OCTOBER 2021 M.Sc. in Food Engineering MELIS SEVER


REPUBLIC OF TURKEY

GAZİANTEP UNIVERSITY

GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES


# DRYING OF PRETREATED APRICOT BY COMBINED SOLAR AND RADIO FREQUENCY SYSTEM

M.Sc. THESIS

IN

FOOD ENGINEERING


BY

MELIS SEVER


OCTOBER 2021

# DRYING OF PRETREATED APRICOT BY COMBINED SOLAR AND RADIO FREQUENCY SYSTEM

**M.Sc. Thesis**

**in**

**Food Engineering**

**Gaziantep University**

**Supervisor**

**Assoc. Prof. Dr. Derya KOÇAK YANIK**

**by**

**Name SURNAME**

**Month Year**

**I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.**

**Melis SEVER**

# ABSTRACT

## DRYING OF PRETREATED APRICOT BY COMBINED SOLAR AND RADIO FREQUENCY SYSTEM

**SEVER, Melis**
**M.Sc. in Food Engineering**
**Supervisor: Assoc. Prof. Dr. Derya KOÇAK YANIK**
**October 2021**
**58 pages**

In this study, the drying of pre-treated apricots was investigated in a new combined drying system (a pilot-scale combined solar assisted air and hot air-assisted radio frequency drying system). Sulfuring and/or immersion in a phenolic extract were applied as pretreatments. In sulfuring process elemental sulfur with different concentrations (0.5, 1.0, 1.5, 2.0, 2.5 kg of elemental sulfur/ton of apricot) was used. In phenolic extract treatment different concentration of phenolic extract (0.25, 0.75, 1.25, 1.75, 2.25 % extract) obtained from pistachio hull was used. The quality of apricots dried by developed system have been compared with the apricots dried with traditional drying method in terms of moisture content, browning index, color, texture, phenolic content, antioxidant activity and residual sulfur content. According to the results, the best quality dried apricots were obtained after sulfuring (2 kg of elemental sulfur/ton of apricot). The color (Lab), moisture, hardness, residual sulfur content, browning measurement are characteristics of this final product were 45.2±1.9, 17.8±1.4, 36.2±2.7, 20.54±0.97, 1355.87±64.73, 1598±30.8, 0.22±0.02 respectively. Financial support for this study is provided by TUBITAK Project No: 118O026.



**Key Words:** Dried Apricot, Sulfuring Process, Air Assisted Solar Drying, RF Drying.

# ÖZET

**ÖN İŞLEM GÖRMÜŞ KAYISININ RADYO FREKANS İLE KOMBİNE EDİLMİŞ GÜNEŞ ENERJİ DESTEKLİ HAVA İLE KURUTULMASI**

**SEVER, Melis**
**Yüksek Lisans, Gıda Mühendisliği**
**Danışman: Doç. Dr. Derya KOÇAK YANIK**
**Ekim 2021**
**58 sayfa**

Bu çalışmada, ön işlem görmüş kayısıların kurutulması, pilot ölçekli yeni bir bütünleşik kurutma sistemi (güneş enerjisi destekli hava ve sıcak hava destekli radio frekans kurutma sistemi) kullanılarak araştırılmıştır. Ön işlem olarak fenolik ekstraktta daldırma ve/veya kükürtleme uygulanmıştır. Sülfür dioksit ile muamele işleminde farklı konsantrasyonlarda (0,5, 1,0, 1,5, 2,0, 2,5 kg elementel sülfür/ton kayısı) elementel sülfür kullanılmıştır. Fenolik ekstrakt işleminde ise antep fıstığı yumuşak kabuğundan elde edilen fenolik ekstrakt farklı konsantrasyonlarda (% 0,25, 0,75, 1,25, 1,75,% 2,25 ekstrakt) kullanılmıştır. Kurutma koşulları, güneş destekli hava ile kurutma sıcaklığı, güneş destekli hava ile kurutma süresi, hava akış hızı, RF elektrotlarının mesafesi ve RF kurutma süresi için sırasıyla 63,5 ° C, 895 dk, 5,5-6 m / s, 77 mm ve 385 dk olarak uygulanmıştır. Kuru kayısının kalitesi; renk (Lab), nem, sertlik, kalıntı kükürt içeriği, esmerleşme ölçümüne bakılarak belirlenmiştir. Yapılan analizler doğrultusunda en iyi ürün 2 kg elementel sülfür/ton kayısı seçilmiştir. Analiz sonuçları sırasıyla; 45,2±1,9, 17,8±1,4, 36,2±2,7, 20,54±0,97, 1355,87±64,73, 1598±30,8, 0,22±0,02 olarak hesaplanmıştır. Bu çalışma için mali destek, TÜBİTAK Proje No: 118O026 tarafından sağlanmaktadır.



**Anahtar Kelimeler:** Kuru Kayısı, Kükürtleme İşlemi, Hava Destekli Güneş Enerjisi İle Kurutma, RF Kurutma

''*Dedicated to my family*''

## ACKNOWLEDGEMENTS

This thesis could not be studied without people and institutions that provide both financial and moral support. The basic elements of this study were constituted in the light of professional guidance and psychological support.

First of all, I would like to extend my deepest gratitude to my supervisor Assoc. Prof. Dr. Derya KOÇAK YANIK for her valuable advises, guidance, patience that cannot be underestimated, experience, practical suggestions, unpredictable sympathy while I was preparing this thesis. I really appreciated to make herself available whenever I needed. Thanks for her encouragements and helps with my English.

I would also like to extend my sincere thanks to Prof. Dr. Fahrettin GÖĞÜŞ, Prof. Dr. Ali Coşkun DALGIÇ, Res. Assist. Hatice Neval ÖZBEK and Aysel ELİK for helpful advise and experience. Thanks for answering my every logical and illogical questions without any hestitation and being there for me.

I would like to express my deepest appreciation to my family that encourge me all the time when I needed. Many thanks to all of my beloved family for prayers, advice, never ending love, support and trust which I sometimes doubted myself during my studies. Special thanks to my brother, my mother and father, Melih SEVER, Ayşe Oya SEVER and Mehmet İrfan SEVER for their presence, individual financial and moral supports.

Thanks should also go to my department, Gaziantep University, Food Engineering department for giving all the chances I needed to have and all the devices. Thanks to letting me learned every significant knowledgements.

Financial support for this thesis is provided by the Scientific and Technological Research Council of Turkey (TUBITAK) 1003 Project No: 118O026.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

**Page**

# LIST OF SYMBOLS

| | |
|---|---|
| **°C** | Celcius |
| **Min** | Minute |
| **S** | Second |
| **Mm** | Milimeter |
| **Ml** | Mililiter |
| **A** | Absorbance |
| **G** | Gram |
| **ΔE** | Color change |
| **N** | Newton |
| **B** | Beta |
| **MHz** | MegaHertz |
| **Kg** | Kilogram |
| **P** | Probability |
| **pH** | Power of Hydrogen |
| **Ppm** | Parts per million |
| **Mg** | Miligram |
| **µg** | Microgram |
| **µmol** | Micromole |
| **µM** | Micromolarity |
| **µL** | Microliter |
| **H** | Hour |
| L* | Lightness |
| **a*** | Redness-Greeness |
| **b*** | Yellowness-Blueness |
| **C*** | Chroma value |
| **h °** | Hue angle |

# LIST OFABBREVIATIONS

| | |
|---|---|
| **SAHA** | Solar Assisted Hot Air Drying |
| **HARF** | Hot Air Assisted Radio Frequency Drying |
| **EU** | European |
| **SD** | Sun Dried |
| **Ex** | Extracted |
| **RF** | Radio Frequency |
| **MAP** | Modified Atmospheric Pressure |
| **Ta** | Titratable Acidity |
| **RDA** | Recommended Dietary Allowance |
| **LPG** | Liquefied Petroleum Gas |
| **BC** | Before Century |
| **FAOSTAT** | Food and Agriculture Organization |
| **GAE** | Gallic Acid Equivalent |
| **RH** | Relative Humidity |
| **BI** | Browning Index |
| **TPC** | Total Phenolic Content |
| **IC** | Inhibitory Concentration |
| **SO2** | Sulfur dioxide |
| **O2** | Oxygen |
| **AOAC** | Association of Official Analytical Chemists |
| **UV-Vis** | Ultraviolet and Visible |

| | |
|---|---|
| **PLC** | Programmable Logic Controller |
| **ANOVA** | Analysis of Variance |
| **DPPH** | 2,2-diphenyl-1-picrylhydrazyl |
| **TPTZ** | 2,4,6-tripyridyl-s-triazine |
| **FRAP** | The Ferric Reducing Ability of Plasma |
| **PVC** | Polyvinyl Chloride |
| **PE** | Polyethylene |
| **ISO** | International Organization for Standardization |
| **CIE** | International Color Determination Commission |

# CHAPTER I

# INTRODUCTION

The fresh apricot (Prunus armeniaca L.) is a cultivated type of Zerdali (wild apricot) which is produced by inoculation (Özbek et al., 1978) and also the apricot is a significant crop due to its production rate which is reaching around 2.2 million tons. Apricot grows at places where have high humidity and severe winter climate conditions. World production is between approximately 150-200 thousand tons of dried apricots. Turkey is counter balance the world of dried apricot production about approximately 75% (Inserra et al., 2017). In our country most of the dried apricot production (> 80%) is made and produced in Malatya. Turkey is also one of the dried apricot exporting countries in the world and most of the dried apricots are exported (Erdogan et al., 2003). Therefore, dry apricot export is important for our country's foreign currency input. Malatya is the province which is a supplier of both fresh and dried apricot. Kan et al., (2014), proved that Turkey is the second homeland of apricot due to its production rate. In Turkey, there are a lot of different varieties of apricot. Hacıhaliloğlu variety is the most convenient one for drying. Fruits of Hacıhaliloğlu variety are medium-sized, oval-shaped, and yellow in color with a thin peel. Moreover, its fruit flesh is hard, less juicy, very sweet and flavored (Asma, 2011).

Commercially two types of dried apricot; sun dried and sulfured apricot are present (Sobutay et al., 2003). In both sun-dried and sulfured, fresh apricots (half or whole) are laid down directly on soil or on a cover to dry under the sunlight. There are some negative results of this traditional drying method such as too dark and brownish color, long drying time (7-8 days), particularly hygiene problems due to being open to uncontrollable atmospheric conditions. Moreover, the presence of dust, stones, dirt, insects and etc., is a common contamination problem for this traditional drying method and directly affects the marketing of dried apricots (T.R. Ministry of Food, Agriculture and Livestock, 2014; Sobutay, 2003). However, the traditional drying method is usually preferred by farmers because of not require any capital, being a simple drying model, and no energy consumption (Gezer et al., 2003).

Sulfuring is a worldwide accepted practice as a pre-treatment that provides color protection and antimicrobial effect during the drying, storage and distribution period of apricots as well as other fruits (Özkan and Cemeroğlu, 2002; Coşkun et al., 2013). Sulfur application delays β-carotene destruction (Türkyılmaz et al., 2013) which provides inhibition of enzymatic and non-enzymatic browning reactions and finally results in bright natural color dried products.

However, health concerns due to residual sulfur have brought limitations in this regard (Igual et al., 2012). Dried apricot residual sulfur limits applied in some countries are as follows; USA and Australia 3000 ppm, Canada 2500 ppm, EU countries 2000 ppm (Ünal et al., 2010). In our country, according to the "Turkish Food Codex-Communiqué on food additives other than colorants and sweeteners" published in the Official Gazette dated 16/11/1997 and reiterated number 23172, the maximum sulfur amount in dried apricots was limited to 2000 ppm. If the amount of $SO_2$ is high, taste and smell problems are occurred (Taylor et al., 1986; Freedman, 1980; Miranda et al., 2009; Sobutay, 2003). On the other hand, if it is low there might be some troubles as darkening on the surface of dried product and microbiological risk may appear during storage and distribution. Hence, the residual sulfur should be kept at an optimal level in dried apricots. The amount of residual sulfur in dried apricots is not related only to the initial $SO_2$ concentration applied in sulfuring process but also is related to how much $SO_2$ is swept away from the product during the drying stage (Stafford and Bolin, 1972). Therefore, all these parameters must be taken into account in achieving the optimum residual sulfur level.

Second critical parameter for dried apricot is moisture content. According to the Turkish Food Codex, the maximum moisture content of dried apricots as 25%. First of all, high moisture content causes some microbial risks during storage. Also some quality parameters depend on its moisture content. For instance, texture properties and the hardness of dried apricot depends on its water content. If it is too dry, texture is firm and not chewable. Hence the moisture content should be at an optimum level as it was in sulfur content. Finally, 20-25% moisture content is an acceptable level for both minimized microbial risk and desirable texture properties.

Even if they are not a common practices, pre-treatments other than sulfuring have also been studied in scientific respect. In the study of Coşkun et al., 2013, food products have been treated with sulfur with different types of methods. Sulfuring by burning elemental sulfites that the elemental sulfur is burned and the gate of sulfur house is closed. Other method is sulfuring with $SO_2$ gas from liquified $SO_2$ tank which is enforced like that fresh fruits are placed in plastic crates in single layer and the crates were stacked on top of each other in the sulfur house. Then, the apricots are sulfured by Sulfur gate. Last exposing method is that sulfuring by dipping into sodium metabisulfite ($Na_2S_2O_5$) solution. For this method, the apricots are dipped to the $Na_2S_2O_5$ solution for a certain time.

Packaging and storage are other important aspects for dried fruits. Even if the initially packed sample is high in quality, packaging defects and improper storage conditions (high temperature and humidity) may result in inconsumable final product. Being a regional product and long-term marketing of dried apricot requires bulk storage in the regions where production is high. In the commonly used bulk storage method, dried apricots are stored in 70-80 cm piles for a long time and mixing is done occasionally during this period (Fatih Şen Karaçalı and Eroğul, 2015). In the case of retail sale different options such as 12.5 kg paper box, 250/500/750 gr in Pvc, foam or wooden plates and PE bags are available. Generally, dried apricots are stored uncontrollable conditions. Şen et al., (2015) studied on packaging of dried apricot in different packing materials (wooden crates, jute sacks, PE bags) and reported that the PE bags are better particallarly with its high moisture proof.

Pistachio (*Pistacia vera* L.) hull is the largest waste of pistachio industry which is accumulated every year at harvest time and can lead to environmental pollution. Pistachio hull has caught up the interest of researchers due to its natural phenolics and antioxidant compounds. Besides, it has antimutagenicity and microbial activity (Özbek et al., 2020). Therefore, pistachio hull phenolic extract may have the potential to be applied to apricot as a pre-treatment prior to drying to prevent some deteriorative reaction during the drying and storage period of dried apricot.

In conclusion, it is inevitable to design controlled, hygienic, fast and low-cost drying systems and investigate their effects to obtain high quality apricots. Additionally, pre-treatments that are alternative to sulfuring should be evaluated to overcome the some adverse effect of sulfur usage. In this context, the aim of this study is to investigate the effect of a new combined drying system (a pilot-scale combined solar assisted air and hot air-assisted radio frequency drying system) on drying of sulfured and phenolic-extract treated apricots.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Fresh Fruits in Turkey

Turkey has good fertilized land, water resources, and different terms of microclimate conditions for the possibility of raising many plant species (flora) (Gürbüz, 2010). Various fruits and vegetables can grow according to climatic conditions and land quality in Turkey i.e. pear, apple, plum, cherry, cranberry, hazelnut, peanut, pistachio, almond, walnut, chestnut, olive, fig, pomegranate and grape. Turkey exports fruits and vegetables all around the world. The requirement of fig, apricot, cherry, grape, lemon, and apple around the world are supplied with Turkey with respect to 26%, 14%, 17%, 6%, 6%, and 4%, respectively (Gürbüz, 2010).

## 2.2 Fresh Apricot (Prunus Armenica L.)

### 2.2.1 Origin and History

Apricot (*Prunus Armeniaca* L.) (Figure 2.1) is classified under the Prunus species of Prunoide sub-family of Rosaceae family of the Rosales group (Dağ et al., 2016). Generally, a standard shape of apricot is; drupe, similar to plum, with a thin outer skin surrounding the yellow flesh. According to the type of apricots, apricot fruit can be in several shades of color ranging from yellow to orange with a reddish random overlay on its surface. According to researches, the homeland of apricots is China, where it was brought to Anatolia by Iran and Transcaucasia during Alexander the Great's Asian expeditions (330-323 BC) (Gülcan et al., 2006; Aubert et al., 2010; Asma, 2011). Because of this fact, Anatolia was assumed as the second homeland of apricot. After the Roman and Persian wars in First Century BC, apricot was expanded to worldwide. Firstly Italy, then Greece and then finally it was reached to Spain and England in Thirteenth Century. In Seventeenth Century apricot was succeed to reach France and America (Faust et al., 1998; Buttner, 2001). Since ancient time, folk medicine used apricots as a remedy for various diseases, such as infertility, eye inflammation and spasm.

**Figure 2.1** Fresh apricot picture

### 2.2.2 Apricot Growth and Harvesting

Apricot trees grow in loamy, sandy-loamy and loamy-calcareous soils and its' climate conditions are semi hot and dry fields. However, some varieties and types of species can also grow in subtropic climate conditions (Batmaz, 2005) and there are many varieties of apricots grown despite of Siberia's cold, North Africa's subtropic area, Central Asia's desert area, Japan and East China's moist area (Asma, 2000).

Climate conditions effect the growth and maturing of the fruits directly. Also the region which apricot trees grow is a substantial effect on fruits quality. Additionally, appearance of fruit is very important for consumers. Apricot is a delicate fruit and can be easily damaged during harvesting. That's the reason why harvesting should be done carefully. Apricot harvest can be done by dropping the fruit from the trees by shaking the branches. This method may cause some damage and bruise on the fruit surface. Moreover harvesting without any protective equipment under the tree causes contamination of the fruits falling on the soil. To eliminate this problem, the best practice is to collect the fruits by cleaned hands into a sheet.

