SEPTEMBER 2019 M.Sc. in Biochemical Science and Technology GHAITH ODAY YAQOOB AL-QUDSI

REPUBLIC OF TURKEY

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INVESTIGATION OF THE PRODUCTION OF TRADITIONAL DRIED EGGPLANT AND DEVELOPMENT OF A NEW METHOD FOR DRYING

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IN

BIOCHEMICAL SCIENCE AND TECHNOLOGY

BY

GHAITH ODAY YAQOOB AL-QUDSI

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Supervisor

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Ghaith Oday Yaqoob AL-QUDSI

ABSTRACT

INVESTIGATION OF THE PRODUCTION OF TRADITIONAL DRIED EGGPLANT AND DEVELOPMENT OF A NEW METHOD FOR DRYING

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M.Sc. in Biochemical Science and Technology
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The purpose of this thesis is to determine the effects of the traditional and artificial drying methods on the carved eggplant so as to propose alternative methods for drying. Infrared (IR) and sunlight simulation (SL) drying methods were used to determine the changes in the properties of eggplant during drying. The carved eggplants (as in traditional method (TR)) were placed to specially designed IR and sunlight chambers up to the traditional eggplant moisture level. The changes in the moisture content, total phenolic content, antioxidant content, total anthocyanin content, nutritional values (ash, protein, carbohydrate, fat), color (L*, a*, b* and YI), acidity, aerobic plate count, mold and yeast count values were determined. The drying period was decreased from 72 hour of traditional method to 5 hours by infrared and 30 hours by sunlight simulation drying methods. Better color values were acquired with the IR drying method compared to the traditional method. The lightness and redness of the samples changed significantly ($p \leq 0.05$) with both drying methods. Total anthocyanin content after IR drying was found to be significantly ($p \leq 0.05$) different than sunlight simulation and traditional drying methods. The microbial load significantly ($p \leq 0.05$) decreased with IR drying method. The results showed that both methods proposed might be the alternative methods to eliminate hygiene concerns of the traditional products. The study demonstrated that the two methods proposed might be used to design alternative production line for industry.

Key Words: Eggplant, Drying, Traditional, Infrared, Sunlight, Color, Antioxidant

ÖZET

GELENEKSEL KURUTULMUŞ PATLICAN ÜRETİMİNİN İNCELENMESİ VE KURUTMA İÇİN YENİ BİR YÖNTEM GELİŞTİRİLMESİ

AL-QUDSI, Ghaith Oday Yaqoob
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Bu tezin amacı, kuru patlıcanın geleneksel üretiminin incelenmesi ve güneşte kurutmaya alternatif yöntemler önermektir. İnfrared ve güneş ışığı simülasyonu kullanılarak kurutma sırasında patlıcanda meydana gelen değişimler incelenmiştir. Geleneksel yöntemde olduğu gibi içleri oyulan patlıcanlar özel olarak tasarlanmış infrared ve güneş ışığı simülasyonu kabinlerinde kurutulmuşlardır. Nem, toplam fenolik madde, antioksidan, toplam antosiyanin, besin değerleri (kül, protein, karbonhidrat, yağ), renk (L *, a *, b *, YI), asitlik, mikrobiyal yük değerlerindeki değişimler belirlenmiştir. Geleneksel yöntemde 72 saat olan kurutma süresi infrared ile 5 saate, güneş ışığı simülasyonu yöntemiyle 30 saate düşürülmüştür. IR kurutma yöntemiyle, geleneksel yönteme kıyasla daha iyi renk değerleri elde edilmiştir. Numunenin parlaklığı ve kırmızılığı kurutma yöntemleriyle önemli ölçüde değişmiştir ($p \leq 0.05$). IR kurutma sonrası toplam antosiyanin içeriği, güneş ışığı simülasyonu ve geleneksel kurutma yöntemlerinden önemli ölçüde ($p \leq 0.05$) farklı bulunmuştur. IR kurutma yöntemiyle mikrobiyal yük önemli ölçüde ($p \leq 0.05$) azalmıştır. Sonuçlar, önerilen her iki yöntemin de son üründe geleneksel yöntemdeki hijyen ile ilgili dezavantajlarını ortadan kaldırmak için uygun olabileceğini göstermiştir. Çalışma, önerilen iki yöntemin endüstriyel üretim hattı tasarlamak için kullanılabileceğini göstermiştir.

Anahtar Kelimeler: Patlıcan, Kurutma, Geleneksel, İnfrared, Güneş Işığı, Renk, Antioksidan

TO MY FAMILY ...

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LIST OF ABBREVIATIONS

Dried IR	Dried eggplant by infrared method
Dried SL	Dried eggplant by sunlight simulation method
Dried TR	Dried eggplant by traditional method
TAC	Total anthocyanin content
TPC	Total phenolic content
DPPH	2,2-diphenyl-1-picrylhydrazyl
TPTZ	2,4,6-Tris(2-pyridyl)-s-triazine
FRAP	Ferric reducing antioxidant power
G3G	Cyanidin-3-glucoside
FW	Fresh weight
GAE	Gallic acid equivalents
TE	Trolox equivalence
PCA	Plate count agar
PDA	Potato dextrose agar

CHAPTER 1

INTRODUCTION

1.1 Eggplant

Eggplant (*Solanum Melongena L*) is a vegetable, which is raised in the tropical and subtropical regions and contain a large variation of different shaped vegetables (George, 2009; Kashyap et al., 2003; Knapp et al., 2013; Mishra et al., 2013; Salunkhe and Desai, 1984; San José et al., 2016; Uthumporn et al., 2015). Depending on the shape, the eggplant can be divided in three botanical varieties: among them: the egg shaped (*S. melongena var. esculentum*), the long and slender type, (*S, melongena var. serpentinum*) and the dwarf shaped (*S. melongena var. depressum*) (Maroto, 2002; Rajam and Kumar, 2007) (Figure 1.1).

Eggplant is originated from East Asia mainly India, secondary Japan and China. Although it is an Asian vegetable, it has spread to the Mediterranean and now it is being cultivated worldwide: Africa, Europe and America (Table 1.1) (Daunay, 2008; FAO, 2019; Frary et al., 2007). According to the Food and Agriculture Organization (FAO) of the United Nation, the production of the Eggplant worldwide was around (52.3 million tons), specifically, 0.6 million tons in Iran, 0.82 million tons in Turkey and 1.3 million tons in Egypt (according to the FAO report in 2019). In fact, Turkey is one of the largest eggplant growers in the world. This vegetable, which annual production reached 883917 tons on an area of 25592 ha in 2017 according to the FAO 2019 report, is cultivated in greenhouses, tunnels and in the open field. While the production of eggplant for the year 2018 was 332742 tons according to the Turkish statistical institute (TÜİK, 2019) (Table 1.2). Eggplants consist of 92.7% water, 1.4% protein, 1.3% fibers, 0.3% fat, 0.3% minerals and the remaining 4% consists of various vitamins and carbohydrates (Khan, 1979).

As in many vegetables, it is preferred to be consumed while the eggplant is fresh. After the harvest, the eggplant should be kept in suitable conditions in order to keep its freshness. However, drying is the oldest method used to extent consumption out of the harvest period. Fresh eggplants, which can be dried in different ways, are traditionally dried in the sun in Turkey.

Figure 1. 1 Phenotypic variation in eggplant genotypes. [1] (Guillermo et al., 2014), [2] (Nisha et al., 2009), [3] (Knapp et al., 2013), [4] (San José et al., 2016). [5] (Akanitapichat et al., 2010), [6] (Uthumporn et al., 2015).

In Turkey, the most widely used drying method for vegetables (eggplant and pepper) is natural drying. Natural drying method is applied in other provinces, where dried eggplant is produced in Gaziantep (Figure 1.2). Climatic characteristics are very important in dry eggplant production. Gaziantep dry eggplant production area, showing climatic characteristics close to each other; Oğuzeli, Nizip, Karkamış and Araban districts. Gaziantep dried eggplant is an ancient famous and important dried vegetable. The most distinctive feature of Gaziantep dried eggplant is its color, taste and softness after cooking. Gaziantep dried eggplant is characterized as a light colored, thin wall thickness and softened after cooking (TPI, 2017).

Figure 1. 2 Eggplant growth in Gaziantep.

Table 1. 1 Worldwide production of eggplant (FAO, 2016).

Continent	Area harvested (ha)	Production (ton)
Africa	106526	1896091
Americas	15340	402271
Asia	1702280	49081305
Europe	33801	927715
Oceania	306	1737
World	1858253	52309119

Table 1. 2 Eggplant production in Turkey (TÜİK, 2018).

Year	Production (tons)
2008	180693
2009	197785
2010	221856
2011	229718
2012	241969
2013	252396
2014	261874
2015	250311
2016	291314
2017	344620
2018	332742

1.2 Literature Review

There are many studies on the drying kinetics of eggplant; using convective hot air dryer (Doymaz, 2011; Ertekin and Yaldiz, 2004), osmotic dehydration kinetics followed by convective drying (García-de la Cruz and Menegalli, 2004), cabinet drying (Doymaz and Göl, 2011), vacuum drying (Wu et al., 2007), ultrasonically assisted convective drying (Garcia-Perez et al., 2011), and fluidized bed drying (Elkhodiry et al., 2015).

Doymaz (2011) mentioned that wet part of the sample decrease during the drying process, allowing a safe storage for a long time. It also leads to a significant reduction in the volume/weight ratio, which reduces storage and transport costs.

The small layer drying behavior of eggplants was tested by Ertekin and Yaldiz (2004) in a laboratory dryer. The researchers determined also the effects of the pre-treatment and the thickness on the drying characteristics, time and quality of the product. It has been observed through their studies that hot air dryer was used to dried eggplant and the drying air temperature was inversely proportional to color lightness, while the drying air velocity was proportional directly to both rehydration ratio and color lightness.

Osmotic dehydration of the eggplant was studied by using the sodium chloride as an osmotic agent, and by hot air drying to accomplish the final moisture content suitable for storage. The permeability of the osmosis was performed at different times of immersion, salt concentrations and temperatures. After osmotic treatment, hot air drying time at 70°C reduced to half (García-de la Cruz and Menegalli, 2004).

Convective drying was used on dried eggplants slices by Doymaz and Göl (2011). Sample thickness and air temperature were tested to determine the effect on the drying kinetics of eggplant. Thickness of eggplants portions were ranged from 0.5 to 1 cm with drying time 330-495 min, respectively. While increasing drying temperature, drying time was reduced to 150 min.

