MODELING DRYING KINETICS OF GRAPE SEEDS AND SKINS FROM TURKISH CULTIVARS

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ABSTRACT

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Grape pomace is a valuable waste product and various end-products have been obtained after treatments. Recently, these have been commercialized due to their health-promoting effects. Drying is a crucial part of these treatments. This study aimed to analyze the drying kinetics of grape pomace parts, which are seeds and skins.

Two grape types were used in this study, namely Emir and Bogazkere varieties of *Vitis Vinifera* species. Seeds and skins of each variety were dried in a tray dryer at an air velocity of 1 m/s with four different air temperatures; 40, 50, 55 and 60°C. The drying curves showed that the drying rate increased with the air temperature.

Six different drying models were selected from the literature and the best fitted model was determined by application of appropriate statistical methods. It was found that for Bogazkere seeds; Modified Two Term Model, for Bogazkere and

Emir skins; Modified Page Model and for Emir skins; Logarithmic Model gave the best fit.

The effective moisture diffusivities of each type were found for each temperature and were determined by two different approaches, experimental and estimation. The values and variation of D_{eff} / L^2 with temperature were calculated and were found to be increasing with temperature and that the D_{eff} / L^2 values were larger for grape skins than grape seeds. Arrhenius type equation was used in order to explain the temperature dependency of D_{eff} / L^2.

Keywords: Drying, grape seed, grape skin, modeling, effective moisture diffusivity

ÖZ

TÜRK ÜZÜMLERİNİN KABUK VE ÇEKİRDEKLERİNİN KURUTMA KİNETİĞİNİN MODELLENMESİ

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Üzüm posası değerli bir atık ürünüdür ve işlendikten sonra bir çok farklı son ürün elde edilmektedir. Son zamanlarda, bu ürünler sağlığa yararlı etkilerinden ötürü ticarileştirilmiştir. Kurutma, bu işlemlerin çok önemli bir safhasıdır. Bu çalışma üzüm posasının içeriğindeki kabuk ve çekirdeklerinin kuruma kinetiklerinin incelenmesini amaçlamıştır.

Çalışmada *Vitis Vinifera* türüne ait Emir ve Bogazkere çeşitleri olmak üzere iki farklı üzüm kullanılmıştır. Her bir çeşidin çekirdeği ve kabukları tepsili kurutucu içerisinde 1 m/s hava hızı ve 40, 50, 55 ve 60°C olmak üzere 4 farklı hava sıcaklığında kurutulmuştur. Kurutma eğrileri göstermiştir ki kurutma hızı hava sıcaklığı ile artmaktadır.

Altı farklı kurutma modeli literatürden seçilmiş ve en iyi uyan model gerekli istatistiksel analiz metotları uygulanarak belirlenmiştir. Bogazkere çekirdekleri için Modifiye İki Terim modelinin, Bogazkere ve Emir kabukları için Modifiye Page

modelinin ve Emir çekirdekleri için ise Logaritmik Modelin en uygun olduğu bulunmuştur.

Tüm çeşitlerin her bir sıcaklıktaki etkin nem yayınma katsayıları bulunmuştur. Bunlar iki farklı yaklaşımla hesaplanmıştır. D_{eff} / L^2 değerlerinin kabuklarda çekirdeklerden daha yüksek olduğu gözlemlenmiştir. D_{eff} / L^2 katsayısının sıcaklıkla olan ilişkisini açıklamak amacı ile Arrhenius tipi denklem kullanılmıştır.

Anahtar kelimeler: Kurutma, üzüm çekirdeği, üzüm kabuğu, modelleme, etkin nem yayınma katsayıları

To my family,

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The last but never the least, my deepest appreciation goes to my family. I am incapable of expressing my thankfulness to my brother R. Berk Gezer for his help and encouragement not only throughout my academic studies but also in my lifetime. Without him, it would be impossible to finish this work in this squeezed time. My parents Öznur Gezer and Turgay Gezer have always faith in me and they were always there for me. I wish to express my deepest love to all of them and thank them for the endless encouragement, patience and love.

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TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

CHAPTER 1

INTRODUCTION

1.1 Grape Pomace

Turkey processed more than 4 million tons of grapes in 2009. About 10 per cent of the produce is used in the wine industry. The increase in the production can be seen in Table 1

Table 1 Grape production in Turkey. (Retrieved from Turkish Statistical Institute)

	Total Area	**Total Production**	**Grape**		
	(Decare)	(Tons)	For table	Raisins	For wine use
2004	5 200 000	3 500 000	1 900 000	1 230 000	370 000
2005	5 160 000	3 850 000	2 000 000	1 400 000	450 000
2006	5 138 351	4 000 063	2 060 167	1 495 697	444 199
2007	4 846 097	3 612 781	1 912 539	1 217 950	482 292
2008	4 827 887	3 918 442	1 970 686	1 477 471	470 285
2009	4 790 239	4 264 720	2 256 845	1 531 987	475 888

Grape pomace is a waste product of the wine factories, thus viticulture industry faces a disposal problem for this by-product. It is commonly discharged to back vineyard. (Doymaz, 2009; Ferrer, 2001) Generally 13.5 – 14.5% of the grapes after crushing results in grape pomace, in extreme cases it may increase up to 20% (Russ, 2004). Since it brings about a big disposal problem, their utilization in alternative areas is investigated.

Grape pomace is re-valued by several different applications. It may be utilized as a soil conditioner or for fertilizer production (Doymaz, 2009; Ferrer, 2001; Özkan, 2004; Arvanitoyannis, 2006) , as a feed stock for animals (Sanchez, 2002) or it may be converted into renewable energy source (Encinar, 1998; Celma, 2007). Most importantly, the end-products of grape pomace after various treatments serves as a potential source of numerous health-promoting compounds and these are generally used as dietary supplements. Production of citric acid (Soccol, 2006), food colorants from the anthocyanins of grape skins (Francis, 1992}, laccase production by use of grape seeds (Rodríguez Couto, 2006) are other ways of benefiting from this waste product.

1.1.1 Contents of Grape Pomace

Grape pomace is composed of skins, seeds and stems, which is also referred as grape marc. It is a highly valuable waste product of wine processing due to its contents while the composition of each may significantly vary according to the vinification technique and grape variety (Schieber, 2001). The percentage of grape seeds in the grape pomace is generally 26, whereas depending on the type it may be as high as 50 (Doymaz, 2009; Roberts, 2008).

The fact that wine is a very important source of phenolic compounds, leads to the question that if grape pomace also consists of these phenols and various researchers studied this topic. It is found that due to the low efficiency of the extraction process during winemaking, grape pomace generally consists of phenols at high amounts of the type anyhocyanins, catechins, flavanol glycosides, phenolic acids and alcohols, and stilbenes as the main constituents (Schieber, 2001).