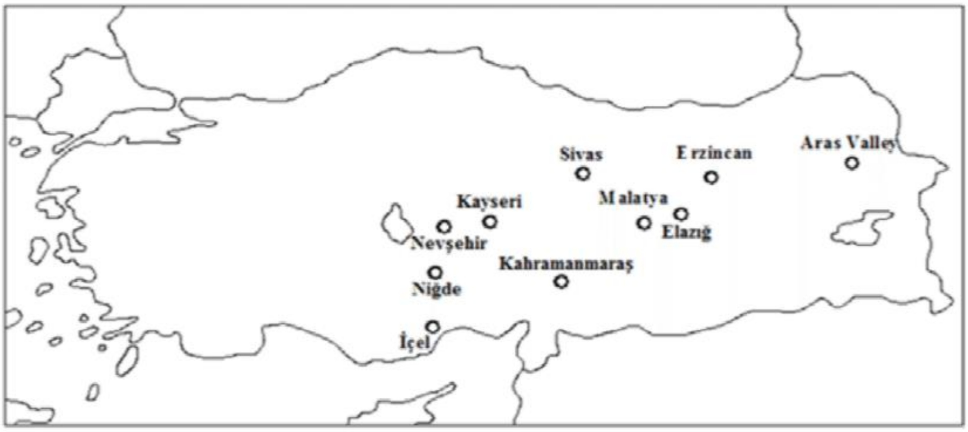


**Figure 2.2** Production of apricot in Turkey

According to FAOSTAT, Turkey is the biggest supplier of apricots mainly in the town of Malatya that defines as capital of apricot. Turkey provides only by itself 84% of world production and Malatya does 50% of Turkey production. 250-350 thousand tons of apricot is produced in Turkey. This range changes in every year (Gezer et al. 2002; Batu, 2009; Özşahin and Yılmaz, 2010). Most important apricot producing centers in Turkey are Malatya, Bursa, Ereğli, İzmir, Erzincan, Aras valley (Igdir Kagizman), Icel (Mut), Elazig, Sivas, Kahramanmaras, Kayseri, Nigde, Hatay and Nevsehir provinces in Figure 2.2 (Akın et al., 2008; Batu, 2009). Nevertheless, the main city of apricot is Malatya, Elazığ is the second most supplier of fresh apricot. In addition, Izmir, Ereğli, Bursa and Iğdır are other cities that produce apricot. The best quality apricots with their unique taste and aroma come from Malatya province due to its unique ecological and soil quality (Guleryuz et al., 1997; Altindag et al., 2006). The importer countries of dried apricot from Turkey are the USA, England, Russia, Germany, France, Australia (Asma, 2011).

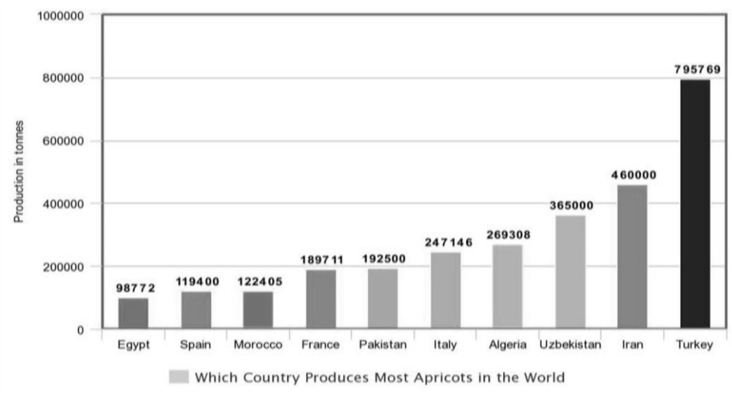


**Figure 2.3** Production of apricot in the world wide.

Figure 2.3 shows the important apricot producing countries around the World. Turkey is the greatest producer of apricot and Iran is the second country. Uzbekistan, Algeria, Italy, Pakistan, France, Morocco, Spain and Egypt are the other countries that follow them.

### 2.2.3 Variety of Fresh Apricot in Turkey

There are many variety of fresh apricot in Turkey namely, Hacıhaliloğlu, Hasanbey, Kabaaşı, Soğancı, Çataloğlu, Çöloğlu, Alyanak, Şalak etc. (Asma, 2000; Hacıseferogulları et al., 2007; Akın et al., 2008). Most of these varieties grow in the Malatya province of Turkey. 70% of the production of fresh apricot are composed of Hacihaliloğlu variety in Turkey (Coşkun et al. 2013; Ünal, 2010). The fruits of this variety are medium in size, 25- 35 g in weight, oval- shaped, symmetrical, and have thin skin. Fruit skin tends to form red cheeks. Its flesh is hard textured, less juicy, and very sweet, flavored. The pH of this fruit is approximately 4.5-4.8 and its total acidity changes between 0.20-0.40 %. The water-soluble dry matter amount (Brix) of this variety at around 24-28%. Table 2.1 summarize the characteristics of apricot cultivars grown in Malatya. Figure 2.4 shows the varieties of fresh apricots grown in Turkey.


**Figure 2.4** Photos of different fresh apricot varieties

**Table 2.1** Characteristics of apricot cultivars grown in Malatya Province

| Province | Cultivars | F.Weight (g) | Fruit Shape | Skin Color | Freedom of Pit | Type of Consumption | Flesh Firmness |
|---|---|---|---|---|---|---|---|
| | Çöloğlu | 30 | Round | Yellow | Free | Table, Dried | Medium |
| | Hacıhaliloğlu | 33 | Round | Orange | Free | Dried | Medium |
| | Şekerpare | 22 | Round | Cream | Free | Table | Soft |
| Malatya | Çataloğlu | 31 | Round | Yellow | Free | Dried | Medium |
| | Soğancı | 46 | Round | Yellow | S.cling | Table, Dried | Medium |
| | Kabaaşı | 38 | Round | Orange | Free | Dried | Firm |
| | Hasanbey | 36 | Cylindiric | Yellow | Free | Table | Medium |

The fruit characteristics requested by Turkish consumers are symmetry, homogeneity in size, flavor, stone freeness and an attractive surface color. In regard to both chemical and physical characteristics, the most commonly cultivated variety in Malatya is Hacıhaliloğlu (85-90%). The second preferable cultivar is Kabaaşı due to its large size and has more resistance to climate conditions and continuously Hasanbey (60-65%) and Sekerpare (Shekarpareh) (25-30%) which means “piece of sugar” in the region of Persia.

These most preferable cultivars can be seen in Table 2.2 (Ayanoglu and Kaska, 1995; Guleryuz et al., 1997, Bircan et al., 2007).

### 2.2.4 Nutritional Content of Fresh Apricots

The quality parameters such as taste, odor, flavor, texture and color might be depend upon the nutritional value of fruit. The main nutrational values can be sugars, acids, some vitamins, proteins, antioxidant substances, carotenoids and polyphenols. Fruits may comprise these components in different ranges and that affects the quality of fruit and edibility. The apricot containing high amount of polyphenols and carotenoid is antioxidant-rich fruit and this shows positive effect on human health about holding down chronic diseases (Karataş and Kamışlı, 2007; Akın et al., 2008; Ali et al., 2011). The chemical composition of apricot is given in Table 2.2.

**Table 2.2** Composition of fresh apricot (Fratianni et al., 2018)

| **Composition Items** | **Value / 100 g fresh apricot** |
|---|---|
| Edible part (%) | 94 |
| Moisture (g) | 86.3 |
| Protein (g) | 0.4 |
| Lipid (g) | 0.1 |
| Total carbohydrate (g) | 6.8 |
| Soluble sugar (g) | 6.8 |
| Fiber (g) | 1.5 |
| Soluble fiber (g) | 0.71 |
| Unsoluble fiber (g) | 0.83 |
| Energy (kcal) | 28 |
| Energy (kJ) | 117 |
| Na (mg) | 1 |
| K (mg) | 320 |
| Fe (mg) | 0.5 |
| P (mg) | 16 |
| Ca (mg) | 16 |
| Thiamine (mg) | 0.03 |
| Riboflavin (mg) | 0.03 |
| Niacin (mg) | 0.5 |
| A Vitamin (retinol equivalent) (mg) | 360 |
| C Vitamin (mg) | 13 |

Water is the main component of all fruits and vegetables. The water content of some fruits and vegetables are as follows: cucumber 96%, tomato 94%, eggplant 92%, carrot

87%, Strawberry 92%, watermelon 92 %, orange 95 %, lemon 90 %, blueberry 85 %, apple 84 %, grapes 81 %, and apricot 80 %. Apricot's water amount depends on both cultivar and its province. According to its cultivar, Hacıhaliloğlu variety has around %80-85 of water and this variety is suitable for drying purposes.

Apricot contains several secondary metabolites (Jimenez et al., 2010), most of them are acting like antioxidants (Wani et al., 2015). These secondary metabolites are polyphenols, carotenoids, fatty acids, volatiles, and polysaccharides. Polyphenols and carotenoids play an important role on fruit quality and they exert various biological activities including antimicrobial activity (Rashidi et al., 2007), antimutagenic activity (Yamamoto, Osaki, Kato, & Miyazaki, 1992), cardioprotective activity (Parlakpinar et al., 2009), hepatoprotective activity (Ozturk et al., 2009), anti-inflammatory, and antinociceptive activity (Chang et al., 2005) that is highly desirable for human health. Fresh apricot is also a good source of fibers and vitamins.

The fruits and vegetables are the source of polyphenol that act as a substrate for enzymatic browning reactions (Türkyılmaz, et al., 2013). Polyphenols have wide range of complex structures. The basic monomer is phenolic ring and generally these monomers are classified as phenolic acids and phenolic alcohols. Polyphenols are very effective compounds on color and taste of fruits. Polyphenols are also known as antioxidant active compounds. The main antioxidants are vitamin A, vitamin C, and carotenoids. Some physical conditions effects antioxidant activity directly such as light intensity, ambient temperature and water availability. Moreover, Brix which is the amount of total soluble solid, TA (titratable acidity) and climate conditions of location that grows apricot trees are essential criteria on antioxidant activity. Additionally, chlorogenic and neochlorogenic acids, (+)-catechin, (-)-epicatechin and rutin (or quercetin-3- rutinoside) are the most important phenolic compounds in this fruit (Drogoudi et al., 2008).

Apricot includes some organic acids and they are malic acid, citric acid, isocitric acid, succinic acid, fumaric acid, shikimic acid, quinic acid in apricot varieties. The most abundant organic acids in apricots are malic acid and citric acid which present in a range between 2,8-26,6 mg/g fresh weight and 0.18-20.5 mg/g fresh weight, respectively.

Sugars are generally energy source for human body. The high sugar level of a fruit defines as maturity index (Ali et al., 2011). Most of fruits include enough sugar amount for human diet. Apricot contains different types of sugars namely as, glucose, fructose, sucrose and sorbitol. These sugars' percentages are 19.21, 13.56, 22.96 and 26.80 respectively. (Incedayı et al., 2016).

Apricot is a good source of vitamin C (ascorbic acid) which is an efficacious free radical scavenger and it is an non- enzymatic antioxidant agent in human body to reduce the risk of cancer and cardiovascular diseases (Halliwell, 1994; Rice-evans et al., 1997). Although, Vitamin C content of apricot does not directly related with season, it partly effects stage of ripening of fruit.

Vitamin A is a fat soluble vitamin which is essential for cell growth, immune system function and eye health (Fratianni et al., 2017). It has been determined that the level of vitamins in fruits can vary greatly from region to region due to the content of elements in the soil (Al-Saleh and Al-Doush, 1997). Hacıhaliloğlu apricot variety is quite rich in vitamin A. 30 g of dried fruit supplies 100% of the RDA (recommended dietary allowance) of carotenoids. β-carotene comprises 60-70% of total carotenoids in apricots. Vitamin A generally effects by sun. Thus, sun drying of apricot might be lack of vitamin A. The purpose of applying some chemical treatments before drying is stabilizing carotenes. β-carotene, which is the pioneer substance of vitamin A, is necessary for epithelia tissues covering our bodies and organs, eye-health, bone and teeth development and working of endocrine glades (Hacıseferoğulları et al., 2007).

Selenium is a kind of mineral which improve immune system. Daily intake for an adult is a range between 100 μg-400 μg. Most of the apricot variety include selenium minerals. According to National Food Composition Database, Hacıhaliloğlu cultivar is contained 0,4 μg of selenium. Selenium pretend to be as part of glutathione peroxidase and has been recognized as a cellular antioxidant in addition to its protecting function against heavy metal toxicity (Al-Saleh and Al-Doush, 1997 ; Oster and Prellwitz, 1989).

**Table 2.3** Amount of Important Minerals for Hacıhaliloğlu Variety

| **Minerals** | **Mineral Content (mg/kg)** |
|---|---|
| K | 2160.3±223.4 |
| Ca | 737.29±2.15 |
| Fe | 418.31±30.45 |
| Mg | 402.82±3.89 |
| Na | 783.12±55.6 |
| P | 1436.5±86.65 |

Despite of vitamins, fresh apricot is also rich in minerals namely Zn, Ca, Cu, Fe, Mg, Na, Mn, P and K. The amount of minerals depends on the variety of fruit and geographical location as other nutrition. Some minerals such as Na, K, P, Ca and Mg of apricot fruit varieties show minor differences when compared with those of wild plum, hackberry and blackthorn fruits (Çalışır et al., 2005; Demir et al., 2002; Marakoğlu et al., 2005). These elements are important because of requirement of cofactors (Akpanabiatu, Bassey, Udosen, and Eyong, 1998). The most abundant minerals are potassium and iron. After drying process, potassium level increases in dried apricot and on the contrary, iron content of fresh apricot is higher than dried apricot's (Fratianni et al, 2017). According to Table 2.3, it's shown that mineral content of Hacıhaliloğlu variety per kg.

## 2.3 Consumption of Apricot

Apricots are consumed in several ways such as fresh, dried, frozen, jam, jelly, marmalade, pulp, juice, nectar, extrusion products. On the other side, its kernels are used for production of oils, benzaldehyde, active carbon and aroma.

10% of apricots produced in Turkey are consumed fresh. However, the rest of the fresh fruit is dried and consumed as dried apricots with 20% moisture content. Also, %40-45 of total world apricot production is processed (Madrau et al., 2009). There are many preservation techniques including drying, canning, freezing and packing in controlled atmosphere (Jimenez et al., 2008).

### 2.4 Shelf Life of Fresh Apricot

Fresh apricot is a perishable seasonal fruit which has a short shelf life about 4-5 days under ambient conditions. On the other side, when storage temperature is low (1- 4ºC) and relative humidity (RH) is high (90-95%), shelf life is extended to 2-3 weeks (Sharma et al., 1992).

#### 2.4.1 Methods of Prolonging the Shelf Life

Fresh apricot is generally harvested on July in Malatya. During handling stages, it is estimated that more than 20-22% of total production of fruits is lost due to spoilage (Sandhya et al., 2010). There may be some postharvest treatments for prolonging the shelf life. These are drying, canning, freezing, chemical treatments, MAP (Modified Atmosphere Packaging). These postharvest treatments also help to maintain quality of product as well as minimizing the loss of nutrients.

##### 2.4.1.1 Chemical Treatments

Chemical treatments can help to extent the shelf life. The use of chemicals such as hydrogen peroxide, chlorine-based solutions, peroxyacetic acid, organic acids, nitric oxide and sulfur dioxide can delay browning reactions, inhibit ethylene biosynthesis, reduce respiration rate, and eliminate water loss. (Lopez-Galvez et al., 2013 ; Kyhos et al., 2010 ; Singh et al., 2013).

According to Türkyılmaz (2013), in the presence of $O_2$, polyphenol oxidase causes undesirable brown-colored melanin pigments. Polyphenols are substrate for enzymatic

browning reaction because of formation of brown color on the surface of fruits. Otherwise, sugars act like substrate for non-enzymatic browning reaction while drying and storing stages. The most significant non-enzymatic reaction is Maillard reaction that occurs when reducing sugars and amino groups of proteins react at the ambient temperature that causes browning in the fruit. Browning reaction can be happened both in drying and storage. Browning rate dramatically accelerates with temperature, time and the composition of sugar and amino acids (Türkyılmaz, 2013).

#### 2.4.1.2 Packaging by MAP

Modified atmosphere packaging (MAP) is a technique in which the oxygen and carbon dioxide concentration levels within the package are modified by sealing products in a polymeric film (Mangaraj et al., 2009). MAP reduces microbial growth, retarding the browning reaction and prolong the shelf life compared to other packaging methods. This method is mostly used when the longterm storage is needed in fruits and vegetables or transportation of perishable fruits and vegetable from one place to another.

#### 2.4.1.3. Edible Coating

Edible coatings provide a barrier for moisture and preserve color, texture and natural aroma as other postharvest treatments. This layer is above the surface of fruit as protective agent. Polysaccharides, lipid-based substances and protein films are example of edible coating (Sandarani MDJC et al., 2018).

#### 2.4.1.4 Irradiation

Irradiation can be used alone or in combination with other methods. According to the type of fruit, dose of irradiation must be adjusted. Irradiation may cause adverse effect on the firmness of fruit. (Sandarani MDJC et al., 2018).

#### 2.4.1.5 Freezing

Freezing is chilling or freezing of the fresh fruits at a certain temperature which below 0ºC.