The thin layer drying behavior of eggplants in a laboratory dryer was examined by shrinkage of dried eggplants increased by vacuum drying technique with an increase in drying chamber pressure (Wu et al., 2007).

Garcia-Perez et al. (2011) recommended that drying should be done by ultrasound technology and ultrasonically assisted convective drying to enhance the convective drying of eggplant by the higher internal mass transport.

Elkhodiry et al. (2015) shown studies on the effect of hot air temperature on the drying rate and moisture content in a fluidized bed dryer and on the actual temperature-dependent moisture diffusivities. In fact, the rate of drying and humidity decreased with time. According to authors results, a higher drying temperature decreases the drying time and increases the effective diffusivity of the moisture. Fluidized bed drying is therefore a practical and feasible method for eggplant preservation and drying while maintaining its qualitative characteristics (low rehydration rate and good color quality).

According to the literature review, there are many studies about eggplant and many drying methods, all of which are related with sliced horizontal or whole eggplant. The studies in caved eggplant is scarce. Besides, it has been determined that no studies have been carried out to make traditional eggplant drying process suitable for production in industrial scale.

1.3 Pigments

The most of the living entities had their colors from natural pigments. These pigments have a lot of biological functions besides coloration (Ong and Tee, 1992).

Plants play an important aesthetic role in providing a wide range of colors for flowers (Grotewold, 2006). Plant pigments are important proof for humans and other herbivores because they help identify plants that find parts of the plant such as roots, tubers, fruits, stems and leaves and determine stages of the plant development. It is clear that plant pigments are physiologically important and the recent research according to Parrado et al. (2018) suggests new protective mechanisms, photoprotective and anti-oxidants playing a positive role in human health. Pigments in the plant are important in the economic field by determining colors and patterns of enticing fruits and flowers. Pigments are also important on the nutritional level because they help us understand new emerging roles in field such as nutrition and health (Lee, 2005).

1.3.1 Chlorophylls

The chlorophylls are the most prevalent and, of course, the most significant of all pigments. In fact, they are the pigments accountable for photosynthesis, which is the basic living method that transforms light energy into chemical energy. Carbohydrates are made from carbon dioxide and water, releasing molecular oxygen in the existence of light. There are chlorophyll a and b in all green plants. Chlorophyll a is the primary pigment in greater crops and chlorophyll b is a secondary pigment.

1.3.2 Carotenoids

Carotenoids are one of the most important classes of pigments in plants and play an important role in identifying the quality parameters of vegetables and fruits (Van den Berg et al., 2000).

It is found mainly find them in algae, plants and photosynthetic bacteria, where they play an important role in the photosynthetic process. As well as, it is finding them in molds, yeast and some non-photosynthetic bacteria, where they might have a protective role against the damage that may be caused by light and oxygen (Britton, 1995; Ong and Tee, 1992).

Carotenoids are also responsible for many of yellow, red and orange hues of plant leaves, flowers and fruits along with the colors in some of the birds, fish, insects and crustaceans. The most known examples of the coloration of the carotenoid are the pinks of salmon and flamingos, the reds of tomatoes and peppers and the orange colors of citrus fruits and carrots (Pfander, 1992). Some 600 different carotenoids are known to exist naturally, while new carotenoids are still being identified (Mercadante, 1999; Ong and Tee, 1992). They are partially responsible for the colors of fall after the leaf chlorophyll has been destroyed (Krinsky and Johnson, 2005).

1.3.3 Anthocyanin

Anthocyanins are the biggest and most varied set of plant pigments extracted from the phenylpropanoid process, with distinct color from red to violet and blue (Van Tunen and Mol, 1991). These phenolic compounds are soluble in water and they are part of a large and widespread group of plant flavonoids. There are less than 20 anthocyanidins (aglycones or chromophores of anthocyanins), with different number and position of their hydroxyl groups and methyl groups. These pigments accumulate in the vacuoles and their stability and hue depending on the intravascular conditions such as pH, co-pigmentation with coexisting colorless flavonoids and formation of complexes with metal ions (Mazza and Miniati, 1993; Tanaka et al., 2008).

1.3.3.1 Nasunin

Nasunin is type of anthocyanin pigment, it was first separated from the group of eggplant by (Kuroda and Wada, 1933), and its structure was identified to be *delphinidin-3-diglucoside* acylated with *p*-coumaric acid (Kuroda and Wada, 1933, 1935). Finally, it was presented as *delphinidin-3-(p-coumaroylrutinoside)-5-glucoside* (Figure 1.3) by Sakamura et al. (1963).

Igarashi et al. (1993) mentioned that nasunin was proposed to inhibit peroxidation induced by a linoleic acid–lipoxygenase system. As a consequence, it is one of the greatest interests to analyses the free radical scavenging activity of nasunin, which have more powerful in vitro activity among several anthocyanins (Igarashi et al., 1993). Nasunin occurs as cis- and trans-isomers, which has been reported to be more stable. On the contrary, have been only found delphinidin-3-rutinoside and small quantities of *delphinidin-3-rutinoside-5-glucoside*, in Bulgarian eggplant (Tanchev et al., 1970), being devoid of acylglycosides.

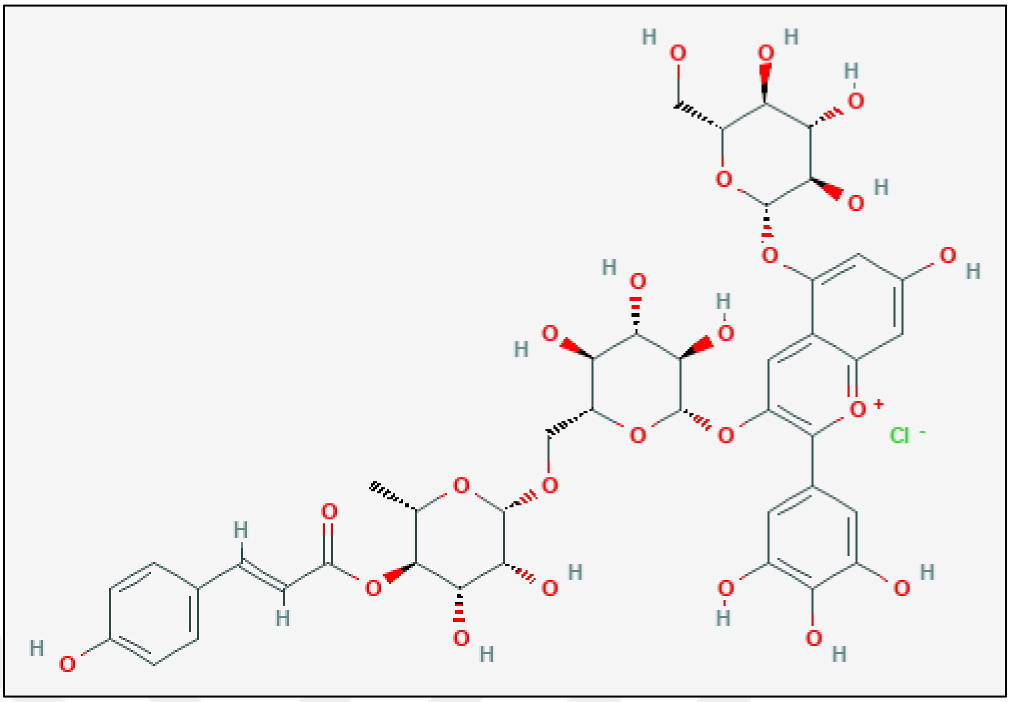


Figure 1. 3 Chemical structure of Nasunin (Pubchem, 2019).

Nasunin is a potent antioxidant and free radical scavenger that is known to protect the cell membranes from damage. However, eggplants were also shown to contain measurable number of oxalates that can cause problems in kidney and gallbladder (Noda et al., 2000; Whitaker and Stommel, 2003).

1.4 Photochemicals

The light is a crucial element in making the anthocyanin, it is important to identify, which wave-lengths of light are most influential. Light energy starts the process of photosynthesis when the pigments absorb it. The organic pigments have the ability to produce a small range of energy rates in which human retina or chloroplast thylakoid can absorb (Marra, 1978). As a consequence, the retinal pigments can absorb the light between 700 nm to 400 nm, which is known as the visible light. Accordingly, plants pigment molecules only absorb light in this specific wave range; plant physiologists call this range for plants the photosynthetically active radiation. Indeed, the light is a form of electromagnetic radiation that travels in waves. Other types of electromagnetic radiation that we are familiar with in our daily lives are the radio waves, microwaves, and X-rays. All together, they constitute the electromagnetic spectrum (Dickerson et al., 1979).

The pigment becomes excited when it absorbs a light photon, which means that it has gained extra energy and it is no longer in its normal, or ground, state. At a subatomic level, the excitation is defined when an electron is bumped into a higher-energy orbital that exists further from the nucleus (Figure 1.4). Only a photon with just the right amount of energy to bump an electron between orbitals can excite a pigment. As a matter a fact, that is why different pigments absorb different wavelengths of light: the "energy gaps" between the orbitals are different depending on each pigment, which means that the photons of different wavelengths are needed in each case to provide an energy boost that matches the gap (Mitch Singer, 2015).

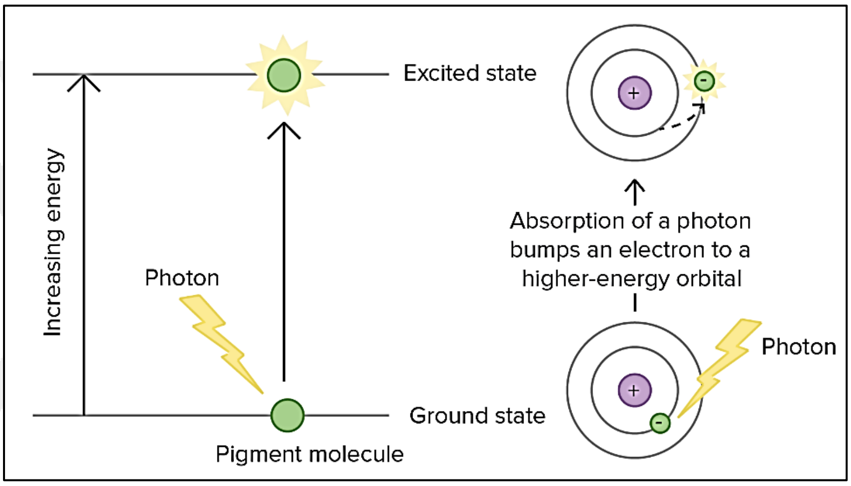


Figure 1. 4 Influence of light on molecules (Mitch Singer, 2015).