In addition to phenolic compounds, grape pomace is also a good source of numerous other valuable constituents like ethanol, tartrates and malates, citric acid, grape seed oil, hydrocolloids and dietary fiber(Kammerer, 2004; Lu 1999).

Distinctive studies have been conducted for treated or untreated grape pomace in order to determine the composition of phenolic compounds. A study about grape marc revealed that polyphenols of gallic acid, furfural, catechin, vanillic acid, epicatechin in amounts between 0.27 and 9.66 mg/L depending on the type of the phenol are present in the marc (Alonso, 2002). Another study about grape seed flour declared that it contains a wide variety of proanthocyanidins, which is a complex mixture of monomers, oligomers and polymers of (+)-catechin, (−)-epicatechin, (+)-gallocatechin, (−)-epigallocatechin and their 3-O-gallic acid esters. Besides its high antioxidant content, grape seed flour contains high dietary fiber up to 40% (Özvural, 2011).

The difference between grape pomace fractions of seeds and skins or peels in terms of polyphenol contents is studied by some researchers. Grape seed extract of a red grape variety, is richer in phenolic content than that of skin (Negro, 2003). A similar case is observed in comparison with white grapes (Martín-Carrón, 2000). On the other hand, the antioxidant activity of these phenolic compounds is found to be higher in grape peel extracts (Shaker, 2006). Besides, grape skins possess a compound named resveratrol, which is not present in other parts of the grape. Resveratrol is a phytoestragen that takes preventive action against cardiovascular diseases (Frémont, 2000).

The phenolic acid contents of the seeds and skins of a white grape cultivar is given in Table 2 and the anthocyanin content of red grape peels is tabulated in Table 3.

Table 2 Phenolic acid contents (mg/ kg DM) of the seeds and skins of a white grape cultivar (Merzling,2001) (retrieved from (Kammerer, 2004))

Phenolic Acid Types	**Skins**	**Seeds**
gallic acid	15.0 ± 0.2	106.5 ± 8.8
protocatechuic acid	42.8 ± 0.5	102.8 ± 25.5
caftaric acid	61.0 ± 2.8	9.3 ± 3.4
p-hydroxybenzoic acid	31.1 ± 0.1	13.8 ± 0.9
coutaric acid	54.5 ± 1.4	30.2 ± 16.3
caffeic acid	1.7 ± 0.2	1.9 ± 0.6
fertaric acid	17.3 ± 1.1	3.0 ± 0.1
syringic acid	1.0 ± 1.2	1.1 ± 0.1
p-coumaric acid	Not detected	7.2 ± 0.7
ferulic acid	2.6 ± 0.0	3.9 ± 0.4
sinapic acid	Not detected	1.0 ± 0.1

Table 3 Anthocyanin contents (mg/ kg DM) of the peels separated from the pomace of a red grape cultivar (Cabernet Minot, 2002) (retrieved from(Kammerer, 2004))

Anthocyanin name*	**Content**
del 3-O-glc	2213 ± 38
cya 3-O-glc	759 ± 35
pet 3-O-glc	2643 ± 18
peo 3-O-glc	4960 ± 16
mal 3-O-glc	20533 ± 92
del 3-O-acglc	392 ± 26
pet 3-O-acglc	545 ± 32
peo 3-O-acglc	1371 ± 82
mal 3-O-acglc	3110 ± 106
cya 3-O-pcmglc	374 ± 8
pet 3-O-pcmglc	974 ± 26
peo 3-O-pcmglc	2151 ± 94
mal 3-O-pcmglc	10591 ± 201
total AC content	50616 ± 774

* Abbreviations: del, delphinidin; cya, cyanidin; pet, petunidin; peo, peonidin; mal, malvidin; glc, glucose; ac, acetyl; pcm, p-coumaroyl; AC, anthocyanin.

1.1.2. Health Aspects of Grape Pomace

After the term “French Paradox” is coined by the scientist Dr. Serge Renaud in 1992, interest on health aspects of the wine increased, and then scientists realized that by-products of wine processing such as grape seeds, skins and pulp may be used as supplements, which have recuperative powers. Thus grape pomace, either separated into seeds and skins or as a whole, is examined in order to understand its health promoting affects by various researchers. A brief summary of these studies can be seen in Table 4.

Health-promoting effects, which are represented in the table are observed owing to the effects of the polyphenols, which are flavanoids, anthocyanins and proanthocyanidins and phenolic acids as mentioned in the previous section. These compounds lead to health promoting effects such as antioxidant activity, acting as free radical scavengers, inhibition of lipoprotein oxidation and oxidation of LDL (Negro, 2003; Lu, 1999; Kammerer, 2004).

It is reported that treated winery waste is widely used in the United States in various forms of health promoting products. There are 22 number of grape seed product, 5 number of grape skin product, 7 number of anthocyanin extract produt, 5 number of red wine powder product and 4 other grape extract product types are commercialized (Shrikhande, 2000). Namely, these are grape seed oil, grape seed extract, grape seed flour, grape skin extract, grape pomace extract, grape skin powder.

Table 4 Health Promoting Effects of Grape Pomace Products

Health Promoting Effect	Product on which the study is conducted	Reference
Antiulcer activity	Grape seed extract	(Saito, 1998)
Anti-cancer effect on breast cancer	Grape seed extract	(Sharma, 2004)
Inhibition of prostate tumor growth	Grape seed extract	(Singh, 2004)
Protective effect on cardiac disorders	Grape seed extract	(Du, 2007)
Potential colon cancer preventive agent	Grape seed proanthocyanidins	(Singletary, 2001)
Protective effect against photocarcinogenesis	Grape seed proanthocyanidins	(Katiyar, 2008)
Wound healing potential	Grape skin powder	(Nayak, 2010)
Antihypertansive action	Grape skin extract	(de Moura, 2002)
Cancer chemopreventive agent	Grape skin	(Pascual-Martí, 2001; Jang, 1997)
Anti-inflammatory effect in diet induced obesity	Grape pomace antioxidant extract	(Hogan, 2010)

1.1.3 Processing of Grape Pomace

Grape pomace is processed in order to obtain the previously mentioned health promoting products such as grape seed oil, grape seed extract, grape seed flour, grape skin extract, grape pomace extract, and grape skin powder. Except for the grape pomace extract, the seeds and skins should be separated. Generally, this separation is conducted via sieve machines in industry (Roberts, 2008).

Drying is a critical unit operation that is applied in the process line of the grape pomace products. It is needed to reduce the moisture content of the material in order to proceed to the following processes. In grape seed oil processing, after separation of the seeds, oil is produced by pressing with a screw extrusion press (Maier, 2009) or alternatively with cold mechanical pressing and in these processes having moisture content below 0.10 g/g dry solids is needed (Roberts, 2008).