#### 2.4.1.6. Drying

Drying is a unit operation which converts liquid or semi-liquid into solid material by reduction of moisture content. Drying process is done due to decrease the spoilage and microbial growth and increase the shelf life. Drying process is applying a heating process in a certain time and temperature by loss of free water of the fruit. In the meantime, color of fruits is changed due to non-enzymatic browning reaction and on the other side the texture of fruit dramatically changed due to heat treatment as well. The color occurs as the shade of brown color. Darkening rate increases with heat treatment. This is the reason why color is an effective parameter for quality.

Freeze drying is a drying system that does not meet the above definition. Freeze-drying is a process in which drying is carried out below the triple point and water evaporates due to the sublimation of ice (King et al, 1973).

Drying process can be carried out continuously or batch. If small scale of production is verified, batch type process is generally applied where equipment is located upstream and downstream. There are both batch and continuous unit operation of drying. Spray, rotary, flash and drum dryers can only be operated in continuous mode. The other drying operations can be both continuous and batch due to its production scheme i.e. fluidized and through-circulation dryers.

#### 2.4.1.6.1 Factors Affecting Drying Speed in Convective Air Drying

The speed of drying depends directly on the factors affecting heat and mass transfer. These factors are mainly the chemical composition of the product, the size of the product, temperature, humidity and speed of the air (Cemeroğlu, 2009).

***Chemical Composition of the Product***

The chemical composition of the product changes during drying. The chemical composition of the product is one of the important parameters affecting the drying rate. Products rich in salt and sugar are more difficult to dry than products that do not contain these substances. Dissolved substances reduce the vapor pressure of the water. This situation makes it difficult for water to evaporate (Cemeroğlu, 2009).

***Product Size***

The rate of drying is directly proportional to the surface area of the particles and inversely to their thickness. The smaller the particles, the greater the surface area and thus the drying rate will be positively affected. However, in order to accelerate drying, it is not always possible to chop the product in particles (Cemeroğlu, 2009). In terms of the consumption area, the consumer expects a certain size in shredded products as well as some products must be dried whole. For this reason, it is necessary to decide by evaluating the piece size, consumer demands and drying speed together in a drying process (Cemeroğlu, 2009).

***Temperature***

One of the most important factors affecting the drying speed is the air temperature used. Increasing the temperature increases the diffusion rate. Thus, the drying speed increases and the drying time is shortened. However, when very high temperatures are used in thin-layer foods, burning may occur and consequently nutritional value losses may be observed (Özen, 2016).

***Speed and Humidity of Air***

Another factor affecting the drying rate is the air speed in the dryer. As the air speed increases, the rate of drying increases. Air velocity is very effective in the early stages of drying. However, it was determined that high air velocity does not have a serious effect in the later stages of the drying process (Cemeroğlu, 2009).

The relative humidity of the air also determines the level to which drying will take place. The drying process continues until there is a balance between the food being dried and the air humidity (Örs, 2019).

## 2.5 Drying Methods of Apricot

Open air sun drying is the traditional and widely used method for apricot drying in Turkey. In this method the general practice is that sulfured or fresh apricots (half or whole) are laid down directly on soil or on a cover to dry under the sunlight. However, this traditional technique is quite unstable and unsafe because of being open to atmosphere and uncontrollable. Hence, some controllable drying methods, such as convective air drying, freeze drying, microwave drying and infrared drying have already been developed and/or investigated for apricot drying in literature (Fahloul et al., 2009; Garcia-Martinez et al., 2013; Kayran and Doymaz et al., 2016).

### 2.5.1 Sun Drying

Sun drying is the most preferred fruit and vegetable drying method due to its low equipment and operation cost. According to Gezer et al., 2003, this process is too slow which takes approximately 6-8 days for proper drying that means of duration of process being too long than other drying methods. Despite of low capital investment, due to be held on the outdoor, it is sufficient for contaminations. The contamination parameters generally dust, dirt, flies, microorganisms. In addition, the product may be exposed to some natural events such as rain, snow, wind during drying due to the uncontrollable atmospheric conditions in this traditional drying method. The product obtained by this method may be risky in terms of food safety.

### 2.5.2 Solar Dryers

Solar dryer used solar energy to dry food products. The basic function of a solar dryer is to heat air to a constant temperature with solar energy. Solar energy dryers; require less space than drying in open sun, keep the product quality at the highest level and are considered hygienic as they protect the product from environmental factors (Prakash and Kumar, 2013). During the drying of food in solar dryers, it is not possible to be exposed to physical effects such as insects, dust, rain, etc. (Ertekin and Yaldiz, 2004; Doymaz, 2007; Doymaz, 2011).

Although solar dryers have many benefits, they also have some drawbacks. For instance, although this system is very efficient during the solar hours (day light), the efficiency reduces at night. In other words, the prior principle for solar drying, is scheming the applicable heaters and chimney to provide drying process and air suction correspondingly. There are some studies based on improvement of solar system for instance, LPG and bio-wastes. By means of improvement the cost of energy decreases directly (Montero et al., 2010). According to some studies, there may be another alternative solution which energy from the sun can be stored in various ways during day light and may be used when it is necessary. For example, it is stated that enough solar energy is stored in the stone bed and used later (Madhlopa and Ngwalo, 2007).

### 2.5.3 Radio-Frequency

Radio frequency is a dielectric heating method like microwave heating. RF is a rapid and uniform temperature distribution application. It has higher energy efficiency and higher penetration depth than microwave drying application. In this system, the product between two electrodes (one with high voltage and the one with ground) is absorbed by the alternating current and this energy is converted into heat energy in the product. In RF systems, the amount of power absorbed by the product with a frequency of 13.56 or 27.12 MHz is generally lower and more controllable than microwave systems.

On the other hand, the system is often suitable for bulk food materials in industrial applications and sudden temperature change must be avoided. There are two mechanisms that occurs during RF application with an increase of temperature. These are named as ionic displacement and dipole rotation. According to Marra et al., 2009, one of the mechanisms which has low frequency is more dominant than the other one and this situation is an advantage of processes where water content of food product decreases in the process and this process can be drying. In every drying, there can be some problems such as uncontrolling process time, temperature fluctuation in food product temperature due to degrading in drying rate. Rf application prevents these constraints. This drying system has strict time and temperature control for avoiding any quality issues. In conventional drying systems, the thermal diffusion coefficient is decreased while drying is performed which means reduction of water content and this make it complicate to condense heat into food product. Therefore, surface temperature of food product rises undesirably. At the same time, due to the decrease in water content, the concentrations of the components that cause blackening increase and browning reactions take place on the surface of the product.

The RF assisted drying has been addressed as a promising technology for the drying of fresh fruits and vegetables in recent years due to its high efficiency, quick processing and high penetration depth (Bedane et al., 2021). However, one of the important requirements of RF drying is air blowing during the process to sweep the water vapor which evaporates from the food. Hence, RF drying technique with hot-air blowing (hot air-assisted RF) can provides high speed and efficient drying.

In this type of drying method, principle is providing fully complete or semi-complete drying of the product which is between two electrodes which is fed with alternating current. According to voltage one of the electrodes might be higher than the other electrode for absorbing electrical energy and this energy is converted into heat energy in the product.

### 2.5.4 Microwave Assisted Drying

Microwaves are electromagnetic waves within a frequency band of 300 MHz to 300 GHz. In the electromagnetic spectrum, the microwaves are located between the radio frequency range at lower frequencies and by infrared and visible light at higher frequencies. Thus, microwaves are part of the spectrum covering nonionizing radiation

(Regier, 2017). Microwave drying is a type of drying which uses microwaves to penetrate the food product. Microwaves are converted into heat by dipole rotation and ion migration in polar molecules. In MW drying, water evaporating from food is removed from the system with the help of a fan. Microwaves are penetrating from the surface to the center of the food material. Microwave drying has some pros and cons. There are several advantages of microwave drying such as high thermal efficiency, shorter drying time and improved product quality compared to conventional hot air drying. Microwave drying needs less area than conventional dryers and on the other side it requires less operational cost. Other advantages of microwave drying are the prevention of high surface temperatures and continuation of product respiration. (Vadivambal and Jayas, 2007). Disadvantages can be classified as high initial investment costs, loss of aroma and physical damage in the product, drying of uniform size and shape products, the necessity of high safety precautions, the difficulty of the use of untrained people and the difficulty of homogeneous microwave distribution in the drying environment. (Karaaslan, 2012).

### 2.6 Dried Apricot

The chemical composition of a dried apricot is given in Table 2.4. Some important quality parameters of dried apricot are color, moisture content, texture, residual sulfur (pre-treated products).

**Table 2.4** Dried Apricot's chemical composition (Hui, 2006)

| Composition Items | Value / 100 g edible part |
|---|---|
| Water(g) | 20-25 |
| Protein (g) | 3.39 |
| Fat (g) | 0.51 |
| Carbohydrate | 62.64 |
| Total sugar (g) | 53.44 |
| Total fiber (g) | 7.3 |
| Energy (kcal) | 241 |
| Na (mg) | 10 |

**Table (Cont.)**

| | |
|---|---|
| K (mg) | 1162 |
| Fe (mg) | 2.66 |
| P (mg) | 71 |
| Ca (mg) | 55 |
| Thiamine (mg) | 0.015 |
| Riboflavin (mg) | 0.074 |
| Niacin (mg) | 2.589 |
| Vitamin A (IU) | 3604 |
| Vitamin C (mg) | 1 |

### 2.6.1. Quality Parameters of sulfured dried apricot

The most important quality parameters of dried apricots are residual sulfur dioxide ($SO_2$) amount, color, texture, browning measurement and water content. On the other side, pH and titratable acidity (%malic acid), Brix, phenolic content, antioxidant content, organic acid and β-carotene content, sugar content, microbial and sensory characteristics may be controlled.

#### 2.6.1.1 Residual Sulfur Content

Drying can be performed after some pretreatments or without any protective process. Sulfuring is a general practice which can be used as a pre-treatment before the drying of most of the fresh produce. Sulfuring reduces the risk of microbiological activity, prevent darkening rate, stabilize the carotenes, retard the maillard reaction and to ensure the permanence of natural color of apricot (Mir et al., 2009).

The most suitable chemical is sulfur dioxide ($SO_2$) for human consumption. The other chemicals such as methyl bromide, ethylene bromide give much hazards both for human and environment i.e. air pollution. Sulfuring might be performed in different ways. Sulfuring by burning elemental sulfites that the elemental sulfur is burned and the gate of sulfur house is closed. Secondly, sulfuring with $SO_2$ gas from liquified $SO_2$ tank which is enforced like that fresh fruits are placed in plastic crates in single layer and the crates were stacked on top of each other in the sulfur house. Then, the apricots are sulfured by sulfur gate.

Last exposing method is that sulfuring by dipping into sodium metabisulfite ($Na_2S_2O_5$) solution (DSM). For this method, the apricots are dipped to the $Na_2S_2O_5$ solution for a certain time (Coşkun et al., 2013).

Through these conservation techniques, generally elemental $SO_2$ is applied. Fresh apricots place on the plastic boxes to expose $SO_2$ in a closed cabin for 12 hours before drying process. After that drying is applied until the moisture level range between 20-25% (Özkan et al., 2002). Despite of the increasing interest in natural dried apricots in recent years, sulfured apricot is still preferred in the market because of its visual appeal (golden intense yellow color), translucent appearance and very good gumminess (Abdelhaq and Labuza, 1987). However, high sulfur concentration can cause various health problems (Igual et al., 2012). These illnesses are namely, bronchoconstriction in patients with asthma (Cetinkaya et al., 2006). Therefore, it is important to produce high-quality products with low sulfur concentrations or without sulfur.

Although the amount of residual sulfur allowed by the countries that import dried apricots varies, it is 3000 ppm in the USA and Australia, 2500 ppm in Canada and 2000 ppm in the EU countries (Ünal, 2010). According to the "Turkish Food Codex-food additives other than colorants and sweeteners" published in the Official newspaper dated 16/11/1997 and numbered 23172, the maximum amount of sulfur in dried apricots is limited to 2000 ppm. The high level of $SO_2$ in the final product poses a risk to health as well as taste and odor problems. (Taylor et al., 1986; Freedman, 1980; Miranda et al., 2009; Sobutay, 2003). If the amount of residual $SO_2$ is low, darkening and microbiological risk can be seen during storage and distribution. McBean et al., (1964) reported in their study that even though the sulfured apricots dried by the traditional method retain their yellow color, there were significant color differences between the products and the residual $SO_2$ level in the final product ranged from 1000 ppm to 6000 ppm. The residual sulfur problem in dried apricots is associated not only with $SO_2$ concentration and sulfuring time, but also with quantity of $SO_2$ is removed from the product depending on the weather conditions during drying (Stafford and Bolin, 1972). Unfortunately, most of sulfured dried apricot producers don't give any consideration about amount of $SO_2$ must be exposed at the beginning of the sulfuring process. Most of producers used $SO_2$ to burn more than 2000-2500 ppm. They believe it will fly over by the time in storage conditions. It is true that part of sulfur is disappeared with respect to time. However, the dried product that we buy in the grocery, might not convenient for the human health because of containing above range of sulfur content. This is the reason why residual sulfur content is critical for quality control.

#### 2.6.1.2 Water Content

According to the Turkish Food Codex, the maximum water content in dried apricots is determined as 25%. Below these rate, excessively dried apricot is procured and that means it is hard to chew and not applicable for human consumption. On the contrary, above that rate, risk of deterioration increases dramatically during storage. Because of these reasons, it is a critical point to keep water content at a range of 20-25% in dried apricots.

#### 2.6.1.3 Color

The color of sulfured dried apricot is an important quality attribute that influences the consumer's preferences. Some consumers prefer sun-dried apricots that do not contain color preservatives such as SO2, while others prefer sulfurized (light yellow) dried apricots.

If the appearance of dried apricots looks synthetic (too yellow), this gives the perception that the product has been exposed to large amounts of sulfur dioxide, and the consumer may consider it unhealthy (Cetinkaya et al., 2006).

#### 2.6.1.4 Texture

Textural characteristics of dried products are sensory properties and determines human perception. The hardness, adhesiveness, springiness, cohesiveness, etc., are some of the textural attributes of dried fruits and vegetables. Hardness as an indicator of surface hardening in dried fruits is one of the characteristic which measures to determine textural properties of dried apricot.

Hardness is the power of food to resist any applied force, and it is the force required for solid food to resist the pressure between the grinding teeth (Kumral et al., 2019).

### 2.6.1.5 Browning Measurement

Browning measurement is an important parameter for dried food quality. When heat is applied on the food product. Surface color will be changed due to non-enzymatic maillard reaction. It must be controllable during the drying stage for both human health and appetite. Unless preservation techniques are not used, browning of the surface is degraded than without any treatment.

### 2.6.1.6 Total Phenolic Content and Antioxidant Activity

Malatya apricots are rich in phenolic compounds. Phenolic compounds are important in terms of its effects on taste-odor formation, antioxidant and antimicrobial activity. Phenolic compounds are secondary metabolites which, synthesized during amino acid metabolite on the plants. They are consisting of both phenolic acids and flavonoids. These compounds give a special astringence taste on fruits and vegetables. Total phenolic content depends on genetic factors and environmental conditions (Heim et al., 2002).

Dried apricots' total phenolic content are changed between 2498-4329 mg/kg in dry weight (Kaplan et al., 2019). On the other side, it was determined that the total phenolic content of apricots in sulfur dried apricots decreased by 10% to 44%. Phenolic compounds do not only prevent oxidation in the structure of foods, but they can also protect from harmful damage to the human body. It is known that phenolic substances have pharmacological effects on human metabolism and have therapeutic values. In general, it is stated that the amount of flavonoids in processed foods is approximately 50% lower than in fresh products. The amount of total phenolic content, which is a quality criterion for fruits, is a very important parameter in determining the phenolic material losses in the process stage.

According to Kaplan et al. (2019), total phenolic content depends on different drying methods. In this study, while total phenolic content of both sun dried and conventional dried apricot are decreased dramatically, sulfured dried apricot's total phenolic content is increased. It is thought that the reason for the increase in the phenolic compound value in sulfur drying is not due to the high dry matter value after drying, and that sulfur dioxide is perceived as a phenolic compound (Arias et al., 2008). Due to study of Özkan et al., (2003), variety of Hacıhaliloğlu has highest value both in total phenolic content and antioxidant activity.

The term antioxidant is a general expression of antioxidant contents of foods. Antioxidants bioavailability depends on the type of foodstuff, harvest time and methods of harvesting, climate, storage, the temperature, humidity, light, etc. In the study of Özkan et al., 2003, Hacıhaliloğlu has maximum value for antioxidant activity. Çataloğlu, Kabaaşı, Çöloğlu varieties are following properly. After drying, antioxidant activity is reduced approximately 11-20 %. Taste, odor, appearance and textural properties are sensory parameters. The hardness (texture) directly affects the chewiness. For products with different hardness.

## 2.7 Literature review on apricot drying

Table 2.5. shows some drying methods with respect to apricot variety and involving pre-treatment or not. Garcia-Martinez et al. (2013) reported the effect of the drying process (hot air and/or microwaves) on the color, mechanical properties, and ascorbic acid, vitamins A and E, and total carotenoid content of apricot. According to their observations, ascorbic acid content of fruit which is dried by microwave drying is greater than other application (hot air drying). Also, microwave application has less duration of drying than hot air drying. In the study of Karabulut et al. (2007), Hacıhaliloğlu apricots (Prunus armenica L.) were dried by hot air and direct sun. Hot air drying has different temperatures to notice the variations on color and β-carotene content of apricot. Kayran and Doymaz (2016) studied with hacihaliloğlu variety and their drying method was infrared drying. They determined that drying characteristic of apricot considerably affected by infrared power. They concluded that there was a symphony between drying time and infrared power. When the infrared power increased dramatically, drying time decreased. Fahloul et al. (2009) conducted research on freeze drying of canino variety of apricots. They observed apricot quality by means of vitamin C and total sugars criteria. Vitamin C is a perishable organic compound to the heat application and they concluded that freeze drying gave less damage on vitamin C than other drying methods. On the other side, it was observed that total sugar increased by application of freeze drying. Coskun et al. (2013) studied quality difference on both hacıhaliloğlu and kabaaşı variety of apricot by direct sun drying. They concluded that hacıhaliloğlu variety is more suitable for drying purpose than kabaaşı.