1.5 Bioactive or Phytochemicals compounds

Eggplant is a good source of vitamins and minerals, particularly iron, (Kashyap et al., 2003) and hence, it is important for human nutrition. Eggplant is ranked as one of the top ten vegetables in terms of oxygen radical scavenging capacity due to the fruit's phenolic constituents (Cao et al., 1996). Eggplant is a rich source of bioactive compounds, which is known to be a substance that as a biological activity which is able to synchronize metabolic processes (Minussi et al., 2003; Zhang and Hamauzu, 2004). Bioactive compounds contain phenolic substances, antioxidant compounds, carotenoids, vitamins, and flavonoids which are already available in fruits and vegetables (González-Molina et al., 2010). These substances have the ability to decrease the risk of carcinogenesis, atherosclerosis, diabetes, Alzheimer, cataracts and antimicrobial actions (Atoui et al., 2005; Stommel and Whitaker, 2003; Zhang and

Hamauzu, 2004). An increase in consumer recognition in bioactive components has led to a link to foods, which contain more functional bioactive compounds (Hasler et al., 2000). Food processors are now focusing more on food products with a higher bioactive compound in order to meet the market trend. Phytochemicals including polyphenolic compound, nutrients, and non-nutrient compounds such as vitamins, fibers and minerals (iron) are the main elements which lead to health boosting ingredients (Kashyap et al., 2003). These health boosting ingredients of fruits and vegetables can serve as the main ingredients in producing food with a beneficial dietary value. Eggplants contain these main antioxidants which are two vitamin C and E, phenolic, carotenoids and Flavonoids compounds; It contains a big defense system; vitamin C and carotenoids in which both play a role as the first defense line against oxidative stress (Krinsky, 2001; Shi et al., 2001); while the second defense line is known to contain Flavonoids and Vitamin C to offer a protective activity in human low-density lipoprotein (LDL) and participate in the formation of vitamin E (Zhu et al., 2000). Many research analyses have shown approaches to minimize the losses and maintain nutritional value in the vegetables and fruits (Özkaya and Dundar, 2009; Özkaya and Dündar, 2009).

1.6 Drying

Drying is the one of the most ancient techniques of food preservation and it is also one of the most used processes to improve food stability, since it decreases the water activity of the product, reduces microbiological activity and physical and chemical modification during storage (Mayor and Sereno, 2004). The most common drying method in many developing countries is the drying in the open air. This technique can be conducted in the direct sunlight or under shaded conditions. Indirect sunlight heats food effectively by driving out water from the within the components, but direct sunlight and heat can significantly affect thermally-sensitive vitamins and pigments. Changing the phases and making a solid-state product at the end are crucial stages of the drying process. Drying is an energy-intensive process consuming about 10-25% of the total energy used in the manufacturing process worldwide (Passos, 2000). The large diversity of dehydrated foods presented in the market such as dried vegetables, dried fruits, snacks and dried mixes of soups, etc. and the concern for quality and energy conservation makes the needs for understanding the drying techniques even more essential (Krokida et al., 2003). Drying foods is important for many reasons such as getting free-flowing properties, reducing bulk, desired size, shelf life extension, storage and easy handling and transportation. It also makes preservation a lot easier since the microorganisms that spoil food and decay cannot grow and multiply in a dried environment and many of the enzymes that cannot function in the absence of water. (Earle, 1983).

Water is present mainly in two forms in vegetables: free and bound. Free water occurs as pure water, and bound (connected) water is physically or chemically bound to food materials. Dehydration of food is not just removing water from the food elements, since it also serves to preserve the shape, sensory characteristics, and the nutritional value of the original material (Aguilera et al., 2003). The quality of the dried vegetables depends most importantly on the drying conditions implemented in the drying process as well as the type of the dryer. It also depends on the composition and physical properties of the raw material. Quality limits and degradation like the decrease in rehydration capacity, shrinkage, aroma, color and loss of taste and nutritional value are the main problems to be solved during drying (Sablani, 2006). Conventionally, the vegetables are to be dried in the sun or open air. Sun drying, is one of the most used drying methods for vegetables and fruits in the tropical and subtropical countries, because of the climate that allows sun energy without any charge. But, the rate of drying, in sun drying depends mostly on the weather conditions, so the final product quality is mainly acceptable rather than desired or very good (Gallali et al., 2000; Murthy, 2009). On a traditional level, the drying of heat-sensitive materials, is very sensitive issue, there is an upper limit for the drying temperature above which sensory and nutritional quality of the food material will decrease in different amounts depending on the type of the material, time and temperature of drying. The modern belief in the development of new vegetable drying technologies, aims essentially at using a low level of temperatures during drying and/or increasing the heat and mass flues to obtain better-quality products (Kudra and Mujumdar, 2009).

1.6.1 Infrared (IR) drying

One of the popular methods of dehydration is the infrared drying. IR radiation energy is transferred from the heating component to the product surface without even heating the air surrounding it. The radiation penetrates the exposed material and transform to sensible heat (Ginzburg, 1969).

Absorptivity of the dried material decreases while its transmissivity and reflectivity increase during the drying process, due to the decrease of its moisture. The transmissivity, absorptivity and the skin depth depend on the wavelength, density and on the properties of irradiated materials of IR heating. There are advantages of infra-red radiation covering high heat transfer coefficients, easy temperature material control and short time drying (Nowak and Lewicki, 2004).
The drying kinetics depends on the wavelength of radiation and the density, on the distance between infrared energy transmitter, on the air velocity as well as the heat-irradiated surface.

The drying kinetics increases usually with the increase of the material temperature and relative humidity of the drying medium decreasing. But the drying temperature should not be too high, because if so, it could cause a heat labile phytochemical ‘thermal degradation (Rieger and Šesták, 1993). A decrease in the size of the dried materials can also reduce the drying duration. Inactivation of enzymes and improving the microbiological purity of products (Kiseleva, 2007). Such material properties as color, ability to uptake water and mechanical resistance to breakage are not dependent on the way how the heat is supplied to the material undergoing drying (Kocabiyik and Tezer, 2009). The most important variables are material final temperature and the drying rate (Kocabiyik and Tezer, 2009). High drying rate can cause damage of the tissue and the material, making it becoming fragile (Kocabiyik and Tezer, 2009). The drying rate decreases with the decreasing moisture content and infrared power during the IR drying process (Ong and Law, 2011). In the final stages of the drying process, material temperature causes some browning due to chemical changes (Kocabiyik and Tezer, 2009).

1.7 Objective of the Study

The aim of this study is to review on the production technique of eggplants. There is a need to improve the quantity and quality of production since its limited. In order to eliminate shortcomings of traditional method by keeping the quality high, infrared and sunlight simulation drying methods were proposed. The methods were designed to fit industrial production to increase production rate.

The aims of this study are; (I) to investigate the effects of artificial sunlight simulation drying and infrared drying on the drying characteristics and the quality parameters of eggplants and (II) to overcome unintended consequences, an alternative technique for drying which is safer and hygienic has been improved also to make a quantitative and qualitative leap in the Turkish economy in terms of increasing production (III) to work in all seasons and overcome the climatic dependency, that consider the main reason to make the drying process seasonal.

The objectives of this thesis are:

- To offer alternative drying methods for sun drying.
- To investigate the effect of sunlight simulation and Infrared on the color of eggplant before/after drying characteristics and quality parameters of eggplants.
- To investigate the quality in terms of physical and chemical properties of traditional eggplants.
- To investigate the difference of nutritional value of traditional dried eggplants.

CHAPTER 2

MATERIALS AND METHODS

2.1 Materials

Eggplants *(Solanum melongena L.)* were purchased from a local farm in Oğuzeli, Gaziantep, Turkey and stored in a refrigerator at 4°C. In order to prepare eggplants for drying particular, knife and carving tool were purchased from a local store (Figure 2.1).

Sodium carbonate anhydrous (Na_2CO_3), iron (III) chloride hexahydrate ($FeCl_3.6H_2O$) and sodium acetate trihydrate ($C_2H_3NaO_2.3H_2O$) were obtained from ISOLAB chemicals (Germany).

Ethanol (C_2H_5OH), methanol (CH_3OH), Trolox ($C_{14}H_{18}O_4$), TPTZ ($C_{18}H_{12}N$), concentrated hydrochloric acid (HCl) and sulfuric acid (H_2SO_4) were obtained from Sigma-Aldrich (Germany).

Citric acid monohydrate ($C_6H_8O_7 * H_2O$) was purchased from Merck (Austria). Folin–Ciocalteu's phenol reagent was obtained from Merck (Germany). DPPH 1,1-diphenyl-2-picrylhydrazyl was obtained from TRC (Canada).

Figure 2. 1 Carving tools.

2.2 Traditional drying

Traditional drying, in Turkey, is generally used for vegetables drying. Due to the heat, evaporation increases making water evaporate from the surface of food (Togrul, 2003).

Convective hot air drying is for sure one of the most efficient method during the early stages of the drying process. As the process continues, drying progresses slowly down, requiring more energy (Argyropoulos et al., 2011).

Eggplant is grown almost every province in Turkey. However, traditional drying of (dolmalık) eggplant is limited. Most of the produced eggplants are consumed as fresh, while in some provinces consumers dries eggplants for individual household needs. On the other hand, traditional dried eggplant production establishments for commercial purposes were found in Gaziantep, Kilis, Adana, Aydın, Denizli, Kahramanmaraş and Şanlıurfa.

It is not exactly known how much of the fresh eggplants preserved as dried. Some local sources in Gaziantep stated that 60% of the eggplants produced were dried and 40% consumed as fresh, while some sources reported that this rate was 70% for drying and 30% for fresh.

Gaziantep cuisine is the richest and most varied in Turkey. Gaziantep is well-known for its long gastronomic history and has been added to the list in the gastronomy category of UNESCO’s Creative Cities Network since 2015. Gaziantep’s cuisine is recognized as one of the world’s most important cuisines. Nowadays, gastronomy remains the one of the main driving forces of the local economy. Gaziantep cuisine and culture have now started to become increasingly popular in Turkey and in the world. This city has the characteristic of being the most interesting regional center of culinary culture. In Gaziantep, most used and popular traditionally dried vegetables are eggplant, zucchini, acer and pepper. Especially locally-produced round small eggplants are used for drying. The most distinctive feature of Gaziantep dried eggplant is its color, taste and softness after cooking. It is characterized as a light colored, thin wall thickness and softened after cooking. It differs from the products of other provinces in terms of shell color and hardness (TPI, 2017). Oğuzeli is center of production and sun drying of eggplant, in Gaziantep. It is one of the most famous areas that utilize in the process of drying eggplant. It has been a settlement area for planting and drying since ancient times, because of soil properties and favourable climate. The traditional sun drying process has several stages (Figure 2.2).