Separation of seed and skin fractions of the grape pomace is also an essential part of the production since they can form products which have distinctive properties. It is claimed (Roberts, 2008) that drying the seed together with the pomace is not a practical approach not only because it is energy inefficient but also separating afterwards demands more effort and re-wetting process unless grape pomace extract is to be produced.

In grape seed flour and grape skin powder production stages, milling of the material required. For grape skin or seed extracts, extraction of nutritious compounds is the most important part of the production line and it can be conducted via various solvents such as water, ethanol, methanol and acids such as hydrochloric, citric, tartaric, formic, acetic and propionic acids (Metivier, 1980).

1.2 Drying

Drying is defined as the removal of volatile substances by energy application from a mixture that in the end yields a solid product. In general, the volatile substance is water. (Keey, 1972) Drying is one of the oldest methods used for preservation of foods and it is still widely used in today's food industry.

Whereas the main aim of the drying is to preserve food materials by prolonging the shelf life, there may be other objectives in applying this unit operation. These objectives are generally one or combination of the followings:

- Attaining demanded color, texture or flavor
- Reducing the size and weight of the material for ease of transportation
- Obtaining a specific physical form of a food material

In food industry, various types of drying techniques such as solar, freeze, hot-air, spray drying, osmotic dehydration, microwave, impregnation and vacuum drying are applied alone or in combinations (Vega, 2007). Only around 20 types of dryer are used generally in practice from about 200 diverse types of dryer designed and used in industry so far (Baker, 1997). The key factors of selecting a suitable dryer can be expressed as optimizing energy requirements and cost, beholding environmental and safety concerns and acquiring the desired product quality.

Generally, drying methods can be classified by two approaches, one is according to the mode of operation which is continuous or batch, the other is in relation to method of supplying heat which are conduction, convection, radiation or dielectric heating (Keey, 1972). About 90% of the production of dehydrated food products is carried by means of convective method of heating. Although convective dryers may be at times thermally inefficient, they ensure protection of the material from overheating (Baker, 1997).

1.2.1 Types of Water and Equilibrium Moisture Content

Drying must be approached from the side of equilibrium relationships between the material being dried and air-water vapor mixture. When the solid material is contacted with air having a constant humidity for a sufficiently long period, ultimately the solid will reach definite moisture content. This is regarded as equilibrium moisture content (Geankoplis, 2003).

The value of the equilibrium moisture content relies on the direction from which the equilibrium is attained. In fact, it depends on if the solid is dried (desorption) or wetted (adsorption). There is an observed closed-loop relation, called hysteresis and desorption isotherm always shows a larger value of equilibrium moisture content. In Figure 1, this phenomenon is shown (Keey, 1972).

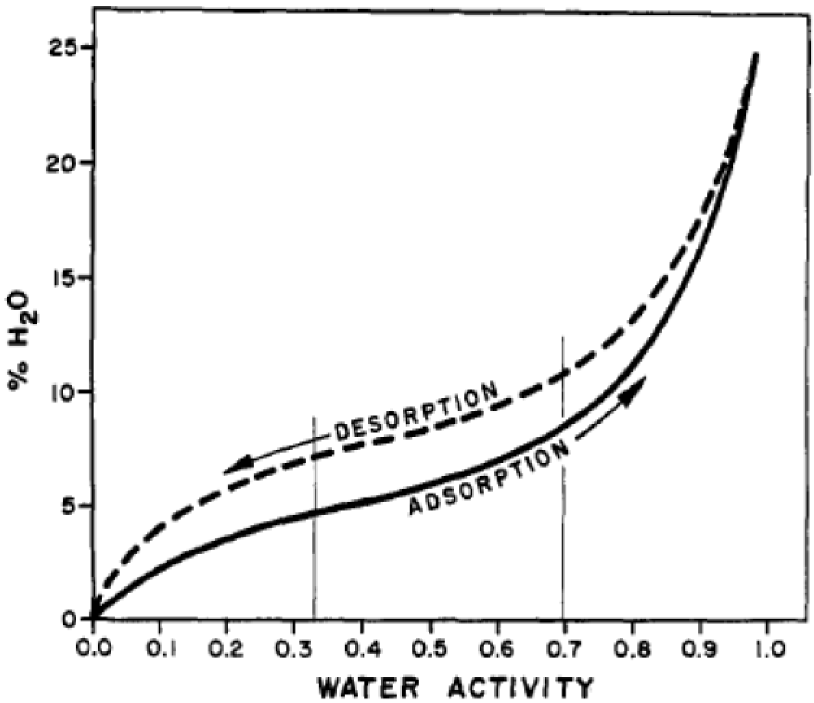

Figure 1 Water vapor sorption hysteresis isotherm representation (Wolf, 1972).

The relationship between equilibrium moisture content and temperature can be described as inversely proportional. The equilibrium moisture content of a solid material decreases with an increase in temperature. Moreover, up to date, it has not been possible to find equilibrium moisture contents of various substances via theoretical understanding. It is needed to find empirical relationships for each of the material while these relationships may differ from sample to sample of the same type of substance (Geankoplis, 2003).

If the equilibrium moisture content of a given material is continued to its intersection with the hundred percent humidity line, the moisture is called bound or interdependent water. The bound water may exist in cell or fiber walls in a dissolved state or in very thin concaved capillaries in liquid state or in adsorbed form onto surfaces. This type of water is in interaction with solid material by forming mono or multi-layer water molecules. Arising from any of the mentioned mechanisms, this water has a lower vapor pressure than the liquid water at the same temperature. Another type of water is unbound or so-called free water. Free moisture amount is the moisture above the equilibrium moisture content and it has the same vapor pressure as the liquid water at the same temperature. This type of water is present in the interstitial places or inside the pores of a material and is grasped by physical force linked to surface tension (Geankoplis, 2003; Keey, 1972).

1.2.2 Principles of Drying

When food is exposed to a hot air stream, heat, which is sufficient for latent heat of vaporization, is supplied to the surface and the water starts to evaporate. This water vapor is transported away by means of air flow. A low water vapor pressure at the surface occurs due to the water removal and a vapor pressure gradient is created between the inner parts of the food which has high amount of moisture and the outer part of the food which is in contact with air. This gradient results in the movement of water molecules to the surface via the following mechanisms (Geankoplis, 2003; Keey, 1972):

- Capillary action due to surface tension
- Capillary action due to interfacial tension (Capillary forces)
- Diffusion of water vapor

Drying behavior of a material, which is exposed to a constant temperature and relative humidity has been generally explained in three characteristic steps: a settling down period, a constant rate period and a falling rate period (Chen, 2008; Geankoplis, 2003; Keey, 1972). This behavior is shown in Figure 2 for drying under constant temperature and humidity.