**Table 2.5.** Summary on literature review on apricot drying

| Apricot variety | Drying method | With/without pretreatment | Reference |
|---|---|---|---|
| Galta Roja | Microwave | No | Garcia-Martinez et al., (2013) |
| **Table (Cont.)** | | | |
| Hacıhaliloglu | Hot air drying | No | Karabulut et al., (2007) |
| Hacıhaliloglu | Infrared drying | Sodium metabisulfite and without pre-treatment | Kayran and Doymaz, (2016) |
| Canino | Freeze drying | No | Fahloul et al., (2009) |
| Hacıhaliloglu and Kabaası | Sun drying | Sulfur dioxide and without pre-treatment | Coskun et al., (2013) |
| Hacıhaliloglu | Sun drying | No | Elmaci et al., (2008) |
| Rojo de Carlet | Hot air drying<br>Microwave drying<br>Hot air–microwave combined drying | Sodium meta-bisulfite solution | Igual et al., (2012) |
| Alkaya | Sun drying | Sulfur dioxide and without pre-treatment | Inserra et al., (2017) |

**Table (Cont.)**

| | | | |
|---|---|---|---|
| Hacıhaliloglu | Microwave drying | No | Incedayi et al., (2016) |
| Hacıhaliloglu | Hot air drying and sun drying | Sulfur dioxide | Karabulut et al., (2018) |
| Pelese and Cafona | Hot air drying | No | Madrau et al., (2009) |
| Hacıhaliloglu | Hot air driyng | Sulfur dioxide and without pre-treatment | Özkan et al. (2002) |
| Hacıhaliloglu | Sun drying | Sulfur dioxide | Salur-Can et al., (2017) |

# CHAPTER III

# MATERIALS AND METHODS

## 3.1 Materials

***Fresh Apricots***

Fresh apricots (Prunus armenica L., Hacıhaliloğlu variety) collected from Malatya Apricot Research Station Garden then they were transported in air-conditioned vehicles and placed in cold storage in Gaziantep University Food Engineering Department on the same day. Apricot was purchased in 3 runs for drying experiments. Unripe, overripe, rotten or injured apricots are eliminated in each batch before drying operation. After sorting, the fresh apricots which have identical size and color were stored in a cold storage room at 3ºC until the drying process performed. Parts of the apricots from the first batch were managed for preliminary trials to calibrate solar assisted hot air system (SAHA) and hot air assisted-radio frequency system (HARF) while the rest of the apricots which were not include any pre-treatments were handled in SAHA-HARF system after pretreatment (sulfuring and/or extract treatment).

***Pistachio Hull***

Pistachio hulls as a waste of wet-dehulling process were obtained from a pistachio manufacturer located in Gaziantep, Turkey. Pistachio hulls were spread on a cover and dried for 3-4 days. Then they were gathered and stored in a cold place until phenolic compounds were extracted.

***Chemicals***

Chemicals were provided by TUBİTAK 1003 project for this study. Acetic acid, ethanol, formaldehyde, methanol, lead (IV) acetate, folin ciocalteu reagent, sodium carbonate, elemental sulfur, TPTZ solution, gallic acid, Iron (III) Chloride, DPPH (2,2-Diphenyl-1-(2,4,6-trinitrophenyl) hydrazin-1-yl) were purchased from Sigma-Aldrich. All reagents and solvents were used as analytical grade.

## 3.2 Methods

### 3.2.1 Pre-treatments

#### 3.2.1.1 Sulfuring

Fresh apricots (15 kg) were placed in a 30x40 cm steel trays in a form of one row. Apricot trays were placed in the sulfur cabinet, so that the apricots do not touch each other (3 layers). After the sulfur was burned, the door of the sulfur cabinet was closed and air was supplied with a small pump for oxygen demand. Sulfuring treatment was done in different concentrations (0.5-2.5 kg elemental sulfur/ton). Duration of sulfuring was 12 hours at an ambient temperature. After sulfuring, apricots were switched to the next stage which was drying in SAHA-HARF system.

#### 3.2.1.2 Phenolic Extract Treatment

***Preparation of Phenolic Extract***

100 g of Pistachio hulls (% 2 moisture content) was ground to reduce the particle size and then mixed with 1000 mL of ethanol/water (1:1) solution for the extraction of phenolic compounds. After that in order to remove the soluble sugar from the phenolic extract a liquid-liquid extraction were performed by using ethyl acetate. After removing of ethyl acetate the ethanolic phase were centrifugated and then evaporated by using rotary vacuum evaporator to get sugar-free phenolic extract. The extract was stored at 4ºC until uses.

***Treatment with Phenolic Extract***

Fresh apricots (15 kg) were placed in a single row in steel baskets of 30x40 cm size. Apricot baskets were immersed in aqueous phenolic extract solution (1.75 %) for 60 minutes at room temperature (25ºC). After that, the apricots were taken into the drying cabin of the SAHA-HARF.

***Sequential Treatment of Phenolic Extract and Sulfuring***

Firstly, fresh apricots (15 kg) were treated with phenolic extract (1.75 %) as explained in section 3.2.1.2. Then the fresh apricots dipped in the extract and removed were placed in the sulfur cabinet and sulfurized as described in section 3.2.1.1. In this sequential process the sulfur concentration was 1 kg elemental sulfur/ton apricot. After this sequential pretreatment procedure, apricots were dried in SAHA-HARF system.

### *Apricot Pitting*

Seeds of the apricots were removed by hand (by pitting). Pitting process was done just before the apricots transferred to HARF system from SAHA system. At this stage the moisture content of the apricots was approximately % 40-45 in wet basis.

## 3.3 Drying Processes

### 3.3.1 Sun Drying

15 kg of pre-treated (Sulfured) apricots were placed into steel trays and left to dry under the sun on the terrace of Gaziantep University Food Engineering Department for conventional sun drying. After 3 days, the apricots were pitted by hand then seedless apricots were replaced in the steel trays and continued to dry until to reach 20-25 % moisture content.

### 3.3.2 Solar Assisted Hot Air drying (SAHA)-Hot Air Assisted-Radio frequency Drying (HARF)

Within the scope of this study (Figure 3.1), the purchasing process has been initiated after the solar drying system design processes required for the purpose of performing pre-drying processes.

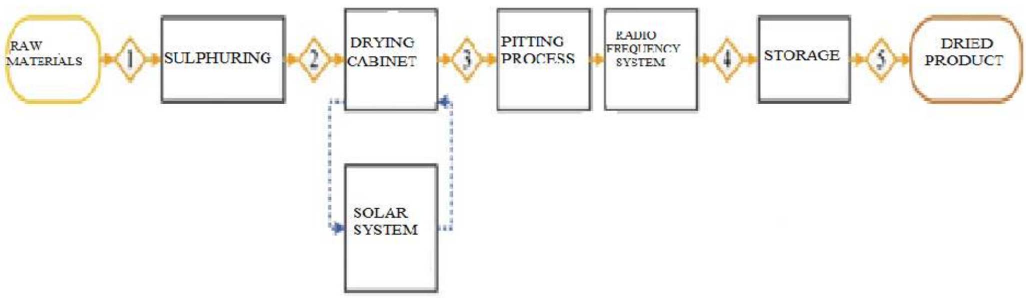


**Figure 3.1** General flow chart of apricot drying system

The solar energy system, which was designed after the purchasing process, was installed (Figure 3.2). Solar energy systems (stone beds, solar system solar panels, photovoltaic batteries) were placed on the terrace of Gaziantep University Food Engineering Department Application laboratories and the drying cabinet and heat transfer chamber were placed on the roof.

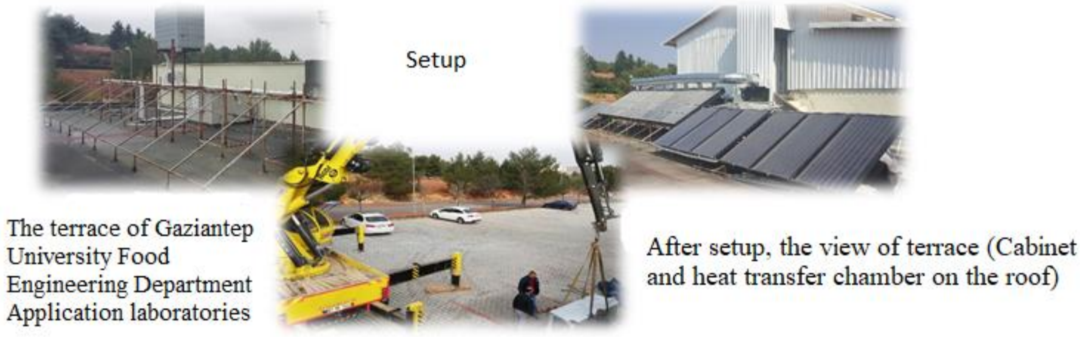


**Figure 3.2** Duration of setup

***Solar assisted hot air drying system***

In order to ensure minimum energy consumption of the drying system, applications where solar energy can be used in different ways are designed. In addition to the stone bed and water heating system where the air will be heated, the electricity required by the circulation pumps of the aqueous system was obtained by photovoltaic batteries.

- Basic components of solar drying system;
- Stone bed solar panels
- Water system solar panels
- Hot water storage tank
- Photovoltaic solar panels
- Moisture condensing chamber
- Heat transfer chamber
- Jet fan
- Drying cabinet
- PLC control system

The schematic representation of all components in the solar drying system is given in Figure 3.3.

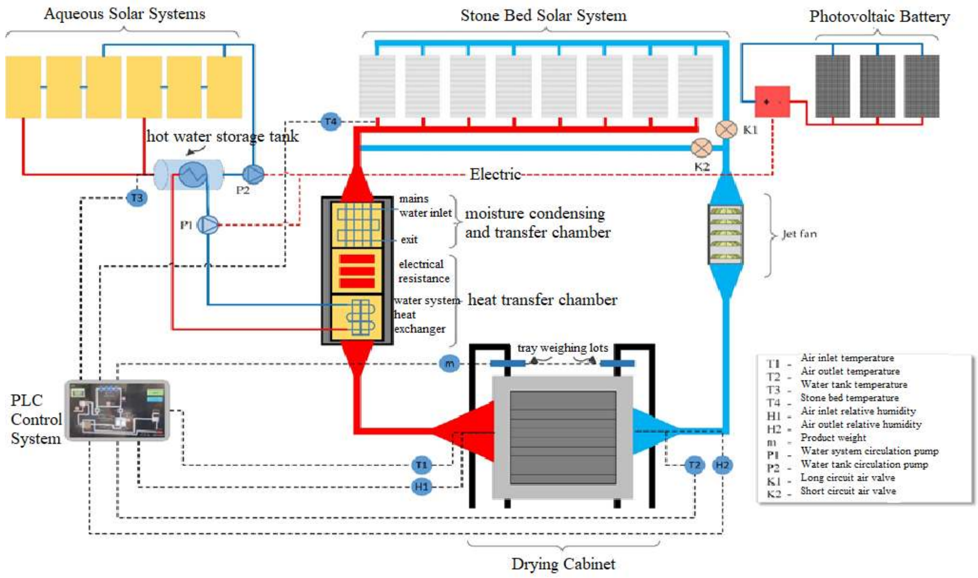


**Figure 3.3** Schematic representation of solar drying system

***Solar panels***

Three different solar panels are placed in the system. These panels;

- Stone bed
- Aqueous system
- Photovoltaic batteries.

In this system, 8 stone beds, 6 solar system solar panels and 3 photovoltaic batteries were integrated into the drying system (Figure 3.4).

**Figure 3.4** Solar panels of solar drying system

*Stone bed solar panels*

It is designed to directly heat the air in solar panels in order to benefit from solar energy at the maximum rate. For this, the solar panels are filled with flintstones which painted in black. In this way, eight stone beds were created. The inner section and air inlet-outlet structure of the stone beds are shown in Figure 3.5.

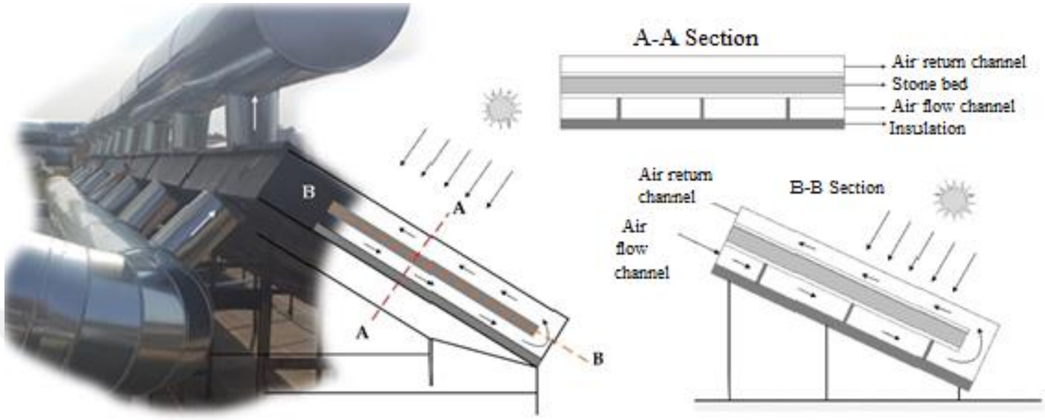


**Figure 3.5** Stone bed solar panels air inlet and outlet system

The stone bed consists of two floors divided into two parallel sections. The air enters from the lower channel and licks the heated stone surface and exits from the upper channel and is transferred to the drying room.

*Water system solar panels*

Firstly, the water is heated by the solar panels of the water system and the hot water is taken to the storage tank with a circulation pump. This tank is used as a heat exchanger. The water to be used to heat the air in the heat transfer chamber is heated in this tank. A second circulation pump circulates the water used in the heat transfer chamber. The task of the hot water tank is to store energy through the heated water.

*Photovoltaic panels*

There are three photovoltaic panels in the system and the electricity obtained is stored in batteries. When the circulation pumps are activated, electricity is fed from these batteries.

### 3.3.2.1. The Drying System

Drying system consists of a heat transfer chamber, moisture transfer chamber, fan, and drying cabinet. Humid air passes to the heat transfer chamber by leaving its moisture in a tubular moisture condensing system in the moisture transfer chamber (Figure 3.6). Mains water is used in the moisture condensation process and the water inlet and outlet are monitored from the automation system. In the automation system, the opening and closing of the water valve can be adjusted according to the air humidity. The air releasing its moisture is heated to the drying temperatures set by the automation system in the heat transfer chamber in the same way. Heating in the heat transfer chamber is provided by the hot water from the water system. In cases where the temperature of the water system is in the same chamber and the air heated in the stone bed are insufficient, electrical resistances come into play. There are 3 pieces of 3000 W resistances in the heat transfer room. These resistances come into play depending on the energy requirement of the drying cabinet.


**Figure 3.6** Moisture condensing and heat transfer chambers

The temperature and relative humidity of the air reach the desired level enters the drying cabinet (Figure 3.7). The drying cabinet is a tray dryer, and the weight of the food dried in the tray is monitored by load cell. In addition, the temperature and relative humidity of the air entering and leaving the drying cabinet are monitored over time by the PLC system. There are 10 100x100 cm chrome wire trays in the cabin.

***Control System***

The online control of solar drying system components over time is controlled by the PLC system. The control of the energy collection (solar panels) and the drying system (heat and moisture transfer room, drying cabinet) shown schematically in Figure 3.8 is carried out with this system. The temperature of the solar panels decides whether the resistances will work or not by controlling the drying temperature set in the cabin. With the PLC system, cabin entrance-exit temperature, relative humidity and panel temperatures are controlled and recorded. The PLC system also controls the weight of the product in the cabinet. The control system (Figure 3.8) also records the fan and resistance energy consumption for energy analysis to be performed in other work packages.


**Figure 3.7 Drying Cabinet**

**Figure 3.8 Control Panel**

### *Hot air Assisted-Radio frequency System*

The second drying stage in the apricot drying system is the radio frequency (RF) system. The RF drying system (Figure 3.9) purchased in this context was installed in the application laboratory.

**Figure 3.9** Radio frequency drying system

*Solar assisted hot air & hot air assisted-radio frequency drying procedure*

15 kg sulfured and/or extracted apricots were placed chrome baskets (3 trays which include 5 kg for each.). Solar assisted air drying was done in optimum conditions (Isınay B., 2021) which was 63.5 ºC of temperature, 895 minutes of drying time. In all drying process, air speed was taken as 5,5-6 m/s.

After pre-drying in the SAHA-system, the apricots (12-15 kg) were pitted immediately and transferred into the HARF-system. The parameters in this dying system were set to 77 mm, 47 mm and 385 min for the RF electrode distance, apricot thickness and drying time, respectively. These conditions were determined as optimum parameters in previous study by Isınay B., 2021.

## 3.4 Quality Evaluation

### 3.4.1 Moisture Content

The moisture content of apricots was determined according to AOAC 2000. The apricot samples were kept in the vacuum oven at 70 ° C until the weight of the samples reached constant weight and the moisture content was calculated from the percentage of water removed.