Figure 2. 2 Traditional sun drying process applied in Gaziantep

a-Harvesting: Eggplant 10-15 cm, purple, plump and green stalk should be thin. Labour collect fresh eggplants manually from the field. it is collected and processed within one day at the latest (Figure 2.3).

Figure 2. 3 Fresh eggplants.

b- Cutting and carving: Sharp knives are used for trimming the lower part to get rid of the stem. The head of the eggplant is cut 2-3 cm and carving process is carried out. Carving tools are used in order to remove the interior pulp. The most important part to be considered in carving process is the thickness. If it is too thick, seeds can stay in the core and dry up slowly as shown in Figure 2.4. If the shell remains very thin, the flavour may be reduced. Carving is based on skill and experience. Handwork is very important in this process. To prevent damage to the eggplant, it’s necessary to remove the pulp without disturbing the outer skin. The thickness of digging fresh eggplant about 0.3-0.5 cm.

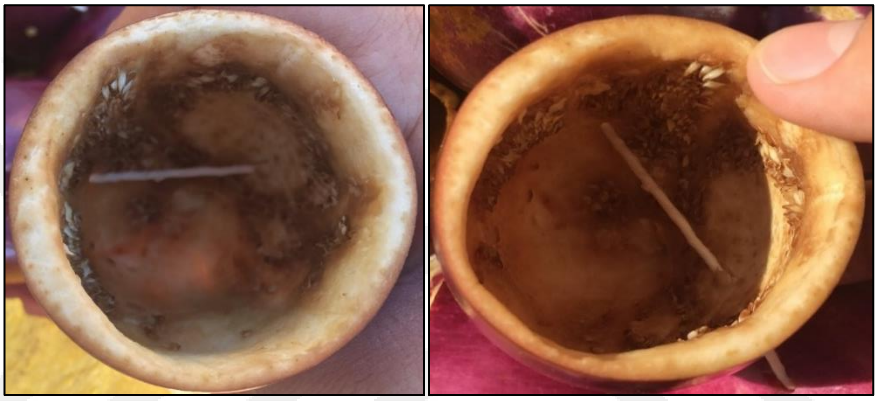


Figure 2. 4 Digging fresh eggplant.

c. Washing: The washing process is carried out by holding the water with the hose to the pile of eggplants. Eggplants take in water and swell and dry without disturbing the shape. It is transferred to drying areas. The eggplant is not washed during the drying process.

d. Hanging: Carved eggplants are being hung through a long rope and the carved side should be to word bottom. A 2.5 meters rope holds 50 pieces of fresh eggplant. Needle is used to line-up the eggplants through this rope. The most important point in this process is that the rope should be about the closed side of the eggplant. This allows the open mouth of the eggplant look through the soil. Otherwise, it may cause the eggplant to rupture during drying (Figure 2.5).

Figure 2. 5 Fresh eggplant hanged with rope.

e. Sun-drying: This process needs shadow of sunlight, drying takes place within 1-3 days under the temperature of 30-41 C°. Drying starts by hanging the ropes on the benches (Figure 2.6 and 2.7). The wind is also as important as the sun during drying. For this reason, the benches were built on the mountain skirts. Eggplant does not directly contact the sun. An environment with semi-sun semi-shadow is provided by tree branches. One of the most important points of drying is red soil under the drying benches. The red soil reflects the sunlight, allowing the product to dry out. Eggplant dries in 1-2 days, but it can go 3-4 days after September. Quality problems such as undesirable flavor, loss of nutrients, rehydration capacity, texture, sensory characteristics, shrinkage, reduction in bulk density and color can be caused by a long-time heat exposure (Figure 2.8). The length of the fresh eggplant is about 7-8.3 cm while the length of dried is about 5-5.3 cm. The drying season starts at the beginning of June and ends in mid-October.

Figure 2. 6 Dried eggplant under the shadow.

Figure 2. 7 Sun drying process of eggplant.

f. Collecting the dried eggplants: By the naked eyes, the physical condition, appearance and crispness of eggplants are monitored to obtain ideal product Figure 2.9.

Figure 2. 8 The excess exposure to the sunlight.

Figure 2. 9 Dried eggplants after traditional drying.

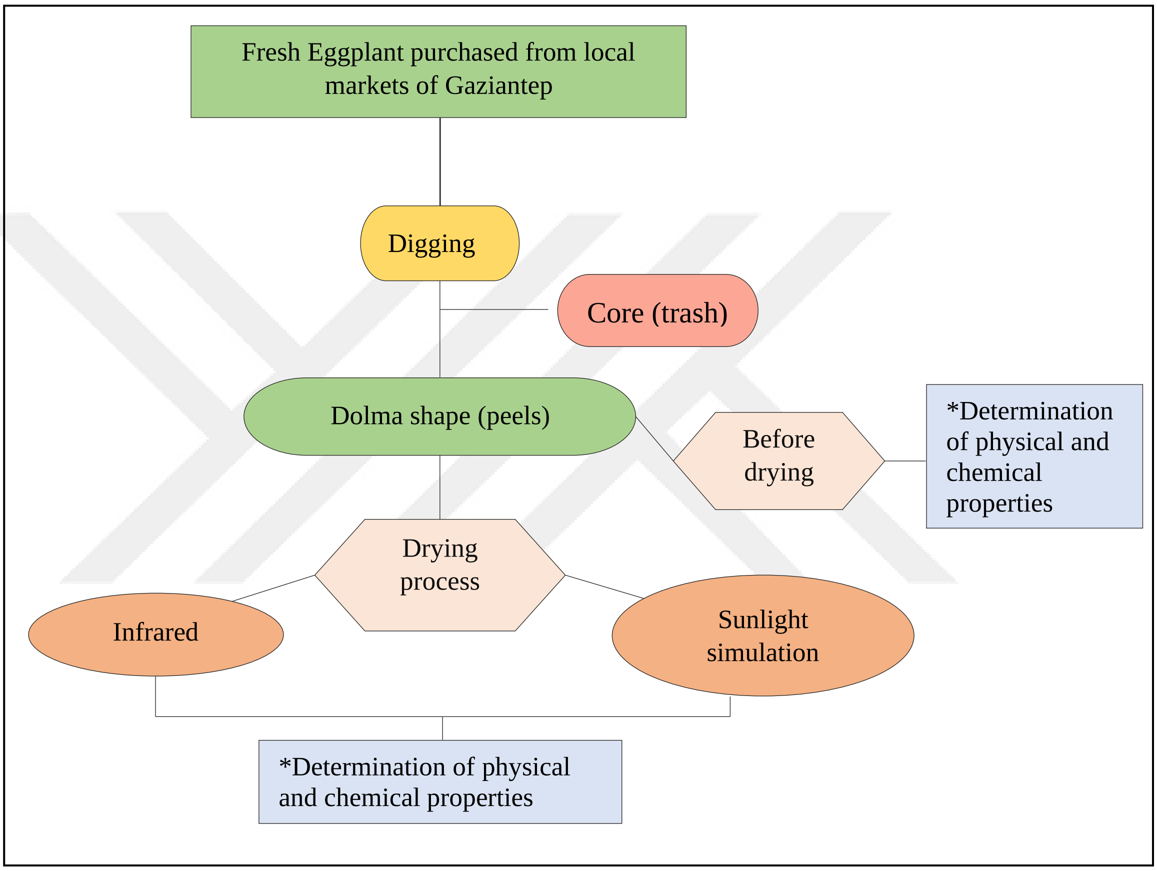
g. Storage: Finally, the ropes of dried eggplants are stored in big plastic bags so as to keep them away from insects, dust, and climate conditions. It's were hanged on the ceiling due to rats and insects in the storage, kept cool and away from humidity for one-year (Figure 2.10).

Figure 2. 10 Dried eggplant hanged on the ceiling in a big plastic bags.

2.2 Artificial Drying Methods of Eggplant

2.2.1 Experimental method

In order to determine the operation parameters of drying process some preliminary studies were conducted to set the appropriate time for drying as well as set the optimum. The experiment setup is shown in (Figure 2.11).



<u>* Physical properties</u>
Color characteristics, thickness and appearance
<u>*Chemical properties</u>
Moisture content, total phenolic content, antioxidant content, total anthocyanin content, nutritional values (ash, protein, carbohydrate, fat), acidity, aerobic plate count, mold and yeast count.

Figure 2. 11 Experimental set-up.

2.2.1.2 IR drying

A chamber was designed with dimensions 110x60x60 cm and the walls of chamber were covered fully with aluminum foil to increase the reflection of infrared radiation. An infrared heater (SFH 3396 2500 W, Sinop, Turkey) was placed to the top. Two identical fans were placed to obtain a regular air flow (10x10 cm) (Bekatech, AC axial fan, Turkey) (Figure 2.12). The drying temperature and humidity were measured by Thermo-hygrometer (HD 50, KIMO, France) (Figure 2.13a) 43°C and 13.5 % RH, respectively. Wind speed (0.77 m/s) was measured by using a digital Flow Meter (LCA6000, Airflow Developments Limited, England) (Figure 2.13b). Moisture content of the samples was measured every two hours.

Figure 2. 12 IR drying chamber.

Figure 2. 13 The tools used in experiments (a- Thermometer; b- Airflow meter)

2.2.1.3 Sunlight simulation method

The sunlight has been simulated with an artificial light using 4 types of lambs, lights of chamber contains D65 Day Light -6500 K (Master TL-D 90 De Luxe 18W/965, Philips, Holland), TL84 White Light 4000 K (Master TL-D 18W/840, Philips, Poland), Inca Light Soft 2300-2800 K (Tekfen, Turkey), UV ultraviolet lamp (ETT, F18 T8 BLB, PRC) as shown in Figure 2.14 (Balci, 2015). The samples were placed to chamber (A&T 102-A, A&T, Turkey) under the controlled conditions ambient temperature (40x40x40 cm, 2450 lux). Fan was used to produced regular air flow. The conditions in the chamber were of 38 °C and 17.3 % RH and the drying process continued up to 30 hours.