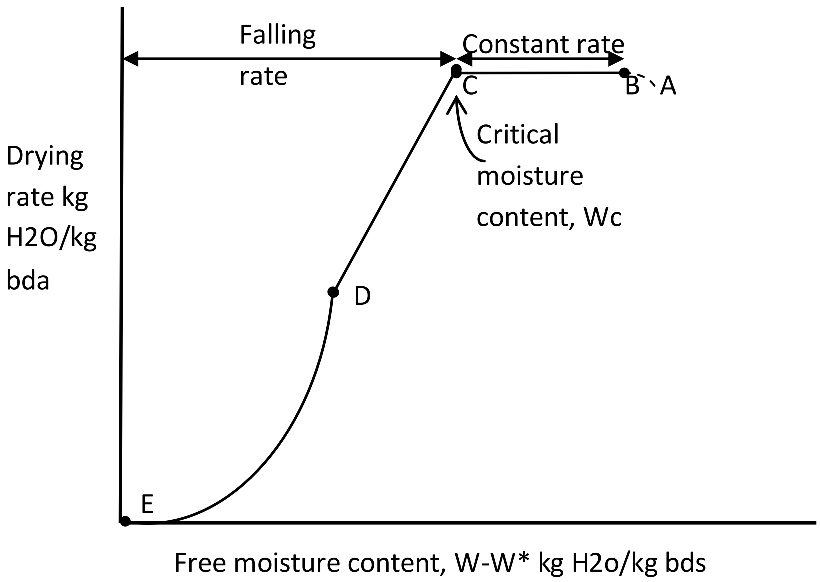

Figure 2 Typical drying rate curve under constant external conditions

At the beginning of the operation, the temperature of the material is not at its equilibrium value and this is the reason for the shift of the value from point A to point B in the figure, which is also referred as settling down period. From point B to point C, the constant rate period persists. In this period, solid surface acquire a continuous film of free water and it behaves as there is no solid, meaning that the rate of evaporation does not depend on the solid and water evaporates as if it is only water. In porous materials, this period continues up to time when the water supply rate from the interior surfaces is less than the evaporation rate from the surface. After that, falling rate period starts. The beginning of this period corresponds to the critical moisture content which is dependent on a couple of factors such as the amount of the dried material and the rate of drying (Geankoplis, 2003).

In the falling rate period, there is not sufficient amount of water to keep the level of water on the surface. First falling rate period, which is shown as the path from C to D, continues up to the point when the surface of the food is totally dry. At this point the second falling rate period starts. Heat needed for evaporation is transferred through the surface to the vaporization regions and water vapor is moved by means of air in the solid. At some cases, no sharp shift occurs at point D due to very low drying rate, this shift is not detectable. The falling rate period is the longest stage of drying and in some foods, if the initial moisture content is less than the critical moisture content, only falling rate period is monitored (Geankoplis, 2003). The researchers reported that there is only falling rate drying period in grape marc and pulp drying (Doymaz, 2009) and grape seed drying (Roberts, 2008).

1.2.3 Mathematical Modeling

Mathematical modeling is the most essential part of drying technology. It is required for the decision on the optimum operating conditions and then designing the drying equipment complying with the desired operating conditions. (Gunhan, 2005) The theory of modeling is based on having a bunch of mathematical equations that can effectively describe the system. Particularly, by applying these equations the operation parameters can be predicted as a function of time only with the knowledge of initial conditions of the process. (Hawlader, 1997; Strumillo, 1986) The mathematical representation of water removal during the unit operation is also recognized as drying kinetics.

Since drying is a very complex process including simultaneous heat and mass transfer, the governing equations are almost impossible to solve without using numerical methods. Thus, making use of following assumptions, simplified models that can be solved by analytical approach are obtained;

1. Negligible shrinkage
2. Uniform initial moisture distribution
3. Constant diffusivity coefficient
4. Negligible external resistance

Fick's second law is generally used for modeling drying kinetics of various kinds of foods based on agriculture in the diffusional drying range. (Doymaz, 2009).

$$\frac{\partial M}{\partial t} = \nabla\left(D_{eff}\nabla M\right) \tag{1}$$

where D_{eff} (m^2/s) is the effective moisture diffusivity which includes all present mechanisms of moisture transport in both vapor and liquid form. The solution of Equation 1 for an infinite slab by the use of the previously defined assumptions is given by Crank (Goyal, 2007) :

(2)

Where, M (kg water/ kg dry matter) is the moisture content at a given time, M_e is the equilibrium moisture content, M_i is the initial moisture content, L (m) is the thickness of the slab, n is a positive integer and M_R is the dimensionless moisture ratio. When dimensionless Fourier number, i.e. D_{eff} $.t/L^2$ is greater than about 0.1, for long drying periods, the series in Equation 2 converge and taking only the first term does not affect the accuracy of the model (Ramesh, 2001; Senadeera, 2003). After simplification, the following equation is obtained;

$$M_R = \frac{8}{\pi^2}\exp\left(-\frac{\pi^2 D_{eff} t}{L^2}\right) \tag{3}$$

Based on Equation 3, a number of researchers defined some models each of which explains the drying behavior in a successful manner. The drying constant "k" is used in the mentioned models instead of transport properties. These equations are named as thin-layer models. Thin layer equations express the drying process in a cohesive manner, regardless of the controlling mechanism. They have been widely applied to predict drying times of several agro-food products and to obtain a general form of drying curves (Togrul, 2004). In general, the thin layer models are developed by recording the removal of moisture with time and linking to the drying conditions for samples which are exposed to constant temperature and relative humidity (Midilli, 2002)

Thin layer models are used to describe the drying behavior of several food materials such as banana (Dandamrongrak, 2002), eggplant (Ertekin, 2004), carrot (Prabhanjan, 1995), olive cake (Akgun, 2005), rosehip (Erenturk, 2004) , black tea (Panchariya, 2002), corn(Henderson, 1961) , apple pomace (Sun, 2007), grape seeds (Roberts, 2008), vegetable waste, (Lopez, 2000) and bagasse (Vijayaraj, 2007), grape marc and pulp (Doymaz, 2009), hull-less seed pumpkin (Sacilik, 2007), corn (Doymaz, 2003), red pepper (Akpinar, 2003), pistachio nuts (Kashaninejad, 2007), apricots, peaches, figs, plums, grapes (Ertekin, 2004).