### 3.4.2 Color Measurement

The luminance (L *), redness (a *) and yellowness (b *) values of apricots were measured from both surfaces of fruit by using HunterLab ColorFlex (A60-1010-615 Model Colorimeter, Hunter Lab, Reston, VA) device in CIE Lab system. The device has been standardized using White (L0 = 93.01, a0 = -1.11 and b0 = 1.30) and black ceramic plates each time. Measurements were carried out in daylight mode (Daylight Color D65 / 10 *). 10 different apricots were selected randomly from the apricot samples and colors were measured. The average of 10 measurements was recorded as a result. Chroma (C*), Hue angle (h*) and total color differences ((ΔE*) were calculated from L *, a * and b * values by using the following equations.

$$C^*=\sqrt{a*^2+b*^2} \tag{1.1}$$

$$h^*=\arctan(b^*/a^*) \quad (1.2.)$$

$$\Delta E=\sqrt{\Delta L^2+\Delta a^2+\Delta b^2} \quad (1.3.)$$

### 3.4.3 Texture Analysis

The hardness of dried apricot samples was determined according to method proposed by Varaschim Link et al. (2018) with some modification. The hardness of dried apricot samples was measured by using a 2 mm stainless steel probe in a TAXT2i Texture Analyzer (Stable Micro Systems, Godalming, Surrey, UK). The hardness was defined as the force (Newton). Deformation was kept % 40. 30 measurements (10 fruits, from 3 different points of the upper surfaces) were made to determine hardness of dried apricot. The mean of these measurements was given as result.

### 3.4.4 Total Phenolic Content and Antioxidant Activity

Total phenolic content of apricot was determined by Folin-Ciocalteu method (Avena-Bustillos et al., 2010). Antioxidant activity was determined by both 2,2-diphenyl-1-picrilhydrazil (DPPH) and Iron Reducing Power (FRAP) methods.

***Extraction of phenolic compounds and antioxidants from apricots***

10 apricots were taken as sampling and blended about 2 minutes in high speed waring mixer (Waring Commercial Blender, 8011ES, USA). 1 g of homogenized apricot puree was taken and 5 mL of distilled water was added, then mixtures were mixed in the incubator (Heidolph unimax 1010) for 100 minutes. It was then centrifuged by centrifugation at 10000 rpm. After that, Liquid part was filtered with 0,45 μm membrane filter.

***Total Phenolic Substance (Folin-Ciocalteu)***

0.2 mL of filtrate from the extract obtained as described above was transferred to a 10 mL volumetric flask. 2 mL of 0.2 N Folin-Ciocalteu reagent and 1,6 mL of 7.5% sodium carbonate solution was added respectively and final volume was made up to 10 mL with deionized water. This mixture was placed in a water bath (50ºC). for 5-8 minutes. Then, the absorbance was measurement at spectrophotometer (Optima SP-3000 nano UV-Vis Spectrophotometer, OPTIMA Tokyo, Japan) at 765 nm. Total phenolic content was determined by a calibration curve (Fig. 3.10) which was prepared with known concentrations of gallic acid. Total phenolic content was expressed as the mg gallic acid equivalent (GAE) in 1g of dry matter.

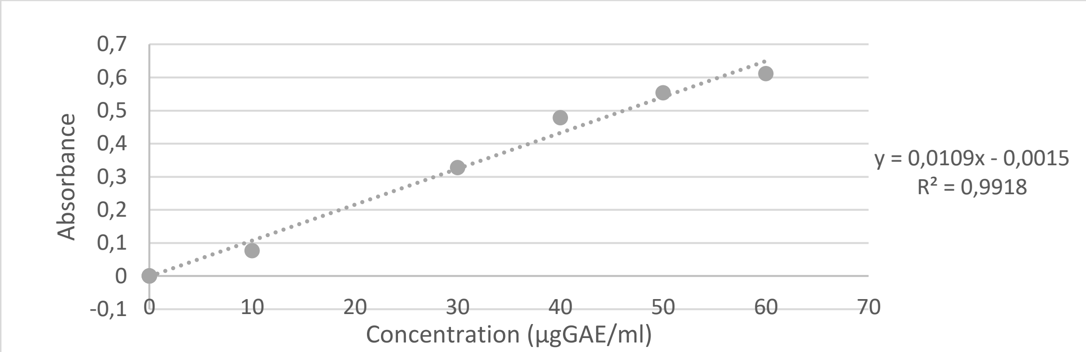


**Figure 3.10** Calibration curve of gallic acid for total phenolic content

***Determination of Antioxidant Capacity (DPPH)***

The DPPH solution was prepared with pure methanol (absorbance 0,795-0,805). DPPH radical is dark magenta in color, this color was gradually disappeared as unmatched electrons are left alone by antioxidants. 1000 µl of extract and 100 µl of DPPH solution were mixed. Samples extracted in this method were kept at room temperature for 30 minutes to react with DPPH solution. At the end of the time, absorbance was measured at 517 nm and % DPPH was calculated using the following equation (Zhang & Hamauzu, 2004).

$$\boldsymbol{DPPH\ Radical\ Scavenging\ Activity}\ (\%) = \left[\frac{Acontrol - Asample}{Acontrol}\right] * 100$$

In the equation, $A_{control}$ and $A_{sample}$ are the absorbance of the control and sample, respectively. The antioxidant capacity of apricots is given by $IC_{50}$ (effective concentration) value, which expresses the amount of antioxidant consumed to reduce 50% of the initial DPPH concentration.

***Antioxidant Capacity (Iron Reducing Power-FRAP)***

FRAP reagent, 10 mM TPTZ solution and 20 mM $FeCl_3 \cdot 6H_2O$ solution were mixed in 37ºC water bath in the ratio of 10:1:1 (v:v:v) respectively. 100 µL of the extract which prepared as described above and 3,0 mL FRAP reagent were mixed and waited 8 minutes. Absorbance was measured at 593 nm by using spectrophotometer (Optima SP-3000 nano UV-Vis Spectrophotometer, OPTIMA Tokyo, Japan). Calibration curve (Fig. 3.11) was prepared with trolox solutions in different concentrations. The result was expressed as the ratio of 1 µmol trolox equivalent.

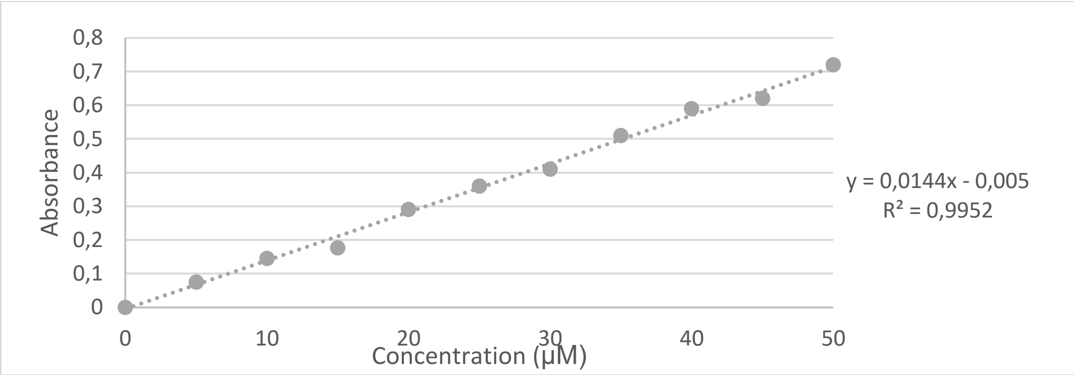


**Figure 3.11** Trolox calibration curve

### 3.4.5 Browning Measurements

Browning of dried apricots was measured in duplicate according to Coşkun et al. (2013) with some modifications. Water soluble brown pigments were extracted with 2 % acetic acid and 1% formaldehyde. Formaldehyde is an anti-sulfur dioxide agent which restrains $SO_2$. Carotenoid pigments were removed using lead acetate and ethyl alcohol. The samples were kept in dark room for 3 hours and mixed in the incubator at 450 rpm for 3 hours. Then, it was centrifuged at 7400 rpm for 15 minutes at 4 °C. Absorbances of samples were measured at 420 and 600 nm using UV–Vis spectrophotometer (Optima SP-3000 nano UV-Vis Spectrophotometer, OPTIMA Tokyo, Japonya). The results were expressed with the equation below as $A_{420}$/g dry weight.

$$A_{420} = A_{420} - A_{60} \qquad ()$$

### 3.4.6 Residual Sulfur Content

The amount of sulfur dioxide ($SO_2$) remaining in dried apricot samples was determined by Franzke et al. (1968) and its revised Monier Williams distillation method (AOAC Method 990.28). 150 ml of pure water was put into the 3-mouthed balloon then 10 ml of 3% hydrogen peroxide was poured into the small tube. 3 drops of bromine phenol blue were dropped onto the hydrogen peroxide. (100 mg bromine phenol blue + 20% ethanol) (pH = 3-4,6). Nitrogen gas was passed through the system for 15 minutes. (60 bubbles per minute). Then, 5 g of apricot was taken from the chopped apricot. (The amount of apricot is noted.). At the end of 15 minutes, 130 ml of distilled water + 40 ml of 15% HCl +5 g sample were added to a 3-mouthed balloon. The cooler water and heater were turned on. After the solution in the 3-mouthed balloon was boiled, it was left for 30 minutes. The gas and the heater were turned off. After 10 minutes, the cooler was turned off. After the entire system is turned off, it was left to stand for half an hour. The solution in the small tube was titrated with 0.1 N sodium hydroxide. (Yellow and blue violet). The consumption was recorded. The residual $SO_2$ amount was expressed by the equation given below and ppm was the unit.

$$\mathbf{SO_2(ppm)} = (0{,}1 * \text{consumption amount(ml)} * 32{,}03 * 1000)/\text{m(g)}$$

### 3.4.7 Sensory Evaluation

Sensory analysis of dried apricot samples was performed according to method proposed by Elmaci et al., (2008) with some changes. Analyzes were carried out in the sensory analysis laboratory of Food Engineering Department at Gaziantep University, where there are individual booths and ventilation system. Apricot samples were served to panelists at room temperature (20–23°C) to involve 10 fruits on white porcelain plates coded by using randomly selected 3-digit numbers. Sensitivity of panelists were tested according to ISO-3972:1991. The hardness sensory properties of dried apricots were determined by trained assessors selected from the Department of Food Engineering at Gaziantep University. 9-points hedonic scale was used in the evaluation. This hedonic scale was evaluated as 1="I didn't like at all", 5 ="neutral", 9 = "I liked it extremely". Samples exposed to extraction treatments were not included in the sensory analysis due to safety concern.

# CHAPTER IV

# RESULTS AND DISCUSSION

## 4.1 Physical and chemical properties of fresh apricot

Fresh apricot's physical and chemical properties are given in Table 4.1. The amount of dry matter of the fresh product should be taken into account for the drying process. High dry matter is a desired criteria for the drying of fresh produce. Dry matter content of apricots (Hacıhaliloğlu variety) grown in Malatya region is quite high compared to those grown in other regions (Akin et al., 2008). Therefore, the Hacıhaliloğlu variety of apricot was chosen for drying purpose in this thesis. The water content of fresh apricots was 74.35 ± 1.57% (approximately 26% dry matter). Akin et al., (2008) was reported similar results (about 25% dry matter) for the same variety of fresh apricot. Brix value of apricots was 24.72 ± 1.660. The result was consistent with the Brix value (24.34 ± 0.03 ) previously reported by Türkyılmaz et al., (2014) for the Hacıhaliloğlu variety.

The pH and titratable acidity values of fresh apricots in malic acid were determined as 5.03 ± 0.19 and 0.20 ± 0.06%, respectively. In a study conducted with six different apricot varieties, the pH (5.05) and titratable acidity (0.21% malic acid) values of Hacıhaliloğlu variety apricot were consistent with the results obtained by Hacıseferoğulları et al., 2007.

There are different amounts of organic acids in fruits and vegetables depending on the type and variety. Organic acid content of fresh apricot is given in Table 4.1. The organic acid species of Hacıhaliloğlu variety fresh apricot mainly consists of malic acid, oxalic acid, quinic acid, shikimic acid and citric acid. According to the results, the most common organic acid found in fresh apricot is malic acid (2764.61 ± 1.05 mg / 100g dry weight). Other types of organic acids are citric acid (2225.69 ± 0.30 mg / 100 g dry weight), quinic acid (1958.10 ± 0.79 mg / 100g dry weight), oxalic acid (410.18 ± 0.58 mg / 100g dry weight) and shikimic acid (235.35 ± 0.47 mg / 100g dry weight). Fumaric acid was not detected in fresh apricots. Similarly, Akın et al., (2008) reported that malic acid is the main organic acid in apricots, followed by citric acid. The ascorbic acid (vitamin C) content of fresh apricot was determined as 40.17 ± 0.81 mg / 100g dry weight (Table 4.1). Akın et al., (2008) found that the ascorbic acid content (37.7 ± 1.7 mg / 100g dry weight) of Hacıhaliloğlu apricots was at a similar level.

According to the results, the essential sugars of fresh apricots are sucrose, glucose and fructose. As given in Table 4.1, the glucose content of apricot is 25.55 ± 0.76 g / 100g dry weight, its fructose content is 10.09 ± 0.83g / 100g dry weight and its sucrose content is 4.25 ± 0.56g / 100g dry weight. There are many studies which have quite various results regarding the sugar content of fresh apricots. The most important reason for this is that the sugar content of fruits at various maturity levels varies significantly. Durmaz et al., (2010) observed changes in acidity and sugar during the ripening process of 5 different types of apricots, including the Hacıhaliloğlu variety collected from the Malatya region. According to their results, it was determined that, as the maturity level changed, the total sugar ratio changed approximately 2.5-3 times for all the apricot varieties studied.

Phenolic substances are functional compounds found in almost every fruit in small or large amounts (Haminiuk et al., 2012). The phenolic content of apricot used in this study was found as 21.07 ± 1.10 mg GAE / g dry weight. Considering the literature, Akın et al., (2008) found that the total phenolic content of Hacıhaliloğlu fresh apricots was 53.41 mg GAE / g dry weight. However, Karabulut et al., (2018) found that the phenolic content of Hacıhaliloğlu variety apricot was approximately 1.5 mg GAE / g dry weight. As it was seen the results in literature were quite different from each other, as it was in sugar content results this is largely due to the climate and maturity level.

It has been determined that the β-carotene content of the fresh apricot was 8.4 ± 0.3 mg / 100 g dry weight. In a study that examining the physical and chemical properties of Hacıhaliloğlu apricot variety, was found that the β-carotene content of apricot was in the range of 1.949-3.274 mg / 100g dry weight depending on agricultural conditions (Kan et al., 2014). Akın et al., (2008) reported-carotene content of Hacıhaliloğlu variety apricot as 8.88 ± 0.62 mg / 100g dry weight. These differences in β-carotene content are largely due to regional, seasonal or maturation levels.

**Table 4.1** Physical and chemical properties of fresh apricot

| Physical and Chemical Properties | Results |
|---|---|
| Water content (%) | 74.35±1.57 |
| pH | 5.03±0.19 |
| Titratable acidity (% malic acid) | 0.20±0.06 |
| Brix (°) | 24.72±1.66 |
| Sugar content (g/100 g dry weight) | |
| Glucose | 25.55±0.76 |
| Fructose | 10.09±0.83 |
| Sucrose | 4.25±0.56 |
| Ascorbic acid (mg/100 dry weight) | 40.17±0.81 |
| Organic acids (mg/100 g dry weight) | |
| Malic acid | 2764.61±1.05 |
| Citric acid | 2225.69±0.30 |
| Quinic acid | 1958.10±0.79 |
| Oxalic acid | 410.18±0.58 |
| Shikimic acid | 235.35±0.47 |
| Fumaric acid | Not detected |
| β-caroten (mg/100 g dry weight) | 8.4±0.3 |
| Total phenolic content (mg GAE/g dry weight) | 21.07±1.10 |
| DPPH ($IC_{50}$=mg/ml) | 84.10±0.95 |
| FRAP (μmol/g dry weight) | 54.36±0.93 |

The antioxidant contents of fresh apricots were analyzed using two different methods. The $IC_{50}$ value of the fresh apricot was calculated according to the DPPH method and it was found to be 84.10 ± 0.95 mg / ml. When the antioxidant capacity was calculated by using the FRAP method it was 54.36 ± 0.93 µmol / g dry weight Imrak et al., (2017) was reported that the antioxidant capacity value was 94.63 µmol / g dry weight for Hacıhaliloğlu variety apricot.

The color parameters, L *, a * and b * values of fresh apricot used in this study were found to be 61.4 ± 1.7, 18.7 ± 1.7 and 41.2 ± 1.7, respectively. The color values of Hacıhaliloğlu variety fresh apricot were reported as 70.7 ± 2.4 for L *, 6.4 ± 3.0 for a * and 50.0 ± 2.3 for b* by Karabulut et al., (2007). When the results we obtained from the study and the literature are compared, it can be said that the fresh apricot used in this study was much reddish and darker and had a similar value in terms of yellowness.

### 4.2 Determination of optimum sulfur and extract concentrations

In sulfuring process, elemental sulfur with different concentrations (0.5, 1.0, 1.5, 2.0, 2.5 kg of elemental sulfur/ton of apricot) was used. In the phenolic extract treatment, different concentration of phenolic extract (0.25, 0.75, 1.25, 1.75, 2.25 % extract) obtained from pistachio hull was used. The product details of the different pre-treatments applied under the conditions specified in Section 3.3 are determined on the properties (water content, color values, flavor composition, texture analysis, browning measurements, residual sulfur, DPPH, FRAP, TPC) of dried apricots. The effects are presented below. The amount of sulfur present after drying in the sulfurized samples are given in Table 4.2.

