHANES 2001–2014. **Nutrients. 10**, (4): 416.

90. Mozaffarian, D. and R. Clarke, 2009. Quantitative effects on cardiovascular risk factors and coronary heart disease risk of replacing partially hydrogenated vegetable oils with other fats and oils. **European journal of clinical nutrition. 63**, (2): S22-S33.

91. De Souza, R.J., A. Mente, A. Maroleanu, A.I. Cozma, V. Ha, T. Kishibe, E. Uleryk, P. Budylowski, H. Schünemann, and J. Beyene, 2015. Intake of saturated and trans unsaturated fatty acids and risk of all cause mortality, cardiovascular disease, and type 2 diabetes: systematic review and meta-analysis of observational studies. **Bmj. 351**.

92. Micha, R., S. Khatibzadeh, P. Shi, S. Fahimi, S. Lim, K.G. Andrews, R.E. Engell, J. Powles, M. Ezzati, and D. Mozaffarian, 2014. Global, regional, and national consumption levels of dietary fats and oils in 1990 and 2010: a systematic analysis including 266 country-specific nutrition surveys. **Bmj. 348**.

93. Vaclavik, V.A., E.W. Christian, and T. Campbell, 2008. Essentials of food science. Springer.

94. Sun, Q., F.B. Hu, and P.W. Siri-Tarino, 2010. Saturated fat, carbohydrate, and cardiovascular disease.

95. Estadella, D., C. da Penha Oller do Nascimento, L.M. Oyama, E.B. Ribeiro, A.R. Damaso, and A. de Piano, 2013. Lipotoxicity: effects of dietary saturated and transfatty acids. **Mediators of inflammation. 2013**.

96. Cheng, W.w., G.q. Liu, L.q. Wang, and Z.s. Liu, 2017. Glycidyl fatty acid esters in refined edible oils: A review on formation, occurrence, analysis, and elimination methods. **Comprehensive Reviews in Food Science and Food Safety. 16**, (2): 263-281.

97. Li, L., G. Liu, O. Bogojevic, J.N. Pedersen, and Z. Guo, 2022. Edible oleogels as solid fat alternatives: Composition and oleogelation mechanism implications. **Comprehensive Reviews in Food Science and Food Safety**.

98. Marangoni, A.G., 2002. The nature of fractality in fat crystal networks. **Trends in Food Science & Technology. 13**, (2): 37-47.

99. McGauley, S.E. and A.G. Marangoni, 2002. Static crystallization behavior of cocoa butter and its relationship to network microstructure. Chapter.

100. Blake, A., 2015. The Microstructure and Physical Properties of Plant-Based Waxes and their Relationship to the Oil Binding Capacity of Wax Oleogels.

101. Blake, A.I., J.F. Toro-Vazquez, and H.-S. Hwang, *Wax oleogels*, in *Edible oleogels*. 2018, Elsevier. pp. 133-171.

102. Rocha, J.C.B., J.D. Lopes, M.C.N. Mascarenhas, D.B. Arellano, L.M.R. Guerreiro, and R.L. da Cunha, 2013. Thermal and rheological properties of organogels formed by sugarcane or candelilla wax in soybean oil. **Food Research International. 50**, (1): 318-323.

103. Hwang, H.S., S. Kim, M. Singh, J.K. Winkler-Moser, and S.X. Liu, 2012. Organogel formation of soybean oil with waxes. **Journal of the American Oil Chemists' Society. 89**, (4): 639-647.

104. Toro-Vazquez, J.F., J.A. Morales-Rueda, E. Dibildox-Alvarado, M. Charó-Alonso, M. Alonzo-Macias, and M.M. González-Chávez, 2007. Thermal and textural properties of organogels developed by candelilla wax in safflower oil. **Journal of the American Oil Chemists' Society. 84**, (11): 989-1000.