Henderson and Pabis model is an equivalent of the simplified form of the Fick's second law which resulted in Equation 3. This model was developed in order to describe the drying behavior of corn (Henderson, 1961) and can be written as:

$$M_R = \frac{M - M_e}{M_i - M_e} = a exp(-kt) \tag{4}$$

The Lewis model is in fact a particular case of the previous model where "a" is equal to one. This model basically described that the moisture removal from the agricultural materials may be perceived as analogous to the heat flow from a body immersed in a fluid at low temperatures. This equation is considered in parallel with Newton's law of cooling and it is also named as Newton model. Other names such as exponential model and simple model are used for referring this equation in the literature. It was applied in the modeling of drying of black tea (Panchariya, 2002). The mathematical equation is:

$$M_R = \frac{M - M_e}{M_i - M_e} = exp(-kt) \tag{5}$$

In 1949 Page developed a model via modification the Lewis model by addition of an exponent to the time term that is expected to describe the system better than the simple model. The model is given as (Doymaz, 2005; Panchariya, 2002; Simal, 1997)

$$M_R = \frac{M - M_e}{M_i - M_e} = exp(-kt^n) \tag{6}$$

Modified Page model is formed from Page model by introducing an exponential to the k term and it is seen that it describes the drying behavior of soybean and popcorn (Overhults, 1973; White, 1981; White, 1978) with the following equation:

$$M_R = \frac{M - M_e}{M_i - M_e} = exp(-(kt)^n) \tag{7}$$

Logarithmic model is another commonly used equation for describing drying mechanism. It has been used in estimating drying rates of olive cake and rosehip and has given good fits. (Erenturk, 2004; Akgun, 2005) It is defined as:

$$M_R = \frac{M - M_e}{M_i - M_e} = a exp(-kt) + c \tag{8}$$

Other models are found in the literature such as Wang and Singh model (Wang, 1978), Midilli (Midilli, 2002), Verma (Verma, 1985), two term model (Sharaf-Eldeen, 1970). The multiplicity of the models arose from the complexity of the drying operation. This complexity results from the variability of biological and structural properties thus it is very hard to define a general model (Márquez, 2006).

1.2.4 Effective Moisture Diffusivity and Activation Energy

Effective moisture diffusivity in solids which is represented in Equation 3 depends on the temperature of the medium where the drying takes place. In general, the effect of temperature on D_{eff} is mathematically related with an Arrhenius type equation which is (Doymaz, 2009; Roberts, 2008; Srikiatden, 2006):

$$D_{eff} = D_0 \exp\left(-\frac{E_a}{RT}\right) \tag{9}$$

where E_a (kJ/mol) is the activation energy , T is the absolute air temperature (K) , R is the universal gas constant (kJ/mol K) and D_0 (m^2/s) is a constant.

According to the study of Roberts, (2008), the temperature dependency of the effective moisture diffusivities of the grape seeds from the types Riesling, Cab Franc and Concord were found to obey Equation 9 and the activation energy of each were in the range 30.45 and 40.14 kJ/mol. Furthermore, the activation energies of grape marc and pulp were reported as 25.41 and 13.47 kJ/mol, respectively (Doymaz, 2009). These are also comparable with the values of hull-less seed pumpkin 33.15 kj/mol. (Sacilik, 2007), apple pomace (Sun, 2007), vegetable waste, (Lopez, 2000) and bagasse (Vijayaraj, 2007).

1.2.5 Drying and Quality

Foods are composite biological substances, which are valuable for their nutritional, health promoting, and energy supplying properties. When a food is exposed to heat in drying process, its physical condition is changed, which leads to quality and safety alterations. It can be said that the aim in drying operation is to keep the 'acceptable-to-excellent' position of the foods by extending the shelf life together with preserved nutritional values, which are proteins, minerals, vitamins and other bioactive compounds (Chen,X.D. 2008).

The main aim of the thermal processing is to achieve the death of various undesirable microorganisms; however it may lead to adverse affects such as loss of vitamins. An optimization via conducting experiments is required for each of food material since biochemical compositions and target microorganisms of each foodstuff is different than the other (Geankoplis, 2003).

For a thorough understanding on the effects of drying on quality, the process can be discussed in three stages, namely pre-drying, drying and post-drying. Pre-drying includes operations that are required to remove excess moisture before the drying operation and post-drying consist of product-specific processes such as cooling, packaging, storage and rehydration. Various studies are published in order to comprehend the stability during pre-drying and pos-drying stages but in fact, the in-drying stage is the main step where crucial changes on physiology and biology of foods occur (Chen, 2008).

During drying of waste products of wine or juice processes, change in antioxidant activity and polyphenols' stability desire much of the interest. It has been found that at high temperatures the phenolic antioxidants show decomposition to an important extend by evoking various breakdown products (Hamama, 1991). A study on thermal stability of the grape pomace peels revealed that when the conventional drying temperature is 100 and 140 °C, total extractable polyphenols and condensed tannins is reduced significant significantly, whereas drying at 60 °C these are not affected notably. Furthermore, up to 60 °C no effect is observed on the antioxidant activity while at 100 and 140 °C a decrease of 28 and 50% is reported (Larrauri, 1997). Thus, drying temperature should be carefully selected in order not to lose the bioactive compounds in pomace. In another study, it is reported that freeze-drying did not lead to any reduction in antioxidant power of grape marc phenolic extracts with noting that further studies are needed to understand antioxidant maintenance during storage (70 Spigno, 2007).

1.3 Objectives of the study

Grape pomace is a valuable waste product of wine industry. It is utilized by various methods and it turns into different end-products. For most of these products, drying is a crucial step in the process line. This study aims to investigate the drying kinetics of the grape pomace fractions which are seeds and skins.

The grape types used in the study are from two varieties, namely Bogazkere and Emir of the types red and white, respectively. The drying characteristics of these samples are to be described. Optimum thin-layer drying model will be determined for this purpose.

Four different temperatures were selected to test the effect of temperature. The maximum drying temperature was decided to be 60 ºC in order to stay in the safe region for protecting the nutritional values. Effective moisture diffusivities of each sample was calculated. The temperature dependency of the effective moisture diffusivity was estimated via an Arrhenius type equation.

CHAPTER 2

MATERIALS AND METHODS

2.1 Grape Pomace

Grape pomace, which is a waste material of wine processing, was provided by Kavaklıdere Winery, Ankara. Two types of grape pomace were used in drying experiments. One of them was black grape pomace, which was from *Vitis vinifera* species of the variety Bogazkere, grown in the region Diyarbakir and the other one was white grape pomace which was from *Vitis vinifera* species of the variety Emir, grown in the region Nevsehir (Kavaklıdere Anatolian Wines). The dimensions of the grape seeds are given in Table 5 , where L symbolizes the length of the seed and "a" stands for the height of the seed from the wide part. Figure 3 shows a representation of seed shape. Measured raw data can be found in Appendix C. Grape pomace was separated into partitions and kept frozen at -20°C until use.