**Table 4.2** The sulfur concentrations applied and the amount of sulfur present in the product after drying

| **The elemental sulfur concentration applied (kg/ton)** | **$SO_2$ (mg/kg apricot (%25 moisture))** |
|---|---|
| 0.5 | 375 |

**Table (Cont.)**

| | |
|---|---|
| 1.0 | 940 |
| 1.5 | 1250 |
| 2.0 | 1590 |
| 2.5 | 1820 |

As the applied sulfur concentration increased the residual sulfur amount increased after drying. The residual sulfur amount of Hacihaliloğlu apricots, where 2 kg/ton of sulfur was applied and traditional sun drying process was applied, was reported as 1083 mg/kg (Özkan, 2009). As can be seen from the results obtained, the loss of sulfur was lower in the drying process applied in the study, and more residual sulfur was found in the products exposed to the same amount of sulfur.

Color properties (BI, h *, C *) based on moisture, browning value and surface color values (L *, a *, b *) obtained at the end of the drying process are given in Table 4.3.

| **Product** | **Moisture (%)** | **Browning values $A_{420}$ $g^{-1}$ dry weight** | **L*** | **a*** | **b*** | **C*** | **h*** | **BI** |
|---|---|---|---|---|---|---|---|---|
| Fresh | 74.35±1.57 | | 61.4±1.7 | 18.7±1.7 | 41.2±1.7 | 45.2±1.7 | 65.5±1.9 | 123.8 |
| Dried | | | | | | | | |
| Without pre-treatment | 22.31±1.82 | 0.69±0.03 | 32.9±2.7 | 10.8±1.8 | 17.9±2.4 | 20.9±1.7 | 58.8±3.5 | 98.9 |
| Sulfured | | | | | | | | |

**Table (Cont.)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.5 kg/ton | 23.27±1.20 | 0.65±0.03 | 35.5±1.7 | 10.7±1.1 | 18.9±2.3 | 21.7±2.3 | 60.4±3.4 | 94.6 |
| 1.0 kg/ton | 23.73±0.29 | 0.59±0.02 | 44.8±1.3 | 15.0±1.3 | 33.3±1.9 | 36.6±1.4 | 65.6±1.8 | 144.2 |
| 1.5 kg/ton | 23.02±1.44 | 0.57±0.04 | 45.2±1.8 | 15.9±1.1 | 34.0±2.4 | 37.5±2.4 | 64.9±1.9 | 147.2 |
| 2.0 kg/ton | 20.34±2.00 | 0.54±0.02 | 45.3±1.9 | 17.8±1.4 | 36.2±2.7 | 40.3±2.5 | 63.8±2.5 | 163.2 |
| 2.5 kg/ton | 21.10±1,46 | 0.51±0.03 | 46.0±2.0 | 17.8±1.3 | 38.1±2.6 | 42.1±2.7 | 65.0±1.9 | 171.5 |
| Extracted | | | | | | | | |
| %0.25 | 19.98±0.73 | 1.01±0.27 | 32.6±2.5 | 10.5±2.3 | 16.5±2.5 | 19.5±3.2 | 57.5±3.8 | 90.91 |
| %0.75 | 20.54±0.31 | 0.93±0.16 | 31.8±1.7 | 9.5±0.9 | 16.2±1.9 | 18.7±2.0 | 59.6±2.1 | 90.11 |
| %1.25 | 20.76±1.13 | 1.18±0.24 | 29.6±1.9 | 9.0±1.1 | 14.2±2.4 | 16.8±2.6 | 57.6±2.1 | 85.37 |
| %1.75 | 21.18±1.19 | 0.72±0.10 | 30.3±1.6 | 10.3±1.1 | 15.9±1.6 | 18.8±1.8 | 57.3±2.5 | 95.25 |
| %2.25 | 19.02±2.06 | 1.03±0.17 | 29.0±1.9 | 9.1±1.2 | 14.8±1.8 | 17.3±2.0 | 58.4±2.1 | 91.01 |

**Table 4.3** Moisture, browning and color information of fresh apricots, untreated, extracted and sulfured dried apricots

It is seen that the BI, C * and h * values obtained based on surface color measurement are the lowest in non-pre-treated products and increase with increasing sulfur concentration. It has been reported in other studies that C * and h * values increased in sulfur treated apricots. (Karabulut et al., 2007). As can be seen from the browning analysis for the whole product, which is an indicator of browning, the highest browning was observed in apricots without pre-treatment (sulfuring). It was determined that the browning value decreased with increasing sulfur concentration.

Another pre-treatment planned within the scope of the thesis is to use pistachio hull extract in different proportions. Accordingly, it was determined that the products applied at concentrations above 2.5% in the preliminary tests (0.5, 1.5, 2.5, 3.5, 4.5% extracts) had a pistachio odor. For this reason, the drying process was carried out on the pre-treated products at five different extract concentrations (0.25%, 0.75, 1.25, 1.75, 2.25). Color values of the extract pretreated apricots after drying are given in Table 4.3.

As can be seen from the results, it was observed that browning increased in extracted apricots and the surface color values had results that confirmed this. An uneven browning behavior was observed with the increase of the applied extract concentration. However, the lowest browning value was obtained at 1.75% extract concentration. The main reason for the browning tendency in extracted products is thought to be the result of the oxidation of phenolics present in the extract due to high temperature drying air. There is evidence that pistachio hull extract reduces browning (enzymatic) in apples (Al Habbal et al., 2019). However, in the mentioned study, it was stated that the extract was used together with pectin and wax complex and at low temperature. Therefore, eliminating the risks of high temperature and air contact gives the impression that the extract plays an effective role against browning.

Table 4.4 shows the hardness values of different pre-treated products. Although the effect of the sulfuring process on the product hardness is limited, it was seen that it caused a decrease in hardness at low concentrations and an increase in hardness at high concentrations. The obtained apricots were in the hardness range determined by sensory analysis in preliminary studies and behaved like products with high scores in terms of preference. It was observed that the surface hardness of the extracted products increased significantly and there was a significant difference in hardness between the inside and the surface of apricot. The moisture content of the extracted products were generally around 20%, although it was possible that the difference in hardness was thought that the extract caused a faster drying on the surface and the surface hardness differs significantly.

**Table 4.4** Hardness values in untreated, sulfured and extracted products

| Product | Hardness (N) |
|---|---|
| Without pre-treatment | 1293.46±61.96 |
| Sulfured | |
| 0.5 kg/ton | 1208.21±124.86 |
| 1.0 kg/ton | 1109.82±66.58 |
| 1.5 kg/ton | 1316.44±121.59 |
| 2.0 kg/ton | 1352.97±144.73 |
| 2.5 kg/ton | 1380.22±137.7 |
| Extracted | |
| %0.25 | 1625.41±191.07 |
| %0.75 | 1552.52±158.23 |
| %1.25 | 1480.13±112.73 |
| %1.75 | 1429.75±126.49 |
| %2.25 | 1540.94±185.25 |

As a result of the data obtained at the end of sulfur and extract application, it was seen that especially the use of extracts alone did not provide the desired quality of dried apricot production. It had been decided to apply a low concentration of sulfur together with the extract instead of using the extract alone. For this reason, applying an extract at a concentration of 1.75% and sulfur at 1 kg/ton apricot samples is chosen to be produced for executing the other quality analysis. The important factor here is to ensure the production of both high quality and long-lasting dried apricots with low sulfur concentration as well as extract concentration with the least increase in color values and hardness. Although the extract application does not contribute to color, it will play an important role in reducing microbial risks. It was decided that it would be appropriate to apply a low sulfur concentration in order to contribute in terms of color.

In addition, products with 1 kg/ton and 2 kg/ton sulfur application, were decided to continue for further drying processes and comparison studies.

### 4.3 Comparison of Quality Parameters of Dried Apricots

The quality parameters of apricots obtained by different treatments (SAHA-HARF, SAHA-HARF/1S, SAHA-HARF/2S, SAHA-HARF/EX+1S and SD/2S) were compared to obtain the best drying option. In this respect, the phenolic content, antioxidant activity, color, browning, hardness, moisture, residual sulfur content were examined and reported in this section.

#### 4.3.1 Comparison of Phenolic content and antioxidant activity

The total phenolic content of dried apricots obtained at the end of different pretreatments and drying techniques are given in table 4.5.

**Table 4.5** Phenolic content and antioxidant properties of apricots obtained as a result of different pretreatment and drying techniques

| | **SAHA-HARF** | **SAHA-HARF/1S** | **SAHA-HARF/2S** | **SAHA-HARF/EX+1S** | **SD/2S** |
|---|---|---|---|---|---|
| **Total phenolic content (mg GAE/g dry weight)** | $22.11 \pm 1.17^{a,b}$ | $23.95 \pm 1.37^{b,c}$ | $26.83 \pm 1.51^{d}$ | $47.28 \pm 2.50^{c}$ | $24.96 \pm 1.26^{c,d}$ |
| **DPPH ($IC_{50}$=mg/ml)** | $43.36 \pm 2.23^{a}$ | $15.85 \pm 1.07^{c}$ | $17.76 \pm 1.68^{c}$ | $10.54 \pm 0.81^{d}$ | $21.57 \pm 0.34^{b}$ |
| **FRAP (µmol/g dry weight)** | $6.01 \pm 0.39^{a}$ | $15.62 \pm 1.34^{c,d}$ | $13.99 \pm 0.94^{c}$ | $17.24 \pm 1.08^{d}$ | $9.80 \pm 0.68^{b}$ |

Values shown with different letters on the same row are different from each other ($p < 0.05$).

The total phenolic content of sulfured and extracted dried apricots obtained at the end of different pretreatments and drying techniques ranged from 22.11 ± 1.17 - 47.28 ± 2.50 mg GAE / g dry weight (Table 4.5). In a study conducted by Türkyılmaz et al., (2014), the total phenolic amounts of Hacıhaliloğlu apricots which dried under the sun were reported as 29.09 mg GAE / g dry weight. In another study, Ouchemoukh et al., (2012) for dried apricots, this value was found as 6.5 mg GAE / g dry weight. Statistical analysis showed that the applied pretreatment and drying techniques had a significant effect on the total phenolic content of the samples ($p < 0.05$). The highest phenolic content was detected in the product pre-treated with extract and sulfur, and the phenolic content of other products was quite low compared to this product. The reason for this was thought to be the high amount of phenolic substances present in the applied extract. The results obtained showed that the phenolic content of the samples that passed the sulfuring pre-treatment were higher than the non-sulfur samples. The reason for this can be thought as that, the use of $SO_2$ inhibits the reactions initiated by the polyphenol oxidase enzyme. Because polyphenol oxidase is an enzyme that causes a decrease in polyphenol content by affecting the polyphenols in apricot (Karataş, 2014). In addition, the total phenolic content of the samples dried in the SAHA-HARF system was found to be higher than the samples dried under the sun. This situation can be explained by the fact that the low temperature and long processing time applied in the drying process under the solar system. The polyphenol oxidase activity cause a decrease in phenolic compounds (Karabulut et al., 2018).

The antioxidant content of dried apricots was measured by two different methods, DPPH and FRAP (Table 4.5). The analysis of variance showed that the pre-treatments applied and the drying techniques had a significant effect on the antioxidant activities of dried apricots ($p < 0.05$). The $IC_{50}$ value obtained by the DPPH method indicates the concentration of antioxidant substance inhibits 50% of the DPPH radical in the environment. A small value means that the antioxidant activity is high. The results obtained showed that according to both DPPH and FRAP methods, the highest antioxidant activity was obtained from products pre-treated with extract and sulfur. Özbek et al., (2020) proved this notion that it is thought to be due to the presence of components with high levels of antioxidant activity in the applied pistachio hull extract. The lowest antioxidant activity was seen in the samples dried in the SAHA-HARF system without any pre-treatment. This situation can be explained by the fact that the temperature applied in the SAHA-HARF system was higher compared to drying under sunlight. Similar trend was studied by Incedayı et al., (2016), who studied the effect of different drying parameters on the antioxidant activity of dried apricots. It was explained that high temperature caused the loss of components that showed antioxidant activity.

### 4.3.2 Comparison of Browning and Color values

Surface for each dried apricot was obtained as a result of different pre-processes and drying techniques. Color values are given as Hunter L *, a *, b *, C * and h˚ values (Table 4.6). Color changes in apricots are related to loss of pigment which mean to be enzymatic and non-enzymatic reactions during drying. Statistical analysis showed that the applied pre-treatment and drying techniques had a significant effect on the browning and color values of the samples ($p < 0.05$).

According to the data obtained, the L * value of dried apricots varies between 32.9 ± 2.7 and 45.2 ± 1.9. The products with the highest L * values after drying were SAHA-HARF/2S and SAHA-HARF/1S. The sulfuring pre-treatment has a significant effect on the L* value. L * values of products which are not treated with sulfur are low. In addition, L * values were found to be low in products with extract and sulfur application. In a study of Karabulut et al., (2007), the L value of apricots dried in the sun without sulfur dioxide treatment was 30.6; For apricots dried and treated by sulfur dioxide in the sun, the L value was determined as 42.0 in the Hacıhaliloğlu variety, which is very similar to the values obtained from this thesis. Drying for sulfured samples considering the techniques of drying in the SAHA-HARF system, L * values were higher. The SAHA-HARF system has short duration and keeping the sulfur applied in the system compared to drying apricots under sun. In the literature, the L * value is considered as an indicator of browning. (Garcia-Martínez et al., 2013). This information is based on browning and BI values of apricots. Considering as it is verified.

After drying process, a* value of extracted and sulfured dried product is reported as highest a* value among others. The reason was considered as the applied extract contain red colored anthocyanin. It is also seen that b* values increase with the increase of sulfur in products dried in the SAHA-HARF system. However, it is seen that the b * value was lower in sulfured product in traditional sun drying. C * (chroma) value was expressing color saturation increase in sulfured samples. The color angle value, h˚ (hue) indicated that the yellowness increased as it approached 90. The highest h˚ values were obtained from the samples dried by $SO_2$ treatment in the SAHA-HARF system. The desired characteristic golden yellow color in dried apricots was attained by the treatment of dried apricots with $SO_2$ and it helped to protect color change by stopping or slowing down reactions that cause browning. On the browning level of dried apricots; the effects of different pre-treatment and drying techniques were examined and it was found that the browning levels of the samples varied between $0.22 \pm 0.01 – 0.69 \pm 0.02$ $A_{420}$/g dry weight. At the end of the variance analysis, it was determined that the browning levels of the samples were statistically significant ($p < 0.05$) (Table 4.6). The lowest browning values were found in sulfured dried apricot. The reason for this was thought to be that the sulfuring process prevents both enzymatic and non-enzymatic browning reactions in fruits and vegetables. In addition, it had been determined that the browning occurring in the product containing extract and sulfur dioxide was not different from the product treated with 2 kg/ton of $SO_2$, and it had been observed that the extract application played an effective role against browning while reducing the amount of sulfur used.

**Table 4.6** Browning and color values of dried apricots

| Product | Browning Measurement $A_{420}$ in dry weight | L* | a* | b* | C* | h° | BI |
|---|---|---|---|---|---|---|---|
| **SAHA-HARF** | 0.69±0.02$^{d}$ | 32.9±2.7$^{a}$ | 10.8±1.8$^{a}$ | 17.9±2.4$^{a}$ | 20.9±1.7$^{a}$ | 58.8±3.5$^{b}$ | 99.7 |
| **SAHA-HARF/1S** | 0.24±0.01$^{b}$ | 44.8±1.3$^{c}$ | 15.0±1.3$^{b}$ | 33.3±1.9$^{c}$ | 36.6±1.4$^{c}$ | 65.6±1.8$^{c}$ | 145.5 |
| **SAHA-HARF/2S** | 0.22±0.02$^{a}$ | 45.2±1.9$^{c}$ | 17.8±1.4$^{c}$ | 36.2±2.7$^{c}$ | 40.3±2.5$^{c}$ | 63.8±2.5$^{b,c}$ | 165.4 |
| **SAHA-HARF/EX+1S** | 0.22±0.01$^{a}$ | 36.9±0.8$^{b}$ | 18.1±1.3$^{c}$ | 24.6±1.9$^{b}$ | 30.6±1.9$^{b}$ | 53.5±2.5$^{a}$ | 136.9 |
| **SD/2S** | 0.29±0.01$^{c}$ | 38.1±1.7$^{b}$ | 15.8±1.9$^{b,c}$ | 27.3±1.4$^{b}$ | 31.5±3.7$^{b}$ | 59.9±2.9$^{b}$ | 144.0 |

Values shown with different letters in the same column are p <0.05 different from each other. L * value for darkness / lightness (0, black, 100 white); a * (-a green, + a red) and b * (-b blue, + b yellow)

### 4.3.3 Comparison of hardness values

In order to evaluate the dried apricot samples in terms of texture, their hardness was determined. Hardness in dried fruits is an important quality parameter used as an indicator of surface hardening. Hardness is the power of the nutrient to resist any applied effect, and it is the force required for solid food to resist the pressure between the grinding teeth (Kumral et al., 2019). The softer the dried fruit, the better quality it is in terms of texture. There is an inverse relationship between hardness and product moisture content. Table 4.7 shows the hardness values and moisture content of dried (sulfured and/or extracted) and untreated apricots in a traditional sun drying and drying system (SAHA-HARF). As seen in Table 4.7, the hardness values of dried apricots, which have almost the same moisture, are very close to each other. As a result of the sensory analysis carried out in preliminary studies with a trained panelist group, The range was determined as 1100-1450 N and it is the most suitable hardness range for dried apricots. The hardness of the dried apricots, whose hardness values vary between 1115.62 N -1411.18 N after drying, are within the hardness range determined in preliminary studies.