105. Dassanayake, L.S.K., D.R. Kodali, S. Ueno, and K. Sato, 2009. Physical properties of rice bran wax in bulk and organogels. **Journal of the American Oil Chemists' Society. 86**, (12): 1163-1173.

106. Hwang, H.-S., 2020. A critical review on structures, health effects, oxidative stability, and sensory properties of oleogels. **Biocatalysis and Agricultural Biotechnology. 26**: 101657.

107. Blake, A.I., E.D. Co, and A.G. Marangoni, 2014. Structure and physical properties of plant wax crystal networks and their relationship to oil binding capacity. **Journal of the American Oil Chemists' Society. 91**, (6): 885-903.

108. Norris, S., 2005. Trans fats: the health burden. Parliamentary Information and Research Service.

109. Singh, A., F.I. Auzanneau, and M.A. Rogers, 2017. Advances in edible oleogel technologies–A decade in review. **Food Research International. 97**: 307-317.

110. Moghtadaei, M., N. Soltanizadeh, and S.A.H. Goli, 2018. Production of sesame oil oleogels based on beeswax and application as partial substitutes of animal fat in beef burger. **Food Research International. 108**: 368-377.

111. Gao, Y., M. Li, L. Zhang, Z. Wang, Q. Yu, and L. Han, 2021. Preparation of rapeseed oil oleogels based on beeswax and its application in beef heart patties to replace animal fat. **LWT. 149**: 111986.

112. Moon, K., K.-O. Choi, S. Jeong, Y.-W. Kim, and S. Lee, 2021. Solid Fat Replacement with Canola Oil-Carnauba Wax Oleogels for Dairy-Free Imitation Cheese Low in Saturated Fat. **Foods. 10**, (6): 1351.

113. Li, L. and G. Liu, 2019. Corn oil-based oleogels with different gelation mechanisms as novel cocoa butter alternatives in dark chocolate. **Journal of food engineering. 263**: 114-122.

114. Jung, D., I. Oh, J. Lee, and S. Lee, 2020. Utilization of butter and oleogel blends in sweet pan bread for saturated fat reduction: Dough rheology and baking performance. **Lwt. 125**: 109194.

115. Da Pieve, S., S. Calligaris, E. Co, M.C. Nicoli, and A.G. Marangoni, 2010. Shear nanostructuring of monoglyceride organogels. **Food Biophysics. 5**, (3): 211-217.

116. Aggelousis, G. and S. Lalas, 1997. Quality changes of selected vegetable oils during frying of doughnuts. **Rivista Italiana delle Sostanze Grasse. 74**: 559-566.

117. Ayo-Omogie, H.N. and O.Y. Odekunle, 2017. Substituting wheat flour with banana flour: Effects on the quality attributes of doughnut and cookies. **Applied Tropical Agriculture. 22**, (2): 134-137.

118. De Castro, M.D.L. and F. Priego-Capote, 2010. Soxhlet extraction: Past and present panacea. **Journal of chromatography A. 1217**, (16): 2383-2389.

119. Methods, I.S., 1987. Determination of the peroxide value, method 2.501. **IUPAC Standard Methods for the Analysis of Oils, Fats and Derivatives**: 199.

120. Topkafa, M., 2020. Application of the central composite design and response surface methodology for investigation of induction time, conjugated diene, conjugated triene and trans fatty acid content of corn oil enriched with carotenoids. **Journal of the Iranian Chemical Society. 17**, (12): 3383-3392.

121. Aliyu, S. and B. Mufidat, 2020. Effect of Temperature Variation on Viscosity of Selected Cooking Oils.

122. Aydeniz-Guneser, B. and E. Yılmaz, 2022. Sunflower Oil-Polyglycerol Stearate Oleogels: Alternative Deep-fat Frying Media for Onion Rings. **Journal of Oleo Science. 71**, (5): 651-662.

123. Krokida, M.K., V. Oreopoulou, Z.B. Maroulis, and D. Marinos-Kouris, 2001. Colour changes during deep fat frying. **Journal of Food Engineering. 48**, (3): 219-225.