Table 5 Grape Seed dimensions

Grape Type	**L (mm)**	**a (mm)**
Emir	6.30 ± 0.58	3.60 ± 0.47
Bogazkere	6.60 ± 0.33	3.90 ± 0.28

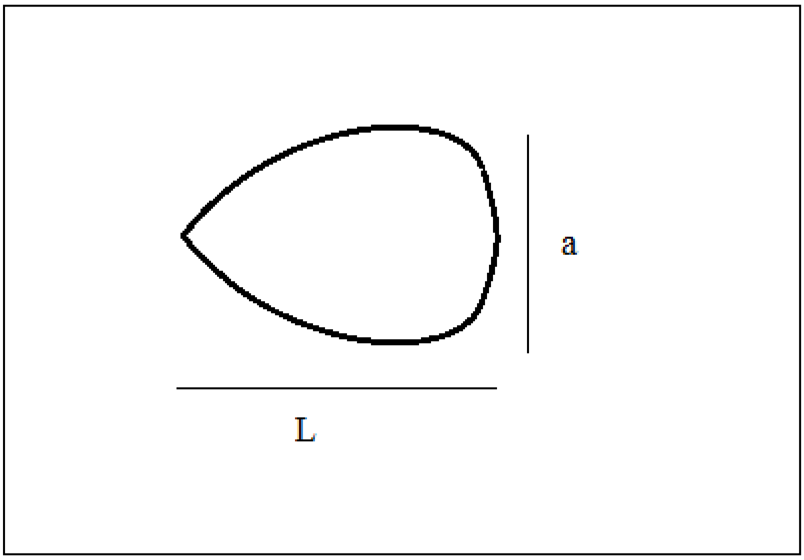

Figure 3 Representation of grape seed

2.2 Sample Preparation

Grape pomace was maintained at the refrigerator temperature (4°C) in order to obtain thawing prior to drying. Thawed grape pomace was separated into seeds and skins by hand.

For analysis of initial moisture content, samples (seeds or skins), were weighed by an electronic balance (Kern, EW 1500-2M, 0.01g sensitivity, Germany) and then placed in an oven (Simsek Laborteknik, ST-055, Turkey) at 100 ± 1°C for 24 hours until the constant weight was reached. The moisture content measurements were performed in duplicates. The average initial moisture contents of the grape seeds and skins are given in Table 6 and the raw is available in Appendix B.

Table 6 Initial moisture contents of Grape seeds and skins

Type	Moisture Content (g water / g dry solid)
Emir Seeds	0.68 ± 0.03
Emir Skins	2.21 ± 0.18
Bogazkere Seeds	1.11 ± 0.06
Bogazkere Skins	5.69 ± 0.20

2.3 Dryer

The drying experiments were conducted in a laboratory scale tray dryer (Armfield Ltd., D27412, Hampshire, England) (Figure 4). It consists of a rate adjustable fan and an adjustable electrical heater with setting switches. The flow cross-section throughout the dryer was 22 x 22 cm^2. Air was circulated in the dryer by a motor driven axial flow fan impeller.

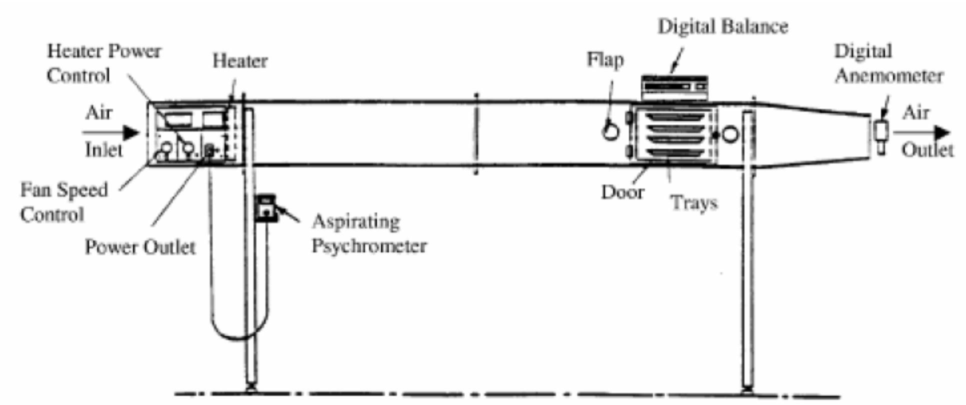

Figure 4 Laboratory scale tray dryer

Before drying of the samples, dryer was operated in order to reach the desired steady-state temperature. After the system had reached the steady state, sample was inserted into the drying tunnel through a latched side door with a glass panel for viewing purposes.

Drying of samples was carried out under constant external conditions at four different air temperatures (40, 50, 55 and 60°C) at constant relative humidity (18.9 ± 3.9 %, 10.6 ± 3.1 %, 8.5 ± 0.8 %, 7.7 ± 1.2 % , respectively) by using 1 m/s air velocity. Relative humidity of the air was measured with a hygrometer (Comet, S3121, Czech Republic). For sample weight measurements, a digital balance (Kern, PFB 1200-2, 0.01g sensitivity, Germany), with a hanger rod attached to bottom of the balance was used. Samples were positioned in a mesh basket as a thin layer of constant thickness and the basket were suspended into the tunnel dryer in parallel position to the air flow in attached position to the hanger rod (Figure 5). The weight of the samples was measured every 10 minutes throughout drying for 8 hours. All experiments were performed in triplicate.

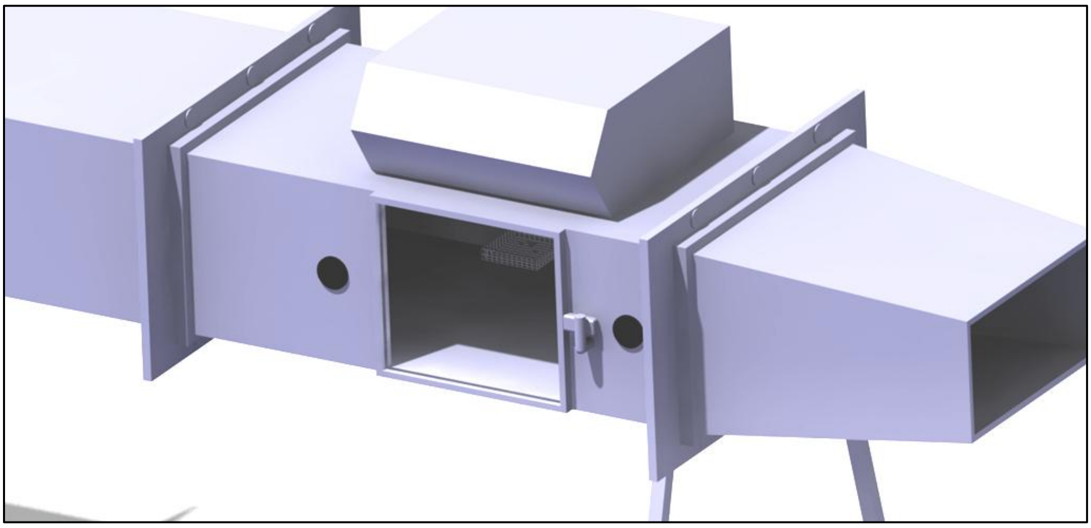

Figure 5 Position of the mesh basket inside the dryer

Dry bulb temperature of the air stream was measured by means of a digital temperature indicator (Dixi, England) having a thermocouple and digital display. The temperature of the experiments was controlled in every 10 minutes and it is attained in the ± 1°C.