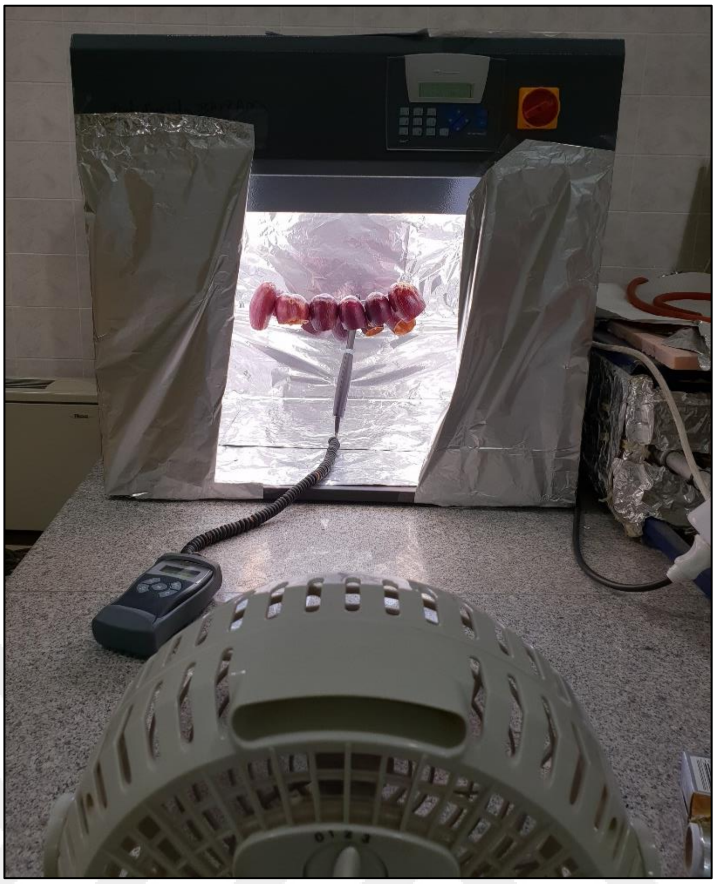


Figure 2. 14 Sunlight simulation chamber.

2.3 Chemical and Physical Analysis

2.3.1 Determination of moisture content

Moisture content (d.b, %) was measured by Method 934.0 (AOAC, 2000) by using an oven (JSOF-100, Korea) at 105±5 ºC in triplicate.

2.3.2 Determination of thickness

Thickness of fresh and dried eggplant was measured by a digital caliper (INSIZE, model: 1108-150, USA) at four sides of samples.

2.3.3 Determination of ash

Ash content (d.b., %) was measured by using Method 930.30 (AOAC, 2000) at 550±5 ºC in triplicate.

2.3.4 Measurement of color values

HunterLab ColorFlex (Model No. 45/0, USA) was used to measure the color values of fresh and dried eggplants in term of CIE L* (lightness/darkness), a* (redness/greenness) b* (yellowness/blueness) and YI (yellow index) values in triplicate (Figure 2.15).

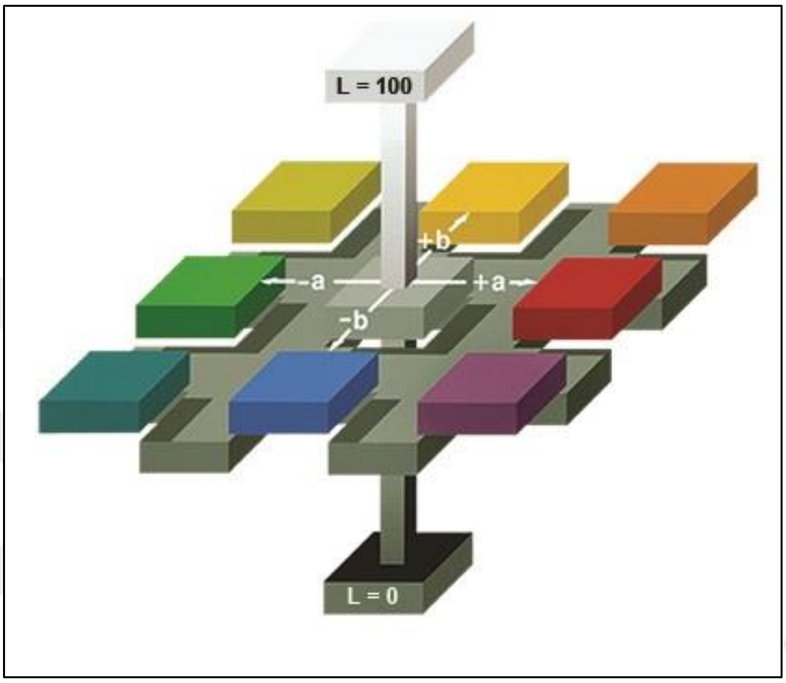


Figure 2. 15 HunterLab color scale (Stotto, 2018).

2.3.5 Determination of protein content

The protein contents of the samples were measured by Kjeldahl Method of AOAC (2000) with nitrogen value (N=5.7) (Fujihara et al., 2001). Analyses were made in triplicate.

2.3.6 Extract of Anthocyanin from fresh and dried eggplant

Extraction conditions were determined according to Can (2017) with slight revisions. Ethanol was used due to high extracting power. Ethanolic extracts contain high amounts of bioactive (Flores et al., 2014).

The sample was crushed by stainless steel blade grinder (Sinbo,Turkey) until the pieces get powder. The solvent (ethanol:water) was added to the sample and 0.5% (m/v) of citric acid was added. According to Harborne (1958), anthocyanin shows maximum wavelength with acid medium. Extraction took 45 minutes with temperature 50 ºC (±5 ºC) on the magnetic stirrer 550 rpm. Stretch film and aluminum foil have been used to cover beaker in order to protect it from oxygen and light influence. Extracts were stored in a refrigerator at 4 ºC until the experiments. Extraction efficiency was calculated according to the equation Eq (2.1).

$$\text{Extraction efficiency (\%)} = \frac{\text{Total phenolic content of extract}}{\text{Total phenolic content of eggplant}} * 100\ \% \qquad (2.1)$$

2.3.7 Determination of total anthocyanin content (TAC)

The total anthocyanin content of fresh and dried eggplants was measured according to the pH-differential method in triplicate (Lee et al., 2005).

2.3.8 Determination of total phenolic content (TPC)

TPC was determined according to Singleton et al. (1999) based on Folin-Ciocalteu's method. A spectrophotometer (Optima SP 3000 nano, Japan) was used to detect phenolic compounds at a wavelength of 760 nm in triplicate.

2.3.9 Determination of 2,2-diphenyl-1-picrylhydrazyl (DPPH•) scavenging activity

The 2,2-diphenyl-1-picrylhydrazyl (DPPH•) major scavenging activity of samples was determined according to Brand-Williams et al. (1995) method in triplicate.

2.3.10 Determination of ferric reducing antioxidant power (FRAP)

The ferric reducing antioxidant power of fresh and dried eggplant were measured according to Benzie and Strain (1996) method with some modifications. Ferric reducing antioxidant power (FRAP) solution were consisted of 300 mM sodium acetate buffer, 10 ml of TPTZ solution and 20 mM iron (III) chloride solution, respectively. After preparing FRAP solution, it was kept in dark place for 10 mins. The wavelength was used to measure the absorbances of the samples at 593 nm. All measurements were done in triplicate.

2.3.11 Determination of acidity

Acidity of dried eggplants were determined according to method 942.15 AOAC (2000). Analyses were made in triplicate.

2.3.12 Determination of aerobic count plate

Total aerobic count was determined according to method 990.12 AOAC (2000) by using PCA petri dish. All analyses were determined in triplicate.

2.3.13 Determination of mold and yeast count

Total mold and yeast count were determined according to method 997.02 AOAC (2000) by using PDA petri dish. All analyses were determined in triplicate.

2.3.14 Statistical Analysis

Statistical analysis was performed with SPSS statistical software (SPSS Inc. version 22, Chicago, IL). Using analysis of variance (ANOVA) at $p \leq 0.05$ significance level. Duncan's Multiple Range Test was used to determine the differences between the samples. Statistically significant correlations ($p \leq 0.05$) were determined according to the Pearson correlation test.

CHAPTER 3

RESULTS AND DISCUSSIONS

In this study, the traditional eggplant drying method was investigated. The change in physical and chemical properties of dried eggplant were determined. In order to propose an alternative drying method to eliminate the negative effect of traditional drying, sunlight simulation and IR drying method were applied the samples with the same production order of traditional methods. The physical properties (MC, AC, PC, FC, color characteristic), chemical properties (TAC, TPC, DPPH, FRAP, acidity) and microbiological changes of samples compared for three different drying methods. Also, the energy consumption of the drying method was compared for determination of suitability for industrial production.

3.1 Physical Properties

3.1.1 Moisture Content

The moisture content of fresh eggplants was 91.72%. The moisture content of samples decreased with different drying methods such as Infrared drying, sunlight simulation method and traditional drying method. The final moisture contents of the drying operations were 7.01%, 7.32% and 8.51 %, respectively (Table 3.1). These results correspond with the results of Ertekin and Yaldiz (2004) and it was noticed the moisture content decreased around 92% in comparing to raw material.

The IR drying process took approximately 5 hours, while the sunlight simulation drying process took about 30 hours, compared to traditional drying process took around 72 hours average on the climate conditions.

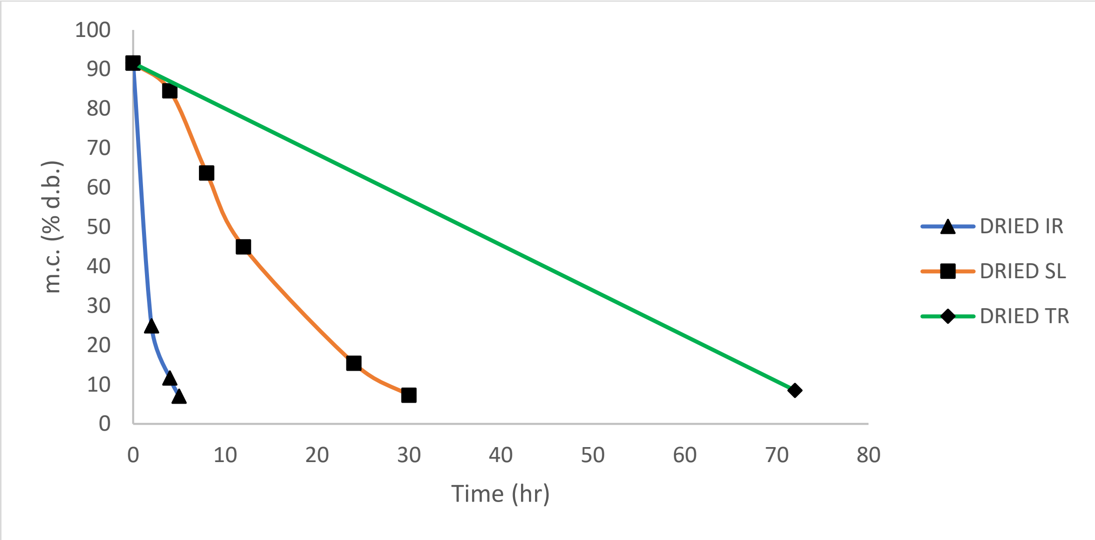


Figure 3. 1 Change of moisture content during drying process.