124. Alimentarius, C., 1999. Codex standard for named vegetable oils. **Codex stan. 210**: 1-13.

125. Hosseini, H., M. Ghorbani, N. Meshginfar, and A.S. Mahoonak, 2016. A review on frying: procedure, fat, deterioration progress and health hazards. **Journal of the American Oil Chemists' Society. 93**, (4): 445-466.

126. Gómez-Alonso, S., V. Mancebo-Campos, M. Desamparados Salvador, and G. Fregapane, 2004. Oxidation kinetics in olive oil triacylglycerols under accelerated shelf-life testing (25–75° C). **European Journal of Lipid Science and Technology. 106**, (6): 369-375.

127. Öğütcü, M., E. Yılmaz, and O. Güneşer, 2015. Influence of storage on physicochemical and volatile features of enriched and aromatized wax organogels. **Journal of the American Oil Chemists' Society. 92**, (10): 1429-1443.

128. Uslu, E.K. and E. Yılmaz, 2021. Preparation and characterization of glycerol monostearate and polyglycerol stearate oleogels with selected amphiphiles. **Food Structure. 28**: 100192.

129. Mattice, K.D. and A.G. Marangoni, *New insights into wax crystal networks in oleogels*, in *Edible Oil Structuring*. 2017. pp. 69-94.

130. Alizadeh, L., K. Abdolmaleki, K. Nayebzadeh, and S.M. Hosseini, 2020. Oleogel fabrication based on sodium caseinate, hydroxypropyl methylcellulose, and beeswax: effect of concentration, oleogelation method, and their optimization. **Journal of the American Oil Chemists' Society. 97**, (5): 485-496.

131. Yılmaz, E., M. Öğütcü, and Y.K. Yüceer, 2015. Physical properties, volatiles compositions and sensory descriptions of the aromatized hazelnut oil-wax organogels. **Journal of food science. 80**, (9): S2035-S2044.

132. Dana, D., I.S.J.A.i.c. Saguy, and i. science, 2006. Mechanism of oil uptake during deep-fat frying and the surfactant effect-theory and myth.Advances in Colloid and Interface Science **128**: 267-272.

133. Yang, D., G. Wu, Y. Lu, P. Li, X. Qi, H. Zhang, X. Wang, and Q. Jin, 2021. Comparative analysis of the effects of novel electric field frying and conventional frying on the quality of frying oil and oil absorption of fried shrimps. **Food Control. 128**: 108195.

134. Saguy, I.S. and D.J.J.o.f.e. Dana, 2003. Integrated approach to deep fat frying: engineering, nutrition, health and consumer aspects. **56**, (2-3): 143-152.

135. Matthäus, B., M. Schubert, N. Erlenbusch, I. Smit, L. Weber, and S. Nikolay, 2020. Oleogels as alternatives for frying fats and oils. **Inform (Silver Spring, Md.). 31**, (7): 22-26.

136. Abdellah, A.M. and K.E.A. Ishag, 2012. Effect of storage packaging on sunflower oil oxidative stability. **American Journal of Food Technology. 7**, (11): 700-707.

137. Aydeniz, B. and E. Yılmaz, 2013. Phytostanol supplementation through frying dough in enriched canola oil. **Journal of the American Oil Chemists' Society. 90**, (5): 687-694.

138. Choe, E. and D.B. Min, 2005. Chemistry and reactions of reactive oxygen species in foods. **Journal of Food Science. 70**, (9): R142-R159.

139. De Abreu, D.A.P., P.P. Losada, J. Maroto, and J.M. Cruz, 2010. Evaluation of the effectiveness of a new active packaging film containing natural antioxidants (from barley husks) that retard lipid damage in frozen Atlantic salmon (Salmo salar L.). **Food Research International. 43**, (5): 1277-1282.