2.4 Mathematical Modeling

Drying kinetics of grape seeds and skins were studied in order to find the most suitable model among five different thin-layer drying models, which are presented in Table 7.

Table 7 Mathematical Models selected for drying curves

Model Name	Model Equation	References
Newton (Lewis or Exponential)	MR = exp (-kt)	(Panchariya, 2002)
Page	MR = exp ($-kt^n$)	(Doymaz, 2005; Panchariya, 2002; Simal, 1997)
Modified Page	MR = exp ($-(kt)^n$)	(White, 1978; White, 1981; Overhults, 1973)
Henderson and Pabis	MR = aexp (-kt)	(Henderson, 1961)
Logarithmic	MR = aexp (-kt) + c	(Erenturk, 2004; Akgun, 2005)
Modified Two Term Model	MR = $a\exp(-k_1t) + b\exp(-k_2t) + c$	

MR represents the dimensionless moisture content, having the formula

$$M_R = \frac{M - M_e}{M_i - M_e} \tag{10}$$

where M (kg water/ kg dry matter) is the moisture content at a given time, M_e is the equilibrium moisture content, M_i is the initial moisture content. Me is measured by waiting when there is no more decrease in the weight of the sample.

The regression analysis was performed by means of Sigma™ Plot 12.0. The model constants and regression coefficients were determined by this software. The drying curves were plotted as dimensionless moisture ratio versus time in order to visualize the drying behavior of the samples.

Coefficient of determination, R^2 and mean square residual error, MSE were used in order to estimate the adequacy of fit. Best fit was obtained when R^2 is equal to "one" and MSE is equal to "zero". For the decision on the most suitable model, these parameters were considered and the model curve was plotted. MSE was calculated according to the following equation :

$$MSE = \frac{\sum_{i=1}^{n}\left(MR_{pre,i} - MR_{exp,i}\right)^2}{n-p} \tag{11}$$

where $MR_{pre,i}$ is the i_{th} predicted moisture ratio, $MR_{exp,i}$ is the i_{th} experimentally observed moisture ratio, n is the number of observations, and p is the number of parameters to be estimated (Neter, 1996)

2.5. Estimation of Effective Moisture Diffusivity

The effective moisture diffusivity (D_{eff}) was determined by means of two different approaches. The first approach was to calculate D_{eff} by using equation ,3 which is a reduced form of Fick's second law of diffusion for an infinite slab. The straight slope of the normalized plot of the dimensionless moisture content (lnMR) versus time is equal to :

$$slope = \frac{\pi^2 D_{eff}}{L^2} \qquad (12)$$

where L is the critical thickness of the slab. D_{eff} / L^2 is determined from Equation 12.

The second approach was to calculate D_{eff} / L^2 by taking the model constants as a slope in Equation 12, instead of the straight slope of the normalized plot of the dimensionless moisture content (lnMR) versus time. In this manner, slope will be equal to the constant "k" if the best fit is observed when Newton model, Page model, Modified Page model, Henderson and Pabis model or Logarithmic model are applied. If Modified Two Term model is found to be the most accurate model, slope will be equal to the constant "k_2".

2.6. Estimation of Activation Energy

The activation energy was determined through the Arrhenius type equation which is

— (9)

where E_a (kJ/mol) is the activation energy , T is the absolute air temperature (K) , R is the universal gas constant (kJ/kgmol K) and D_0 (m^2/s) is a constant. The slope of the plot of natural logarithm of D_{eff} versus the reciprocal of temperature in Kelvin gives the activation energy.

In this study, the equation is modified to Equation 14 and the activation energy is calculated from the slope of the plot of natural logarithm of D_{eff}/L^2 versus the reciprocal of temperature in Kelvin.

—— —— — (13)

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Drying Behavior of the Samples

It was observed that there was not any constant rate drying period, drying totally took place in falling rate period for all samples. Both first and second falling rate drying periods were observed. In addition, it was seen that the drying rate was increased with increasing temperature, as expected.

The change in drying rate with decreasing moisture content for Emir type grape seed, Emir type grape skin, Bogazkere type grape seed and Bogazkere type grape skin are shown in Figures 6, 7, 8 and 9, respectively.