As shown as in Figure 3.1, the drying time of IR drying was about 5 hours, which was significantly lower than sunlight simulation drying. Shorter drying time in IR heater can be explained by the rapid mass transfer within the food during heating. Figure 3.2 indicate the differences between dried eggplants with three different methods.

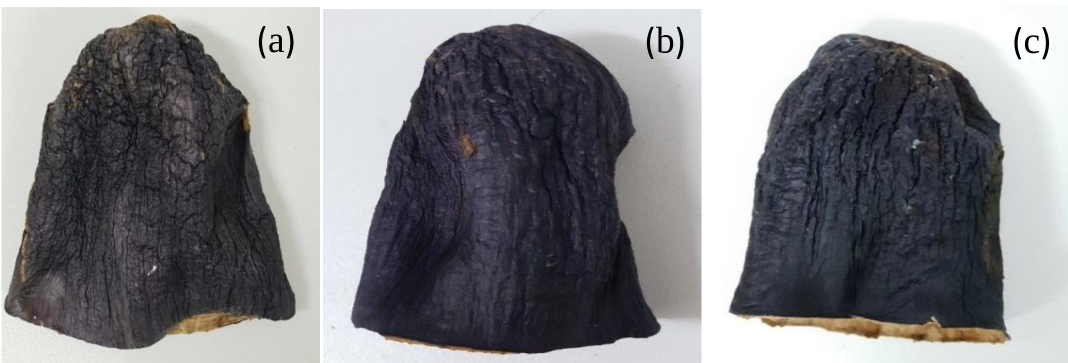


Figure 3. 2 Dried eggplant by (a) Dried TR, (b) Dried SL, (c) Dried IR

Table 3. 1 Moisture content of dried eggplant.

Moisture content (%, d.b.)	Initial	Final
TR	91.58 (±0.08)	8.51 (±0.33)
IR	91.58 (±0.09)	7.01 (±0.76)
SL	91.58 (±0.10)	7.32 (±0.18)

± standard deviation, (d.b.): dry base
TR: Traditional dried, IR: Infrared dried, SL: Sunlight simulation dried

Energy consumption for 1 kg of eggplant by IR drying method was 45.43 kWh/kg (2500 W x 5-hour x 0.785 kWh/kg for 2 fan x 0.5 TL/kwh tax) cost will be ~ 22.7 Turkish lira per kg. While for sunlight simulation drying method, energy consumption for 1 kg was 3.86 kW/h (18 W x 2 lambs x 30-hour x 0.5 TL/kwh tax) with cost ~ 2 Turkish lira per kg. But for traditional drying there are many of expenses and conditions such as renting drying place, transportation costs, laboring costs, loss of the products, contamination, sudden climate change that leads to damage to the product, the presence of birds that are damaging the product also, hygiene effects which is one of the main factors affecting on the quality of the product such as exposure to germs, dust or insects. Therefore, sunlight drying is the cheapest among the others, while sunlight and IR drying is evenly better than traditional drying methods in terms of hygiene.

3.1.2 Thickness

The thickness (mm) of fresh and dried eggplants was shown in Table 3.2. The thickness of the product is one of the quality parameters that affects the decision of the customer. In this study, the ultimate purpose was to obtain the similar results with traditional dried eggplant. The thicknesses of the eggplants were decreased significantly ($p \leq 0.05$) during drying. The thicknesses of the samples were decreased to half of the fresh eggplant with all methods.

Table 3. 2 Thickness values of eggplant samples before and after drying.

Sample	1	2	3	4	Mean	Std. Dev.
FRESH	2.43	2.15	2.61	2.57	2.41^a	0.24
	2.16	2.07	2.32	2.57		
	3.06	3.16	2.57	2.13		
	2.61	1.62	2.57	1.96		
IR	0.92	0.93	0.95	1.42	1.19^b	0.2
	0.99	1.46	1.26	1.26		
	1.25	1.14	1.84	1.54		
	0.93	0.91	1.21	0.98		
SL	0.98	1.18	0.99	1.02	1.22^b	0.36
	1.05	1.03	0.98	1.12		
	1.98	1.65	1.84	1.54		
	0.89	0.97	1.31	0.97		
TR	1.38	1.87	1.07	1.18	1.27^b	0.1
	1.31	1.08	1.14	1.24		
	1.25	1.24	1.22	1.34		
	1.1	1.05	1.44	1.38		

1, 2, 3, 4 in mm shows the different sides of caved eggplant.
The letters show significant difference at $p \leq 0.05$ between samples for each parameter.
TR: Traditional dried, IR: Infrared dried, SL: Sunlight simulation dried

3.1.3 Ash Content, Protein Content, Fat Content

The ash, protein and fat content of the dried samples was determined after each drying method (Table 3.3). The values measured only for the skin of the eggplant on dry basis. In fact, there is no reasonable difference obtained. The values of protein and fat contents were similar for all samples. It noticed that ash content of Dried TR eggplant significantly ($p \leq 0.05$) more different than both IR and sunlight methods. The reason maybe during the traditional drying, the eggplant was exposed to some kind of dust. These results are similar to the studies of Khan et al. (2015); Rodriguez-Jimenez et al. (2018). Rodriguez-Jimenez et al. (2018) found the ash, protein and fat content of sliced eggplant dried in a drying oven as 7.31, 12.5 and 1.75, respectively. It might be concluded that most of the ash and protein in eggplant might be in the skin in contrast to fat content. As a result, drying methods had no direct effect on nutritional value of the eggplants.

Table 3. 3 Ash, protein and fat content after drying methods.

Samples	Ash content (%, d.b.)	Protein content (%, d.b.)	Fat content (%, d.b.)
TR	8.33 ^{a} (±0.94)	16.23 ^{a} (±0.10)	0.30 ^{a} (±0.02)
IR	7.14 ^{b} (±0.31)	16.42 ^{a} (±0.22)	0.28 ^{a} (±0.28)
SL	7.41 ^{b} (±0.06)	16.62 ^{a} (±0.88)	0.28 ^{a} (±0.07)

The letters show significant difference at $p \leq 0.05$ between samples for each parameter.
± standard deviation, (d.b.): dry base
TR: Traditional dried, IR: Infrared dried, SL: Sunlight simulation dried

3.1.4 Color Characteristics

Eggplants color is one of the most important characteristic property for the consumer and it has a direct influence on marketing for both dried and fresh. The fresh eggplant has a bright purple color with average L* (brightness), a* (redness), b* (blueness) and YI (show clear or white toward yellow at positive values and blue at negative values) of 19.39, 15.58, -0.70 and 47.23, respectively (Table 3.4).

Table 3. 4 Color values of eggplant samples before and after drying methods.

Sample	L*	a*	b*	CIE YI
Fresh eggplant	19.24 ^{a} (±0.33)	15.38 ^{a} (±0.54)	- 0.57 ^{bc} (±0.33)	47.60 ^{a} (±2.65)
IR	21.46 ^{b} (±0.21)	1.53 ^{b} (±0.14)	- 2.16 ^{a} (±0.21)	-7.90 ^{b} (±1.40)
SL	21.70 ^{b} (±1.03)	1.75 ^{b} (±0.19)	- 1.22 ^{b} (±0.59)	-1.63 ^{c} (±3.15)
TR	29.77 ^{c} (±0.44)	1.89 ^{b} (±0.65)	- 0.39 ^{c} (±0.69)	2.74 ^{d} (±2.35)

Data followed by different letter within the column are significantly different ($P \leq 0.05$) according to Duncan's multiple comparison test.
TR: Traditional dried, IR: Infrared dried, SL: Sunlight simulation dried

Table 3. 5 Pearson test results of color characteristic.

	L	a	b	YI
Drying	0.88**	-0.76**	0.21	-0.65**
L		-0.53*	0.38	-0.41
A			0.36	0.98**
B				0.54*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The color values of samples were determined before and after each drying method (Table 3.4). The lightness and redness of sample significantly ($P \leq 0.05$) changed with drying methods. According to Duncan test results, IR drying and sunlight simulation drying had similar effects on the lightness however, during the traditional drying, the lightness of eggplant increased to a higher value. The redness significantly decreased ($P \leq 0.05$) with all drying methods. The a* values of dried samples with all method were not different according to Duncan test results. On the other side, there was a negative correlation with redness and lightness. The reason that lightness and redness values of samples changed might be the drying temperature. Nimmol et al. (2007) and (Aydogdu et al., 2015) stated that L* and a* values were significantly ($P \leq 0.05$) affected by both drying temperature and drying method. Since the drying temperature was lowest during traditional drying it was obtained highest lightness and redness values for the product (Figures 3.3 and 3.4). The blueness of samples increased significantly ($P \leq 0.05$) with IR drying method however sunlight simulation and traditional method did not change the value of samples (Figure 3.5). It was not obtained any reasonable correlation with other parameters. The results were paralleled with the studies of Aydogdu et al. (2015).

Table 3.4 shows the YI values significantly ($p \leq 0.05$) decreased with all drying methods. The most white-blueness was obtained with IR drying method according to Duncan test results. However, it was obtained more yellowness than blueness. During traditional drying method this explains the outdoor exposure of the sample with an extended duration of sun light. On the other side, it was obtained a strong correlation with a* value of the samples according to Pearson test results (Table 3.5). Therefore, the change in YI values might be a result of the drying temperature as well. YI index commonly used to evaluate color changes in a material caused by real or simulated outdoor exposure (iControl, 2012). The change of color could be caused by to the browning reactions during the drying as noted by Ertekin and Yaldiz (2004); Madamba et al. (1996); Sarsavadia et al. (1999).