140. Gertz, C., S. Klostermann, and S.P. Kochhar, 2000. Testing and comparing oxidative stability of vegetable oils and fats at frying temperature. **European Journal of Lipid Science and Technology. 102**, (8-9): 543-551.

141. Bascuas, S., A. Salvador, I. Hernando, and A. Quiles, 2020. Designing Hydrocolloid-Based Oleogels with High Physical, Chemical, and Structural Stability. **Frontiers in Sustainable Food Systems. 4**: 111.

142. Albi, T., A. Lanzón, A. Guinda, M.C. Pérez-Camino, and M. León, 1997. Microwave and conventional heating effects on some physical and chemical parameters of edible fats. **Journal of Agricultural and Food Chemistry. 45**, (8): 3000-3003.

143. Gharby, S., H. Harhar, B. Matthäus, Z. Bouzoubaa, and Z. Charrouf, 2016. The chemical parameters and oxidative resistance to heat treatment of refined and extra virgin Moroccan Picholine olive oil. **Journal of Taibah University for Science. 10**, (1): 100-106.

144. Aşkın, B. and Y. Kaya, 2020. Effect of deep frying process on the quality of the refined oleic/linoleic sunflower seed oil and olive oil. **Journal of Food Science and Technology. 57**, (12): 4716-4725.

145. Ruguo, Z., Z. Hua, Z. Hong, F. Ying, L. Kun, and Z. Wenwen, 2011. Thermal analysis of four insect waxes based on differential scanning calorimetry (DSC). **Procedia Engineering. 18**: 101-106.

146. Fennema, O., I.G. Donhowe, and J.J. Kester, *Lipid type and location of the relative humidity gradient influence on the barrier properties of lipids to water vapor*. In *Water in Foods*. 1994, Elsevier. pp. 225-239.

147. Abdulkarim, S.M., K. Long, O.M. Lai, S.K.S. Muhammad, and H.M. Ghazali, 2007. Frying quality and stability of high-oleic Moringa oleifera seed oil in comparison with other vegetable oils. **Food chemistry. 105**, (4): 1382-1389.

148. Alireza, S., C.P. Tan, M. Hamed, and Y.B. Che Man, 2010. Effect of frying process on fatty acid composition and iodine value of selected vegetable oils and their blends. **International Food Research Journal. 17**, (2): 295-302.

149. Asnaashari, M., S.M. Bagher Hashemi, H.M. Mehr, and S.H. Asadi Yousefabad, 2015. Kolkhoung (Pistacia khinjuk) Hull oil and Kernel oil as antioxidative vegetable oils with high oxidative stability and nutritional value. **Food Technology and Biotechnology. 53**, (1): 81-86.

150. Aladedunye, F.A. and R. Przybylski, 2009. Degradation and nutritional quality changes of oil during frying. **Journal of the American Oil Chemists' Society. 86**, (2): 149-156.

151. Souza, A., J.C. Santos, M.M. Conceição, M.C. Silva, and S. Prasad, 2004. A thermoanalytic and kinetic study of sunflower oil. **Brazilian Journal of Chemical Engineering. 21**: 265-273.

CV

PERSONAL INFORMATION

Name and surname: Kurshid ZUBAIREE
Nationality: PAKISTAN

EDUCATION

CLASS	Institution	Date of graduation
Bachelor	UOS, PAKISTAN	2017
High School	H.SS.G PAKISTAN	2013

FOREIGN LANGUAGE

English, Turkish, Urdu, Punjabi

PUBLICATIONS

1. Ülger, İ., Kurshid Zubaıree., Kaliber,
2. Ulger, Prof. Dr. Hasan Yalçın, .,. Soybeanwax-Sunflower Oıl Oleogel As A Healthy Alternatıve Fryıng Medıum For Doughnuts Ases Internatıonal Scıentıfıc Research Conference, Mersin, Türkiye, June 2**2-24, 2022.**