**Table 4.7** Untreated, sulfured and extracted apricots' hardness values after drying

| Product | Moisture (%) | Hardness (N) |
|---|---|---|
| SAHA-HARF | 21.31±1.02 | 1305.16±61.96 |
| SAHA-HARF/1S | 22.73±0.29 | 1115.62±66.58 |
| SAHA-HARF/2S | 20.54±0.97 | 1355.87±64.73 |
| SAHA-HARF/EX+1S | 21.35±0.80 | 1411.18±102.32 |
| SD/2S | 21.64±0.60 | 1122.49±68.03 |

As can be seen in Table 4.7, although the hardness values of the apricots that have been pre-treated or not pre-treated, dried in the traditional drying or drying system (SAHA-HARF) are quite close to each other. The apricots treated with extract and dried in the drying system (SAHA-HARF/EX+1S) are the products with the highest surface hardness. It has been observed that the products treated with extracts dry faster in the drying process carried out under the homogeneous conditions, and it is thought that the reason for the hardening on the surfaces of these products may be the rapid drying on the surface. When the product hardness is related to the final moisture of dried apricots, according to the first measurements after drying, SAHA-HARF/1S has the highest moisture with 22.73% and has the lowest hardness with 1115.62 N. Although it is thought that there is an opposite relationship between hardness and moisture, there are products that are harder even though they have high humidity (Table 4.7). The reason for this is that the measured moisture values represent the moisture of the entire product, and in fact, the humidity is lower on the surface and near the surface compared to the center points.

### 4.3.4 Comparison of Residual sulfur content change After drying conditions

After drying process, SAHA-HARF/1S, SAHA-HARF/2S, SAHA-HARF/EX+1S and SD/2S of residual sulfur change given in Table 4.8.

The products which applied 2 kg of elemental sulfur/ton are SAHA-HARF/2S and SD/2S products were found to be 1598 and 1087 (mg $SO_2$ $kg^{-1}$), respectively. It is thought that the difference between the post-drying $SO_2$ values of these two products, which were exposed to the same amount of sulfur and the same sulfuring time, is due to the different drying methods applied to the products. The solar-assisted air drying following the RF drying system, is considered to prevent the loss of $SO_2$ in sulfured products as it provides a faster drying compared to the traditional drying method. In addition, the fact that the system provides drying by circulating only its own air as a closed circuit may have caused the SAHA-HARF/2S to protect the initial $SO_2$ amount more. In the SAHA-HARF/1S and SAHA-HARF/EX+1S products which treated with 1 kg of elemental sulfur/ton, the initial $SO_2$ amounts were found to be 946 and 840 (mg $SO_2$ $kg^{-1}$), respectively.

**Table 4.8** Residual sulfur content of dried and sulfured apricots in different conditions

| Product | $SO_2$ (mg/kg apricot (%25 moisture)) |
|---|---|
| SAHA-HARF/1S | 946±26.7 |

**Table (Cont.)**

| | |
|---|---|
| SAHA-HARF/2S | 1598±30.8 |
| SAHA-HARF/EX+1S | 840±30.4 |
| SD/2S | 1087±27.4 |

### 4.3.5 Comparison of Sensory properties of apricots

Tables 4.9, 4.10 and 4.11 show the appearance, taste and chewiness scores achieved as a result of the sensory analysis of the products obtained under different drying conditions, respectively. As it contained pistachio hull extraction, it was not tasted. That is why SAHA-HARF/EX+1S scores are not available in Table 4.10 and 4.11. After drying, the most favorite product for appearance is SAHA-HARF/2S and then respectively SD/2S, SAHA-HARF/1S, SAHA-HARF/EX+1S, SAHA-HARF.

As can be seen in Table 4.10, SAHA-HARF/2S is again the most liked product in terms of taste sensory scores. SD/2S, which rank second in terms of appearance, fall behind SAHA-HARF/1S and SAHA-HARF products in terms of taste. This circumstance is thought to be caused by the presence of sulfur, which is not homogeneous and which is assumed to have accumulated on the surface. As can be understood from the SAHA-HARF/2S appreciation scores, which received the highest one, when a homogeneous distribution of sulfur applied at 1600 ppm levels was achieved, it was understood that the unique flavors of apricot were preserved and positively contributed.

As can be seen from the chewability sensory scores given in Table 4.11, SAHA-HARF and SAHA-HARF/2S products received the highest appreciation. SAHA-HARF/1S is pursuing them. Chewability scores were found to be low in traditional sun drying product (SD/2S). According to these results, traditional sun drying does not have the desired chewability properties for the product. It causes an inhomogeneous moisture distribution.

**Table 4.9** Sensory evaluation results (A) and standard deviations of the appearance properties of dried apricots ($SS_A$)

| Product | Appearance (A) | Standard deviation ($SS_A$) |
|---|---|---|
| SAHA-HARF | 6.9 | 0.9 |
| SAHA-HARF/1S | 8.0 | 0.8 |
| SAHA-HARF/2S | 8.2 | 1.1 |
| SAHA-HARF/EX+1S | 7.5 | 0.6 |
| SD/2S | 8.1 | 0.8 |

A: Appearance; $SS_A$: Standard Deviation

**Table 4.10** Sensory evaluation results (T) and standard deviations of the taste properties of dried apricots ($SS_T$)

| Product | Taste (T) | Standard deviation ($SS_T$) |
|---|---|---|
| SAHA-HARF | 7.5 | 0.8 |
| SAHA-HARF/1S | 7.7 | 0.9 |
| SAHA-HARF/2S | 8.5 | 0.8 |
| SAHA-HARF/EX+1S | - | - |
| SD/2S | 7.0 | 0.6 |

T: Taste; $SS_T$: Standard Deviation

**Table 4.11** Sensory evaluation results (C) and standard deviations of the chewiness properties of dried apricots ($SS_C$)

| **Product** | **Chewiness (C)** | **Standard deviation ($SS_C$)** |
|---|---|---|
| SAHA-HARF | 8.5 | 0.6 |
| SAHA-HARF/1S | 7.8 | 0.4 |
| SAHA-HARF/2S | 8.4 | 0.5 |
| SAHA-HARF/EX+1S | - | - |
| SD/2S | 7.4 | 0.7 |

C: Chewiness; $SS_C$: Standard Deviation

# CHAPTER V

# CONCLUSION

- Drying of apricots by using a new combined drying system (solar assisted hot air and hot air assisted radio frequency system (SAHA-HARF)) has been successfully achieved within the 21.3 hours.
- Sulfuring with 2 kg elemental sulfur/ton apricot has been obtained as the best pretreatment among the other sulfur concentrations and extracts application.
- The dry apricots obtained in SAHA-HARF system after 2 kg sulfur/ton apricot application was good in color, texture, moisture, residual sulfur content.
- The apricots dried with traditional drying system as control sample were darker and more rigid than that of obtained by SAHA-HARF system.
- It can be concluded that SAHA-HARF system can be an alternative drying method for the drying of apricot with its short process time and high quality final product.

## REFERENCES


Abdelhaq, E. H., Labuza, T. P. (1987). Air Drying Characteristics of Apricots. *Journal of Food Science*, **52,** 342-345.

Akın, E. B., Karabulut, İ., Topcu, A. (2008). Some compositional properties of main Malatya apricot (Prunus armeniaca L.) varieties. *Food Chemistry*, **107**, 2, 939-948.

Akpanabiatu, M. I., Bassey, N. B., Udosen, E. O., Eyong, E. U. (1998). Evaluation of Some Minerals and Toxicants in Some Nigerian Soup Meals. *Journal of Food Composition and Analysis*, **11(4),** 292–297.

Al Habbal, D., Özbek, H. N., Yanık, D. K., Göğüş, F. (2019). Effect of pectin-wax coating on the quality of fresh-cut apples. *Harran Tarım ve Gıda Bilimleri Dergisi*, **23,** 313-323.

Ali, S., Masud, T., Abbasi, K. S. (2011). Physico-chemical characteristics of apricot (Prunus armeniaca L.) grown in Northern Areas of Pakistan. *Scientia Horticulture*, **130(2),** 386-392.

Al-Saleh, I. A., Al-Doush, I. (1997). Selenium Levels in Wheat Grains Grown in Saudi Arabia. *Bulletin of Environmental Contamination and Toxicology*, **59(4),** 590–594.

Altindag, M., Sahin, M., Esitken, A., Ercisli, S., Guleryuz, M., Donmez, M. F., & Sahin, F. (2006). Biological control of brown rot (Moniliana laxa Ehr.) on apricot (Prunus armeniaca L. cv. Hacıhaliloğlu) by Bacillus, Burkholdria, and Pseudomonas application under in vitro and in vivo conditions. *Biological Control*, ***38*****(3),** 369-372.

Arias-Gil, M., Garde-Cerdán, T., Ancín-Azpilicueta, C. (2007). Influence of addition of ammonium and different amino acid concentrations on nitrogen metabolism in spontaneous must fermentation. *Food Chemistry*, **103,** 4, 1312-1318.

Asma, B. M. (2011). Her Yönüyle Kayısı (Apricots in all aspects). Ankara: Uyum Agency.

Asma, B. M. (2000). Apricot growing. Malatya, Turkey, Evin Publishers (in Turkish).

Aubert, C., Bony, P., Chalot, G., Hero, V. (2010). Changes in physicochemical characteristics and volatile compounds of apricot (Prunus armeniaca L. cv. Bergeron) during storage and post-harvest maturation. *Food Chemistry*, **119**, 4, 1386-1398.

Avena-Bustillos, R. J., Du, W. X, Woods, R., Olson, D., Breksa, A. P., McHugh, T. H. (2012). UltravioletB Light Treatment Increases Antioxidant Capacity of Carrot Products. *Journal of the Science of Food and Agriculture*, **92,** 2341–2348.

Ayanoglu, H., Kaska, N. (1995). Apricot selection studies in the Mediterranean Region of Turkey. *Acta Horticulturae,* **384**, 177-183.

Batmaz, M. F. (2005). Yield Quality of Some Apricot Cultivars in Adana Ecological Conditions (in Turkish, with English abstract). M.Sc. thesis, Çukurova University Science Institute, Adana.

Batu, A. (2009). Kayısının Modifiye Atmosferde Paketlenerek Depolanması Önerisi. *Gıda Teknolojileri Elektronik Dergisi Cilt*. **4(1),** 9-19.

Bedane, T., F., Erdogdu, F., Lyng, J., G., Marra, F. (2021). Effects of geometry and orientation of food products on heating uniformity during radio frequency heating. *Food and Bioproducts Processing*, **125**, 149-160.

Bircan, M., Pinar, H., Yilmaz, C., Caliskan, T. (2007). Determination of some pomological properties of table apricots grown in Mediterranean region for export. *Proceedings of 5 th National Horticulture Congress*, 4-7 September 2007, Erzurum, Turkey. 313-318.

Buttner, R. (2001). Armeniaca. In: P. Hanelt. Institute of Plant Genetics and Crop Plant Researches (eds.). *Mansfelds Encyclopedia of Agricultural and Horticultural Crops*, 523-527.

Cemeroğlu, B., Özkan, M. (2009). Meyve ve Sebze İşleme Teknolojisi. Ankara: Başkent Klişe. 479-620.

Cemeroğlu, B. (2009). Meyve ve Sebze İşleme Teknolojisi. 3 rd edition. 50-543.

Cetinkaya, N., Ozyardımci, B., Denli, E., Ic, E. (2006). Radiation processing as a post-harvest quarantine control for raisins, dried figs and dried apricots. *Radiation Physics and Chemistry*, **75(3),** 424–431.

Chang, H. K., Yang, H. Y., Lee, T. H., Shin, M. C., Lee, M. H., Shin, M. S. (2005). Armeniacae semen extract suppresseslippolysaccharide-induced expressions of cyclooxigenase-2 and inducible nitric oxide synthase in mouse BV2 microglia cells. *Biological and Pharmaceutical Bulletin*, **28,** 449-454.

Codex Alimentarius Commission. (1981). Codex Standard 130–1981. Codex Standard for Dried Apricots. 5. p.

Coşkun, A. L., Türkyılmaz, M., Aksu, Ö., Koç, B. E., Yemiş, O., Özkan, M. (2013). Effects of Various Sulphuring Methods and Storage Temperatures on the Physical and Chemical Quality of Dried Apricots. *Food Chemistry***, 141,** 3670-3680.

Çalışır, S., Hacıseferoğulları, H., Özcan, M., Arslan, D. (2005). Some nutritional and technological properties of wild plum (Prunus spp.) fruits in Turkey. *Journal of Food Engineering*, **66(2),** 233–237.

Dağ, B., Tarakçı, Z., Demirkol, M. (2016). Effect of Some Total Phenolic, Antioxidants, Physico-chemical Properties, Mineral and Heavy Metal Content of Apricots Drying Types. *Batman Üniversitesi Yaşam Bilimleri Dergisi*, 6, 238-250.

Demır, F., Doğan, H., Özcan, M., Haciseferoğullari, H. (2002). Nutritional and physical properties of hackberry (Celtis australis L.). *Journal of Food Engineering*, **54(3),** 241–247.

Doymaz, İ. (2007). Air-drying Characteristics of Tomatoes. *Journal of Food Engineering*, **78**, 1291-1297.

Doymaz, İ. (2011). Drying of Green Bean and Okra Under Solar Energy. *Chemical Industry & Chemical Engineering Quarterly*, **17(2),** 199-205.

Drogoudi, P. D., Vemmos, S., Pantelidis, G., Petri, E., Tzoutzoukou, C., Karayiannis, I. (2008). Physical Characters and Antioxidant, Sugar, and Mineral Nutrient Contents in Fruit from 29 Apricot (Prunus armeniacaL.) Cultivars and Hybrids. *Journal of Agricultural and Food Chemistry*, **56(22),** 10754–10760.

Durmaz, G., Cam, M., Kutlu, T., Hışıl, Y. (2010). Some Physical and Chemical Changes During Fruit Development of Five Common Apricot (Prunus Armeniaca L.) Cultivars. *Food Science and Technology Research*, **16,** 71-78.

Elmaci, Y., Altug, T., Pazir, F. (2008). Quality Changes in Unsulfured Sun Dried Apricots During Storage. *International Journal of Food Properties*, **11(1),** 146–157.

Erdogan, D., Guner, M., Dursun, E., Gezer, I. (2003). Mechanical Harvesting of Apricots. *Biosystems Engineering*, **85,** 19-28.

Ertekin, C., Yaldiz, O. (2004). Drying of Eggplant and Selection of a Suitable Thin Layer Drying Model. *Journal of Food Engineering*, **63**, 349-359.

Fahloul, D., Lahbari, M., Benmoussa, H., Mezdour, S. (2009). Effect of Osmotic Dehydration on the Freeze Dryig Kinetics of Apricots. *Journal of Food, Agriculture & Environment*, **7**, 117-121.

Faust, M., Suranyi, D., Nyujto, F. (1998). Origin and dissemination of apricot. *Horticultural Reviews-Westport Then New York*, **22**, 225-260.

Franzke, C. L., Grunert, K. S., Glowacz, S., Kutschan, R. (1968). Zur Bestimmung geringer Mengen schefliger Saure in Lebensmitteln. *Zeitschrift Fur Lebensmittel-Untersuchung Und-Forschung*, **160**, 13–20.

Fratianni, A., Niro, S., Messia, M., C., Cinquanta, L., Panfili, G., Albanese, D., Di Matteo., M. (2017). Kinetics of carotenoids degradation and furosine formation in dried apricots (Prunus armeniaca L.). *Food Research International*, **99,** 2, 862-867.

Fratianni, F., Ombra, M. N., d' Acierno, A., Cipriano, L., Nazzaro, F. (2018). Apricots: biochemistry and functional properties. *Current Opinion in Food Science*, **19**, 23–29.

Freedman, B. J. (1980). Sulphur dioxide in foods and beverages: its use as a preservative and its effect on asthma. *British journal of diseases of the ches*, **74**, 128-134.

García-Martínez, E., Igual, M., Martín-Esparza, M. E., Martínez-Navarrete, N. (2013). Assessment of the Bioactive Compounds, Color, and Mechanical Properties of Apricots as Affected by Drying Treatment. *Food Bioprocess. Technology*, **6,** 3247-3255.

Gezer, I., Acaroğlu, M., Hacıseferoğulları, H. (2003). Use of energy and labour in apricot agriculture in Turkey. *Biomass and Bioenergy*, **24**, 215-219.

Gezer, I., Dikilitaş, S. (2002). The study of work process and determination of some working parameters in an apricot pit processing plant in Turkey. *Journal of Food Engineering*, **53**, 2, 111-114.

Guleryuz, M, Ercisli, S, Esitken, A. (1997). A study on characteristics features of apricot grown in Erzincan, Malatya and Igdir provinces. *Acta Horticulturae*, 488: 165-170.

Gülcan, R., Mısırlı, A., Sağlam, H., Yorgancıoğlu, U., Erkan, S., Gümüs, M., Ölmez, H. A., Derin, K., Paydaş, S., Eti, S., Demir, T. (2006). Properties of Turkish apricot land races. *Acta Hort,* **701**, 191-198.

Gürbüz, O. (2010). Effect of exchange rate on dried apricot export in Turkey: A vector autoregression (VAR) analysis. *African Journals of Agricultural Research*, **5(18),** 2485 – 2490.

Hacıseferogulları, H., Gezer, I., Ozcan, M. M., Asma, B. (2007). Post-harvest chemical and physical–mechanical properties of some apricot varieties cultivated in Turkey. *Journal of Food Engineering*, **79**, 364–373.

Halliwell, B. (1994). Free radicals and antioxidants: a personal review. *Nutrition Review*, **52**, 253–265.

Haminiuk, C. W., Maciel, G. M., Plata Oviedo, M. S., Peralta, R.M. (2012). Phenolic Compounds in Fruits–an Overview. *International Journal of Food Science & Technology*, **47**, 2023-2044.

Heim, K., E., Tagliaferro, A., R., Bobilya, D., J. (2002). Flavonoid antioxidants: chemistry, metabolism and structure-activity relationships. **13(10),** 572–584.

Hui, Y. H. (2006). Handbook of Fruits and Fruit Processing. 1st Edition. USA: Blackwell Publishing.