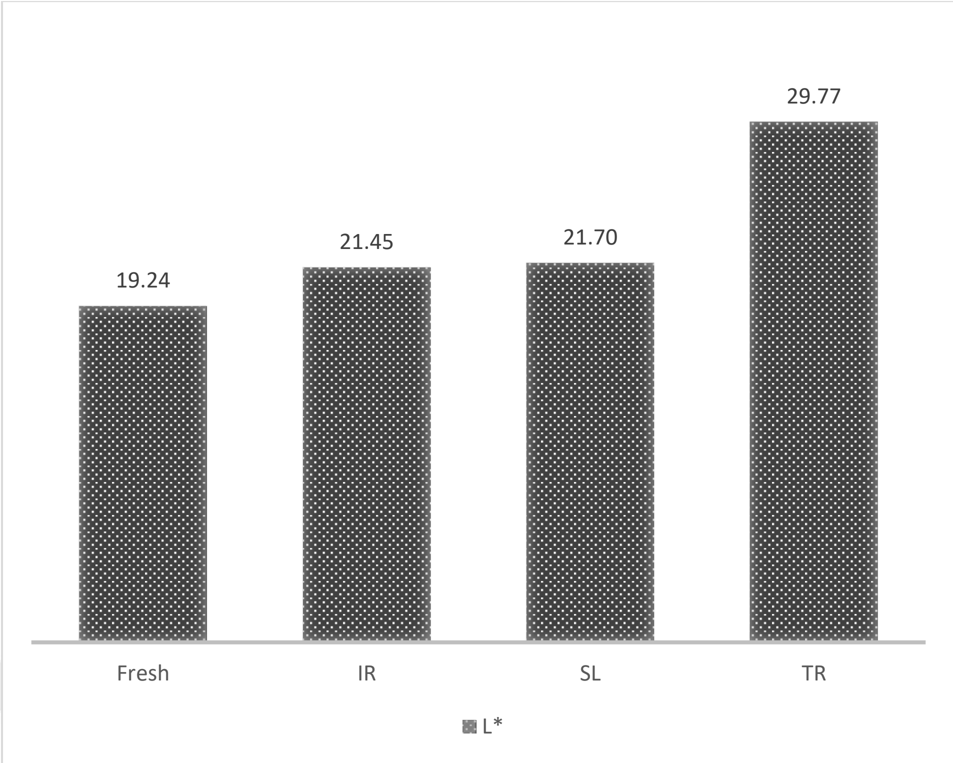


Figure 3. 3 Lightness values before and after drying. (TR: Traditional dried, IR: Infrared dried, SL: Sunlight simulation dried)

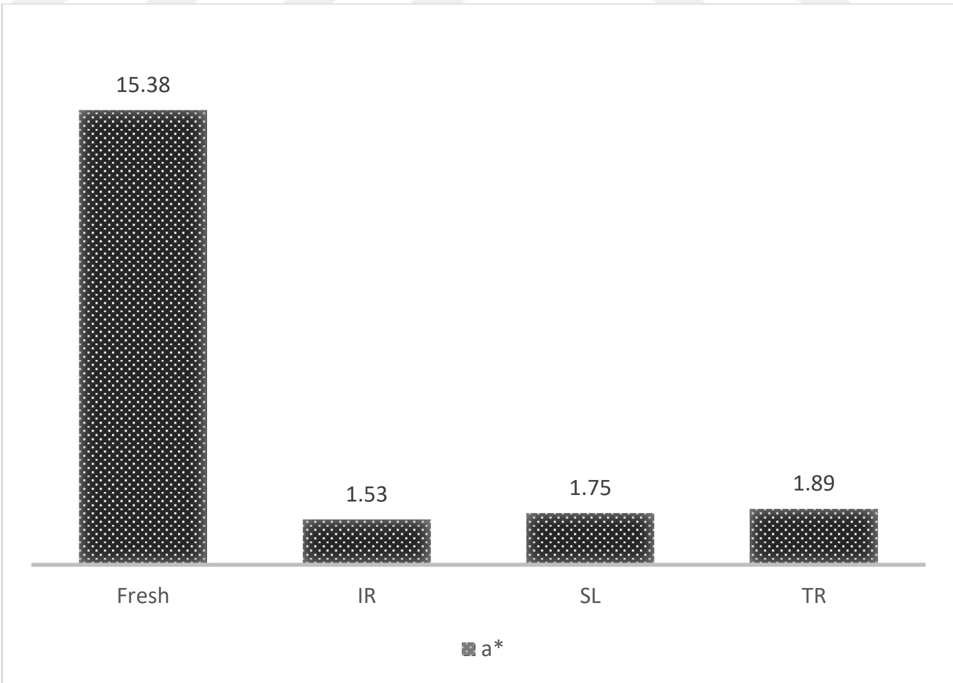


Figure 3. 4 Redness values before and after drying. (TR: Traditional dried, IR: Infrared dried, SL: Sunlight simulation dried)

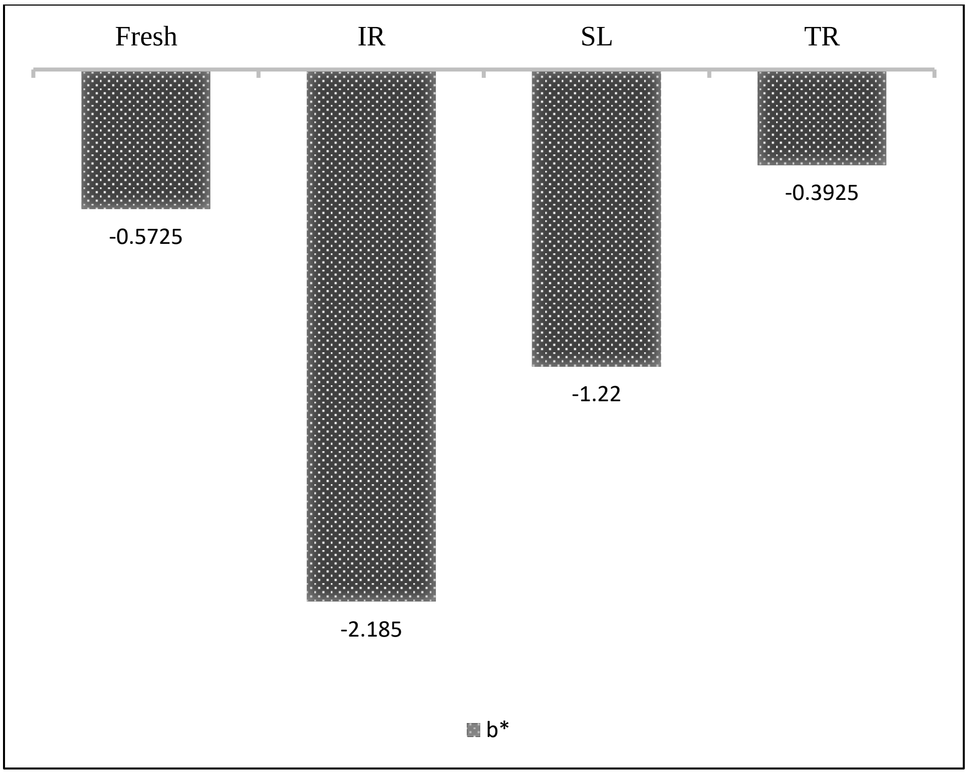


Figure 3. 5 Blueness values before and after drying (TR: Traditional dried, IR: Infrared dried, SL: Sunlight simulation dried).

3.4 Chemical Properties

Total anthocyanin content (TAC), antioxidant content (FRAP), total phenolic content (TPC) and acidity values of fresh and dried eggplant samples were determined (Table 3.6). Bravo (1998) found a correlation between antioxidants activity and phenolic compounds. Thus, antioxidant activity of vegetables and fruits is derived largely from phenolic compounds. It is well known that eggplant peels contain high amount of antioxidant which are very healthy for human consumption. Antioxidant are the most important active ingredient that protects cells against oxidative damage caused by free radicals and reactive oxygen species (Müjgan, 2014).

Table 3. 6 Chemical properties.

Parameters	Fresh	IR	SL	TR
TAC	836.37^{a} (±31.74)	639.54^{b} (±16.60)	260.89^{c} (±2.79)	295.08^{c} (±7.06)
FRAP	92.71^{a} (±2.47)	85.54^{b} (±2.07)	72.79^{b} (±0.20)	84.36^{c} (±1.45)
TPC	34.24^{a} (±2.35)	12.66^{bc} (±0.12)	10.13^{c} (±0.70)	16.54^{b} (±1.06)
Acidity	-	2.70^{a} (±0.04)	1.53^{b} (±0.11)	2.13^{a} (±0.05)

TAC: (mg C3G/100g FW, g C3G/kg soluble solids), FRAP: (µmoles TE/g soluble solids), TPC: (mg GAE/ 100g FW, mg GAE/g soluble solids), Acidity: mg/g (d.b.).
TR: Traditional dried, IR: Infrared dried, SL: Sunlight simulation dried

Anthocyanin is a group of pigments responsible from red to orange color in vegetables. It was noticed that Dried IR gave the highest value in TAC compared to other drying methods. Total anthocyanin content of sample after IR drying was significantly ($p \leq 0.05$) different than the sunlight simulation and traditional drying methods. According to Pearson test (Table 3.7) TAC has a strong positive correlation ($p \leq 0.05$) with a* value. (red color). Also, it was positively correlated ($p \leq 0.05$) with FRAP, TPC and acidity. Total anthocyanin content of fresh eggplant has decreased after drying process due to high temperature. This decreasing may be attributed to the high rate of isomers and oxidation at temperatures higher than 50° C (Eldahshan and Singab, 2013). Similar result was observed in the drying of tomato by Demiray et al. (2013); Mwende et al. (2018). All drying methods used in this study carried out at high temperature. However, the exposure time to that high temperature was lowest during IR drying method. Therefore, the reason of decreasing TAC might be not only the high temperature but also the time of exposure to high temperature.

Table 3. 7 Pearson test results of chemical properties and color values.

	L	a	b	YI	TAC	FRAP	TPC
MC	-0.55	0.99**	0.25	0.98**	0.78**	0.72*	0.97**
L		-0.53	0.44	-0.430	-0.73**	-0.18	0.37
a			0.25	0.98**	0.77**	0.72*	0.97**
b				0.42	-0.28	0.01	0.31
YI					0.67*	0.67	0.96**
TAC						0.80*	0.74**
FRAP							0.80*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

FRAP method was used to determine the antioxidant capacity. FRAP results were determined before and after each drying method (Table 3.6). FRAP decreased significantly ($p \leq 0.05$) with all drying methods, as expected. The lowest decrease was obtained with IR drying method. The FRAP results had a significant positive ($p \leq 0.05$) correlation with TAC and TPC according to Table 3.7. These results are similar to the Mphahlele et al. (2016).