Igual, M., García-Martínez, E., Martín-Esparza, M. E., Martínez-Navarrete, N. (2012). Effect of Processing on the Drying Kinetics and Functional Value of Dried Apricot. *Food Research International*, **47**, 284-290.

Imrak, B., Küden, A., Yurtkulu, V., Kafkas, E., Ercisli, S., Kafkas, S. (2017). Evaluation of some phenological and biochemical characteristics of selected new late flowering dried apricot cultivars. *Biochemical genetics*, **55(3),** 234-243.

Inserra, L., Cabaroğlu, T., Şen, K., Arena, E., Ballistreri, G., Fallico, B. (2017). Effect of Sulphuring on Physicochemical Characteristics and Aroma of Dried Alkaya Apricot: A New Turkish Variety. *Turkish Journal of Agriculture and Forestry*, **41**, 59-68.

Işınay, B. (2021). Effect of Combined Radio-Frequency and Solar Assisted Air Drying on Properties of Dried Apricot. Master Thesis, Gaziantep University, Food Engineering depart., Gaziantep.

İncedayı, B., Tamer, C. E., Sınır, G. Ö., Suna, S., Çopur, Ö. U. (2016). Impact of Different Drying Parameters on Color, β-carotene, Antioxidant Activity and Minerals of Apricot (Prunus armeniaca L.). *Food Science and Technology (Campinas)*, **36**, 171-178.

Jiménez, A. M., Martínez-Tomé, M., Egea, I. (2008). Effect of industrial processing and storage on antioxidant activity of apricot (Prunus armeniaca v. bulida). *Eur. Food Res. Technology,* **227,** 125–134.

Kan, T., Gundogdu, M., Ercisli, S., Muradoglu, F., Celik, F., Gecer, M. K., Zia-Ul-Haq, M. (2014). Phenolic Compounds and Vitamins in Wild and Cultivated Apricot (Prunus Armeniaca L.) Fruits Grown in Irrigated and Dry Farming Conditions. *Biological Research*, **47**, 46.

Kaplan, M., Eskigün, S., Levent, O., Baydir, A. Türk, D., H., Atik, A., Atik, İ., Erdoğan, A. (2020). Change of textural properties during fermentation in pickles made from unriped seeds of two domestic apricot cultivars ('Hacihaliloğlu' and 'Kabaaşı') in Malatya. *Acta Hortic*. **1290,** 207-212.

Karaaslan, S. (2012). Meyve ve Sebzelerin Mikrodalga Destekli Kurutma Sistemleri ile Kurutulması. *Journal of The Faculty of Agriculture*, **7(2),** 123-129.

Karabulut, I., Bilenler, T., Sislioglu, K., Gokbulut, I., Ozdemir, I., S., Seyhan, F., Ozturk, K. (2018). Chemical composition of apricots affected by fruit size and drying methods. *Drying Technology*, 1–12.

Karabulut, I., Topcu, A., Duran, D., Turan, S., Ozturk, B. (2007). Effect of hot air drying and sun drying on color values and β-carotene content of apricot (Prunus armenica L.). *LWT - Food Science and Technology*, **40**, 5, 753-758.

Karatas, F., Kamişli, F. (2007). Variations of vitamins (A, C and E) and MDA in apricots dried in IR and microwave. *Journal of Food Engineering*, **78**, 662–668.

Karataş, N. (2014). Farklı Kurutma Yöntemlerinin Bazı Kayısı Çeşitlerinin Kimyasal ve Fiziksel Özelliklerine Etkisi. PhD Thesis, Atatürk University, Graduate School of Natural and Applied Sciences, Erzurum, 155.

Kayran, S., Doymaz, İ. (2016). Infrared Drying and Effective Moisture Diffusivity of Apricot Halves: Influence of Pretreatment and Infrared Power. *Journal of Food Processing and Preservation*, **41(2),** 12827.

King, C. J., Bellows, R. J. (1973). Product collapse during freeze drying of liquid foods. *In AIChE Symp. Ser*, **69**, 132, 33-41.

Kumral, A. Y., Turgu, V., Yıldız, E., Kumral, N. A., Çevik, R. N., Sevinç, İ., Ersöz, E. (2018). Kuru Kayısılarda Ferrik Oksit ve Ozon Gazı Uygulamalarının, Kuru Meyve Akarı Carpoglyphus lactis (L.) (Acari: Carpoglyphidae) Kaynaklı Mikrobiyal Bulaşma Yüküne ve Meyve Kalite Parametrelerine Etkisinin Belirlenmesi. *Bursa Uludağ Üniversitesi Ziraat Fakültesi Dergisi*, **33(1),** 67-82.

Kyhos, K., Landfeld, A., Strohalm, J., Houska , M, Hoke, K, Zitny, R. (2010). Thermal diffusivity estimation of mashed potatoes and olive oil at high pressure. *Bio and food sciences*, 108-117.

Link, J. V., Tribuzi, G., de Moraes, J. O., Laurindo, J. B. (2018). Assessment of texture and storage conditions of mangoes slices dried by a conductive multi-flash process. *Journal of Food Engineering*, 239, 8-14.

Lopez-Galvez, F., Ragaert, P., Palermo, L. A., Eriksson, M., Devlieghere, F. (2013). Effect of new sanitizing formulations on quality of fresh-cut iceberg lettuce. *Postharvest Biology and Technology*, **85,** 102-108.

Madhlopa, A., Ngwalo, G. (2007). Solar Dryer with Thermal Storage and Biomass-backup Heater. *Solar Energy*, **81(4),** 449-462.

Madrau, M. A., Piscopo, A., Sanguinetti, A. M., Del Caro, A., Poiana, M., Romeo, F. V., Piga, A., (2009). Effect of Drying Temperature on Polyphenolic Content and Antioxidant Activity of Apricots. *European Food Research and Technology*, **228(3),** 441-448.

Mangaraj, S., Goswami, T. K., Mahajan, P. V. (2009). Applications of Plastic Films for Modified Atmosphere Packaging of Fruits and Vegetables: A Review. *Food Engineering Reviews*, **1(2),** 133–158.

Marakoğlu, T., Arslan, D., Özcan, M., Hacıseferoğulları, H. (2005). Proximate composition and technological properties of fresh blackthorn (Prunus spinosa L. subsp dasyphylla (Schur.)) fruits. *Journal of Food Engineering*, **68(2),** 137–142.

Marra, F., Zhang, L., Lyng, J. G. (2009). Radio-frequency Treatment of Foods: Review of Recent Advances. *Journal of Food Engineering*, **91**, 497-508.

McBean, D., Johnson, A. A., Pitt, J. I. (1964). The absorption of sulfur dioxide by fruit tissue. *Journal of Food Science*, **29**, 257-265.

Mir, M. A., Hussain, P. R., Fouzia, S., Rather, A. H. (2009). Effect of sulphiting and drying methods on physico-chemical and sensorial quality of dried apricots during ambient storage. *International Journal of Food Science & Technology*, **44(6)**, 1157–1166.

Miranda, G., Berna, A., Salazar, D., Mulet, A. (2009). Sulphur dioxide evolution during dried apricot storage. *LWT-Food Science and Technology*, **42,** 531-533

Montero, I., Blanco, J., Miranda, T., Rojas, S., Celma, A. R. (2010). Design, Construction and Performance Testing of a Solar Dryer for Agroindustrial byproducts. *Energy Conversion and Management*, **51**, 1510-1521.

Oster, O., Prellwitz, W. (1989). The daily dietary selenium intake of West German adults. *Biol Trace Elem Res,* **20**, 1.

Ozturk, F., Gul, M., Ates, B., Ozturk, I. J., Cetin, Vardi, N., Otlu, A., Yilmaz., I. (2009). Protective effect of apricot (Prunus armeniaca L.) on hepatic steatosis and damage induced by carbon tetrachloride in Wistar rats. *Br. J. Nutr.*, **102**, 1767-1775.

Örs, B. (2019). Sağlıklı ve Cazip Kuru Kayısı Üretimine Yönelik Yeni Bir Teknik: İndirgen Atmosferik Kurutma. Master Thesis, Iğdır University, Graduate School of Natural and Applied Sciences, Iğdır, 137.

Özbek, H. N., Yanık, D. K., Fadıloğlu, S., Göğüş, F. (2020). Optimization of microwave-assisted extraction of bioactive compounds from pistachio (Pistacia vera L.) hull. *Separation Science and Technology*, **55,** 289-299.

Özbek, S. (1978). Özel Meyvecilik (Kışın Yaprağını Döken Meyve Türleri). Çukurova Üniv. Ziraat Fak. Yay. No:128, Adana.

Özen, E. (2016). Farklı Kurutma Teknikleri İle Domatesin Kurutulması. Master Thesis, Fırat University, Graduate School of Natural and Applied Sciences, Elazığ, 68.

Özkan, M., Cemeroglu, B. (2002). Desulphiting Dried Apricots by Exposure to Hot Air Flow. *Journal of the Science of Food and Agriculture*, **82**, 1823-1828.

Özkan, M., Kirca, A., & Cemeroğlu, B. (2003). Effect of moisture content on CIE color values in dried apricots. *European Food Research and Technology*, ***216*****(3),** 217-219.

Özşahin, A., D., Yılmaz, O. (2010). Prunus armeniaca L. cv. Hacihaliloglu fruits extracts prevent lipid peroxidation and protect the unsaturated fatty acids in the Fenton reagent environment. *Asian Journal of Chemistry*, **22,** 10, 8022-8032.

Parlakpinar, H., Olmez, E., Acet, A., Ozturk, F., Tasdemir, S., Ates, B., ... & Otlu, A. (2009). Beneficial effects of apricot-feeding on myocardial ischemia-reperfusion injury in rats. *Food and chemical toxicology*, ***47*****(4),** 802-808.Pérez-Jiménez, J., Neveu, V., Vos, F., Scalbert,

A. (2010). Identification of the 100 richest dietary sources of polyphenols: an application of the Phenol-Explorer database. *European Journal of Clinical Nutrition*, **64(3),** S112–S120.

Prakash, O., Kumar, A. (2013). Historical Review and Recent Trends in Solar Drying Systems. *International Journal of Green Energy*, **10,** 690-738.

Rashidi, M., Seyfi, K., Gholami, M. (2007). Determination of kiwifruit volume using image processing. *J. Agri. Biol. Sci.*, **2,** 17-22.

Regier, M., Knoerzer, K., Schubert, H. (2017). Introducing microwave-assisted processing of food: Fundamentals of the technology. *Woodhead Publishing Series in Food Science, Technology and Nutrition, The Microwave Processing of Foods (Second Edition), Woodhead Publishing*, 1-22.

Rice-Evans, C. A., Miller, N. J., Paganga, G. (1996). Structure–antioxidant activity relationships of flavonoids and phenolic acids. *Free Radical Biology and Medicine*, **20**, 9.

Salur-Can, A., Türkyılmaz, M., Özkan, M. (2017). Effects of sulfur dioxide concentration on organic acids and β-carotene in dried apricots during storage. *Food Chemistry*, **221**, 412-421.

Sandarani, M. D. J. C., Dasanayaka, D. C. M. C. K., Jayasinghe, C. V. L. (2018). *Journal of Agricultural Science,* ***9*****(1),** 1–6.

Sandhya, (2010). Modified atmosphere packaging of fresh produce: Current status and future needs. *LWT-Food Science and Technology*, **43(3),** 381-392.

Sharma, N., Chandel, K. P. S. (1992). Low-temperature storage of Rauvolfia serpentina Benth. ex Kurz.: An endangered, endemic medicinal plant. *Plant Cell Reports,* **11**, 200–203.

Singh, Z., Singh, R. K., Vidhu, A., S., Pravendra, N. (2013). Mango - Postharvest Biology and Biotechnology. *Critical Reviews in Plant Sciences*, **32**, 4, 217-236.

Sobutay, T. (2003). Kayısı Sektör Araştırması İstanbul Ticaret Odası Dış Ticaret şubesi Araştırma Servisi. Şubat, 1-37.

Stafford, A. E., Bolin, H. R., Mackey, B. E. (1972). Absorption of aqueous bisulfite by apricots. *Journal of Food Science***, 37,** 941-943.

Şen, F., Karaçalı, İ., Eroğul, D. (2015). Effects of Storage Conditions and Packaging on Moisture Content, Water Activity and Tissue Hardness of Dried Apricots. *Meyve Bilimi*, **2**, 45-49.

T.R. Ministry of Food, Agriculture and Livestock. General Directorate of Crop Production. (2014). National Apricot Work shop. Technical Report. 18-19.

Taylor, S. L., Higley, N. A., Bush, R. K. (1986). Sulfites in foods: uses, analytical methods, residues, fate, exposure assessment, metabolism, toxicity and hypersensitivity. *Advances in food research*, **30**, 1– 76.

Türkyılmaz, M., Özkan, M., Güzel, N. (2014). Loss of Sulfur Dioxide and Changes in Some Chemical Properties of Malatya Apricots (Prunus Armeniaca L.) During Sulfuring and Drying. *Journal of the Science of Food and Agriculture*, **94,** 2488-2496.

Türkyılmaz, M., Tağı, Ş., Özkan, M. (2013). Changes in chemical and microbial qualities of dried apricots containing sulfur dioxide at different levels during storage. *Food and Bioprocess Technology*, **6**, 1526–1538.

Ünal, M. R. (2010). Apricot Research Report. Fırat Development Agency. Malatya.

Vadivambal, R., Jayas, D. S. (2007). Changes in Quality of Microwave-treated Agricultural Products: A Review. *Biosystems Engineering*, **98(1),** 1-16.

Wani, S., M., Masoodi, F., A., Wani, T., A., Ahmad, M., Gani, A., Ganai, S., A. (2015). Physical characteristics, mineral analysis and antioxidant properties of some apricot varieties grown in North India. *Cogent Food & Agriculture*, **1(1).**

Yamamoto, K., Osaki, Y., Kato, T., Miyazaki, T. (1992). Antimutagenic Substances in the Armeniacae Semen and Persicae Semen. *Yakugaku Zasshi*, **112(12),** 934–939.

Zhang, D., Hamauzu, Y. (2004). Phenolic Compounds and Their Antioxidant Properties in Different Tissues of Carrots (Daucus Carota L.). *Journal of Food Agriculture and Environment*, **2**, 95-100.

## CURRICULUM VITAE

**Personal Information**

**Name Surname:** Melis Sever

**Master Degree:**

Department of Food Engineering, Gaziantep University (2018-2021)

Master Thesis Study:

Drying of Pretreated Apricot by Combined Solar and Radio Frequency System

Master Project:

Pilot Scale Dried Apricot Production with Radio Frequency System and Solar Energy Assisted Air Drying System and Optimal Process Design: Pre-Treatment (Sulfurization / Extract Application), Drying and Storage, 1003 TUBITAK Project No: 118O026 (2019-2020)

**Academic Qualifications**

**Bachelor Degree:**

Department of Food Engineering, Gaziantep University (2013-2018)

Graduation Project:

Positive Effects of Omega-3 on human health (2018)

**Publications:**

1. Hatice Neval ÖZBEK, Aysel ELİK, Melis SEVER, Şakire Ecem BULUT, Derya KOÇAK YANIK,Ali Coşkun DALGIÇ, Ferruh ERDOĞDU, Fahrettin GÖĞÜŞ. (2021). Kombine güneş enerjisi destekli hava ve sıcak hava destekli radyo frekans kurutma sistemiyle kurutulan kayısıların bazı kimyasal ve mikrobiyal özellikleri üzerine depolamanın etkisi. *Food and Health*, *7*(4), 259-271.
2. Özbek Hatice Neval, Elik Aysel, Işınay Büşra, Sever Melis, Bulut Şakire Ecem,

3. Koçak Yanık Derya, Dalgıç Coşkun Ali, Erdoğdu Ferruh, Göğüş Fahrettin (2021). Kombine kurutma sistemiyle kurutulan kayısıların renk parametreleri üzerine depolamanın etkisi. *Akademik Gıda*, Baskıda.

**International and National Presentations:**

1. Melis SEVER, Büşra IŞINAY, Şakire Ecem BULUT, Hüseyin TOPÇAM, Hatice Neval ÖZBEK, Aysel ELİK, Fahrettin GÖĞÜŞ, Ali Coşkun DALGIÇ, Ferruh ERDOĞDU, Derya KOÇAK YANIK. (2019). Drying of whole sulphured apricots using pilot level solar energy assisted air drying and radio- frequency finishing system. 3rd INTERNATIONAL ZEUGMA CONFERENCE ON SCIENTIFIC RESEARCHES, November 22-24, Gaziantep, Turkey, 302-303.
2. Büşra IŞINAY, Melis SEVER, Şakire Ecem BULUT, Hatice Neval ÖZBEK, Aysel ELİK, Hüseyin TOPÇAM, Ferruh ERDOĞDU, Derya KOÇAK YANIK, Ali Coşkun DALGIÇ, Fahrettin GÖĞÜŞ. (2019). Effect of combined radio-frequency and solar assisted air drying on properties of dried apricot. 3rd INTERNATIONAL ZEUGMA CONFERENCE ON SCIENTIFIC RESEARCHES, November 22-24, Gaziantep, Turkey,300-301.
3. Şakire Ecem BULUT, Büşra IŞINAY, Melis SEVER, Hüseyin TOPÇAM, Aysel ELİK, Hatice Neval ÖZBEK, Ferruh ERDOĞDU, Derya KOÇAK YANIK, Fahrettin GÖĞÜŞ, Ali Coşkun DALGIÇ. (2020). Process Simulation of Drying of Apricot with Combined Radio Frequency and Solar Energy Assisted Air Drying (Poster Presentation). 2nd International Eurasian Conference on Science, Engineering and Technology (EurasianSciEnTech 2020), 07-09 October, Gaziantep, Turkey.