TPC results were given in the Table 3.6 before and after each drying method. It was noticed that TPC was decreased, however Dried TR gave the highest value after drying. According to ANOVA results drying methods significantly ($p \leq 0.05$) effective on TPC. According to Person correlation test, TPC was positively correlated ($p \leq 0.05$) with TAC and FRAP. The values obtained after all drying methods were higher than the previous results in term of phenolic content as they are based on slices that contain peel and pulp (Cao et al., 1996). The difference in TPC parallel to the study of Jung et al. (2011), authors mentioned that the peels of eggplant is rich in the phenolic compounds more than pulp. According to Lim and Murtijaya (2007) the total phenolic content was decreased with IR and sunlight simulation drying methods due to heat sensitive polyphenol oxidases. A significant decreasing lead to degradation of phenolic compounds in antioxidants of eggplant during freeze drying was seen by Zaro et al. (2015), as well.

Karaman et al. (2014) elucidated DPPH free radical scavenging activity is determined in terms of IC_{50} value which is meaning the concentration of a sample that induces 50% inhibition of DPPH free radicals. IC_{50} values for fresh, dried IR, dried SL and Dried TR were 1.909, 122.616, 58.122 and 46.540, respectively. It was noticed also low quantities of IC_{50} in dried TR and the highest retention rate was observed in dried IR. The results show that temperature conditions in IR had a significant effect on retention of the bioactive compounds. In addition, traditional drying depends on the climate conditions contributing to dissimilar casualties, also exposed to dust and unwanted insects (Lim and Murtijaya, 2007). Long drying periods have also been shown in some cases to lead to higher losses in non-blanched tissues due to enzymatic browning (Kerkhofs et al., 2005; McSweeney and Seetharaman, 2015). This can clarify the low retention of bioactive compounds due to traditional drying where the period of drying is extended depending on the climate conditions. Zaro et al. (2015) has been reported the high losses (80%–98%) of CQA (Caffeoylquinic acid) and

TEAC (Trolox equivalent antioxidant capacity) content after cooking on chlorogenic acid retention in white and purple eggplant regardless of the drying method.

The Table 3.6 also shows acidity values after drying methods. It was noticed that Dried IR gave the highest value compared with other drying methods. Sunlight simulation drying methods significantly ($P \leq 0.05$) different from other samples according to the Duncan tests results. Person correlation test Table 3.7 shows that acidity has no correlation with TPC but was positively correlated ($P \leq 0.05$) with TAC and FRAP with coefficients 0.881 and 0.888, respectively. Scientists found that the Chlorogenic acid (CQA, 5-O-caffeoylquinic acid) is the major phenolic antioxidant in all genotypes (Plazas et al., 2013; Prohens et al., 2013). Nonetheless, the available information in the studies is very limited. The vegetable bioactive compounds quality has been shown to decrease after processing and cooking in most cases (Faller and Fialho, 2009). The present study provides the useful information about antioxidant activity, total anthocyanin content, total phenolic content and acidity of dried (dolmalık) eggplant shell. The findings of this study support the fact that the eggplant shell had high amount of antioxidant, even after drying, especially with infrared drying method.

3.5 Microbial Load

Aerobic plate count (APC), yeast and mold (YM) results were shown in Table 3.8 after drying methods.

Table 3. 8 Microbial load with different drying methods for eggplant.

Samples	APC ($*10^7$)	YM ($*10^7$)
Dried IR	Not found	Not found
Dried SL	6.09	4
Dried TR	3.27	2.68

APC: Aerobic plate count (CFU/g), **YM**: Yeast and Mold (CFU/g) and **CFU**: colony forming unit.
TR: Traditional dried, IR: Infrared dried, SL: Sunlight simulation dried

As shown in Table 3.8 APC and YM significantly ($P \leq 0.05$) decreased with IR drying method as expected. It should be noted that the use of the infrared drying method has a significant direct impact on the inactivation of microorganisms and enzymes compared to the other drying methods used. According to Krishnamurthy et al. (2008), infrared heating can be used effectively for the inactivation of bacteria, molds, pathogenic micro-organisms and yeasts. Its application to improving food safety is gaining popularity because of its superior thermal efficiency, shorter response time and faster heating. There were a lot of bacteria and mold (enzymatic activity) because sunlight did not have the ability to inhibit enzymatic activity compared to infrared. Due to its lack of hygienic effect, traditional drying also has a high percentage of bacteria and mold. Hamanaka et al. (2000) explained the mechanisms of inactivation of microorganisms by infrared heating, inactivation being carried out by damaging the cell's DNA. It is similar to microwave heating and UV-C light. The treatment of microorganisms by infrared heating results in cell wall rupture, leakage of cytoplasmic contents, cytoplasmic narrowing and mesosome degradation, as well as cytoplasmic damage. Increasing the power of the infrared heat source increases the total energy absorbed by the microorganisms as well as the temperature, because the absorption of the infrared radiation by the water molecules of the microorganism is an important factor of their inactivation resulting in rapid microbial inactivation (Bingol et al., 2011; Hamanaka et al., 2000; Molin and Östlund, 1975). These results showed that infrared drying was the suitable method compared with sunlight simulation and traditional drying methods for eggplant.

CHAPTER 4

CONCLUSION

The dried eggplant in Turkey is unique in terms of its shape (dolma). Due to the increasing interest in local products in recent years, it is quite popular and demand has increased in recent years. In addition, dried eggplant is a traditional product belonging to Gaziantep region legally registered geographical sign certificate was obtained. According to this, it has its own unique and different flavor, appearance and aroma when dried eggplant is produced by sun drying in the climatic conditions of the region. However, there is no available information about the percentage of the fresh eggplant produced throughout the country is dried. It is estimated that more than half of the eggplants are used as dried (dolmalık). The sun drying of locally grown eggplant is the main process to extent consumption period. The main problems with traditional sun-dried method are discoloration, shrinkage and shelf-life problems in additional to lack of control of the drying process, loss of product quality, lack of uniformity in drying, the risk of aflatoxin, hygienic problems and contamination by molds, bacteria, rodents, birds and insects, long drying times are dependent on climate.

The results showed that both methods proposed might be the alternative methods to eliminate hygiene concerns of the products. A shorter drying time with IR drying and decreased energy consumption with SL drying was obtained compared to traditional drying method. The color values have affected significantly ($P \leq 0.05$) by the drying methods. It was found that drying methods had no effect on the nutritional value in terms of ash, fat and protein content. The color of product after IR was better compared to the traditional drying method. The highest anthocyanin content and antioxidant content were obtained with the IR drying method. In addition, the number of bioactive compounds is more than other drying methods, as well as absence of bacteria, mold and yeast after infrared drying. Infrared drying method was better than other by the most of parameters (appearance, quality, hygiene and duration of process) except energy consumption. As a conclusion, it is recommended to investigate further about the process parameters of the infrared drying.

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APPENDIX

Table A. 1 ANOVA results of physical properties

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Moisture Content	16041.749[a]	3	5347.250	9702.573	.000
	L*	179.270[b]	3	59.757	855.805	.000
	a*	430.481[c]	3	143.494	768.201	.000
	b*	5.175[d]	3	1.725	8.006	.009
	YI	5486.827[e]	3	1828.942	382.638	.000
Intercept	Moisture Content	9680.424	1	9680.424	17565.109	.000
	L*	6423.201	1	6423.201	91989.995	.000
	a*	325.417	1	325.417	1742.137	.000
	b*	12.342	1	12.342	57.284	.000
	YI	1397.953	1	1397.953	292.469	.000
Sample	Moisture Content	16041.749	3	5347.250	9702.573	.000
	L*	179.270	3	59.757	855.805	.000
	a*	430.481	3	143.494	768.201	.000
	b*	5.175	3	1.725	8.006	.009
	YI	5486.827	3	1828.942	382.638	.000
Error	Moisture Content	4.409	8	.551		
	L*	.559	8	.070		
	a*	1.494	8	.187		
	b*	1.724	8	.215		
	YI	38.239	8	4.780		
Total	Moisture Content	25726.583	12			
	L*	6603.030	12			
	a*	757.392	12			
	b*	19.241	12			
	YI	6923.018	12			

Corrected Total	Moisture Content	16046.158	11			
	L*	179.828	11			
	a*	431.975	11			
	b*	6.898	11			
	YI	5525.066	11			

Table A. 2 ANOVA results of chemical properties

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	L	114,866[a]	3	38,289	1248,709	,000
	a	275,598[b]	3	91,866	350,869	,000
	b	2,568[c]	3	,856	3,071	,153
	YI	3447,223[d]	3	1149,074	281,987	,000
	TAC	470283,018[e]	3	156761,006	798,049	,000
	FRAP	407,806[f]	3	135,935	43,330	,002
	TPC	691,780[g]	3	230,593	79,797	,001
Intercept	L	4261,953	1	4261,953	138995,607	,000
	a	218,196	1	218,196	833,366	,000
	b	10,465	1	10,465	37,545	,004
	YI	820,125	1	820,125	201,261	,000
	TAC	1979571,434	1	1979571,434	10077,726	,000
	FRAP	56246,915	1	56246,915	17928,994	,000
	TPC	2695,468	1	2695,468	932,770	,000
Sample	L	114,866	3	38,289	1248,709	,000
	a	275,598	3	91,866	350,869	,000
	b	2,568	3	,856	3,071	,153
	YI	3447,223	3	1149,074	281,987	,000
	TAC	470283,018	3	156761,006	798,049	,000
	FRAP	407,806	3	135,935	43,330	,002
	TPC	691,780	3	230,593	79,797	,001
Error	L	,123	4	,031		
	a	1,047	4	,262		
	b	1,115	4	,279		
	YI	16,300	4	4,075		
	TAC	785,721	4	196,430		
	FRAP	12,549	4	3,137		
	TPC	11,559	4	2,890		
Total	L	4376,941	8			
	a	494,842	8			
	b	14,148	8			
	YI	4283,648	8			
	TAC	2450640,173	8			
	FRAP	56667,270	8			
	TPC	3398,808	8			

Corrected Total	L	114,988	7			
	a	276,646	7			
	b	3,683	7			
	YI	3463,523	7			
	TAC	471068,739	7			
	FRAP	420,354	7			
	TPC	703,339	7			