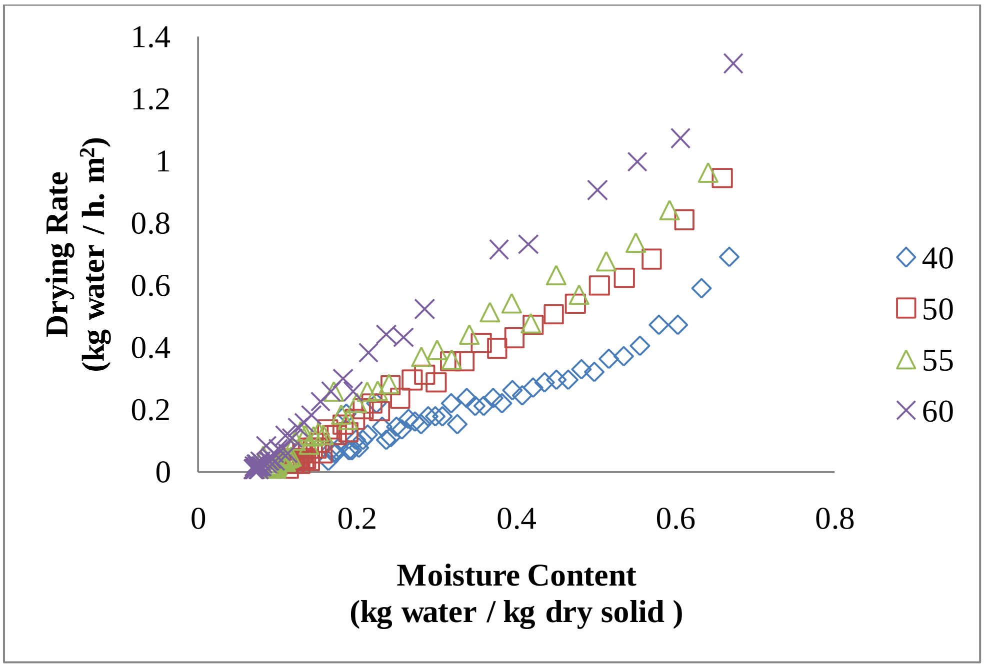

Figure 6 Drying Rate Plot of Emir Type Grape Seed at different temperatures

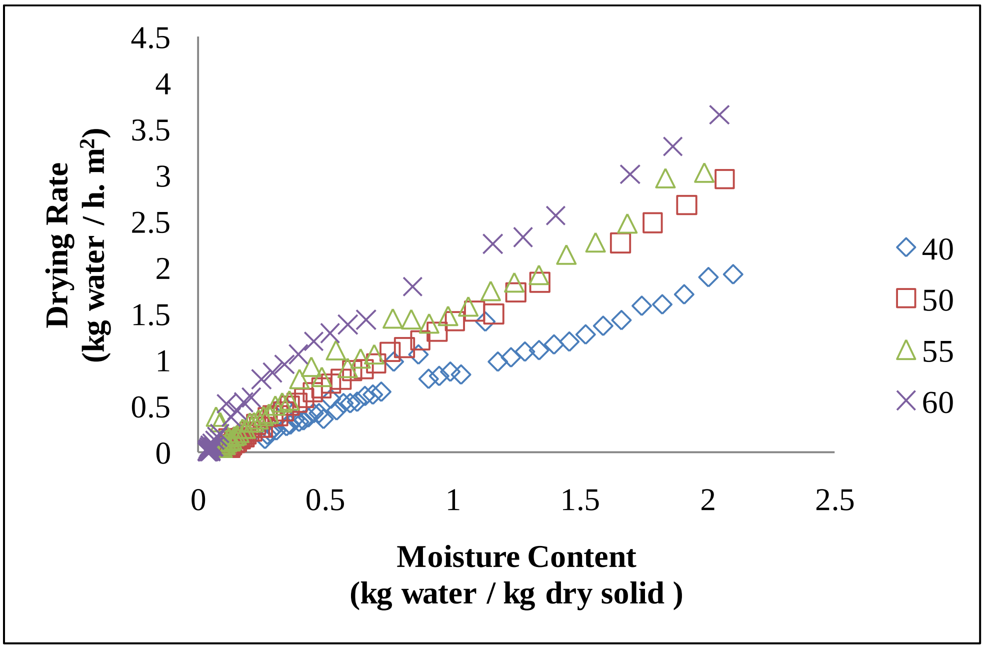

Figure 7 Drying Rate Plot of Emir Type Grape Skin at different temperatures

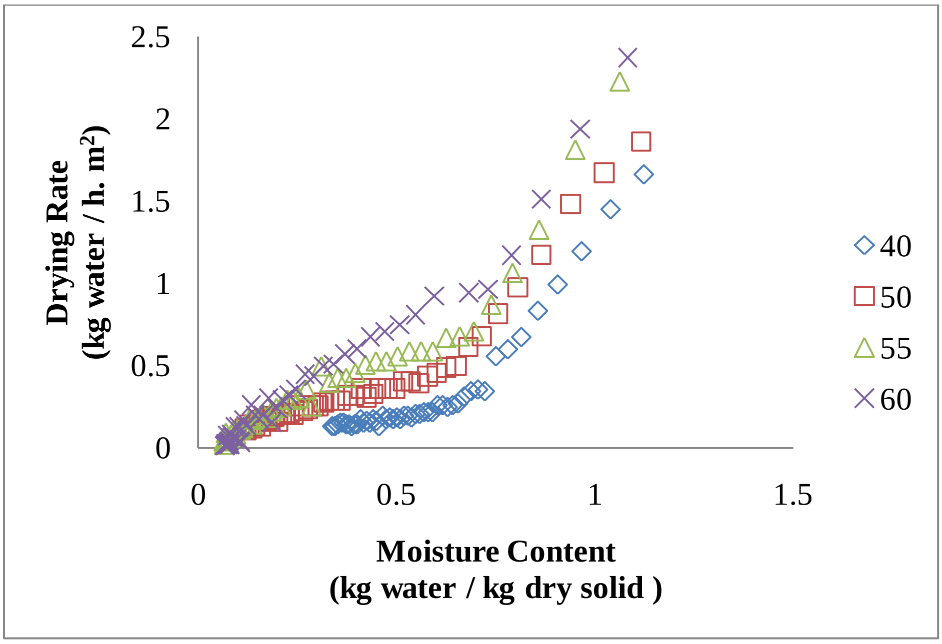

Figure 8 Drying Rate Plot of Bogazkere Type Grape Seed at different temperatures

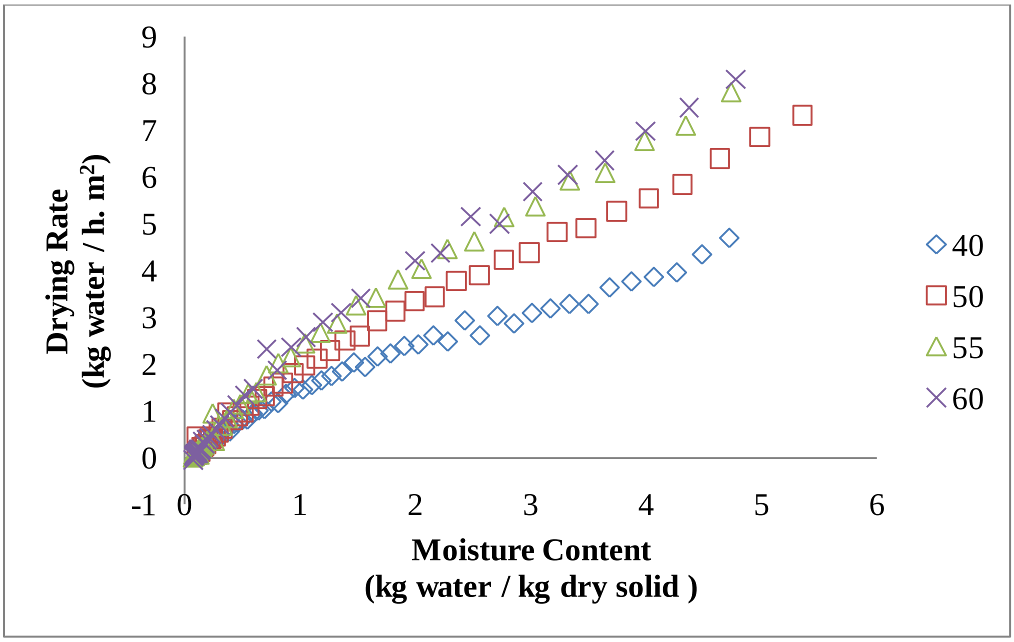

Figure 9 Drying Rate Plot of Bogazkere Type Grape Skin at different temperatures

3.2 Hot Air Drying

In order to analyze the drying kinetics, the term moisture ratio, MR, was used with the accurate equilibrium moisture content inserted. The hot air drying curves is shown in Figures 10, 11, 12 and 13 for Emir type grape seed, Emir type grape skin, Bogazkere type grape seed and Bogazkere type grape skin, respectively.

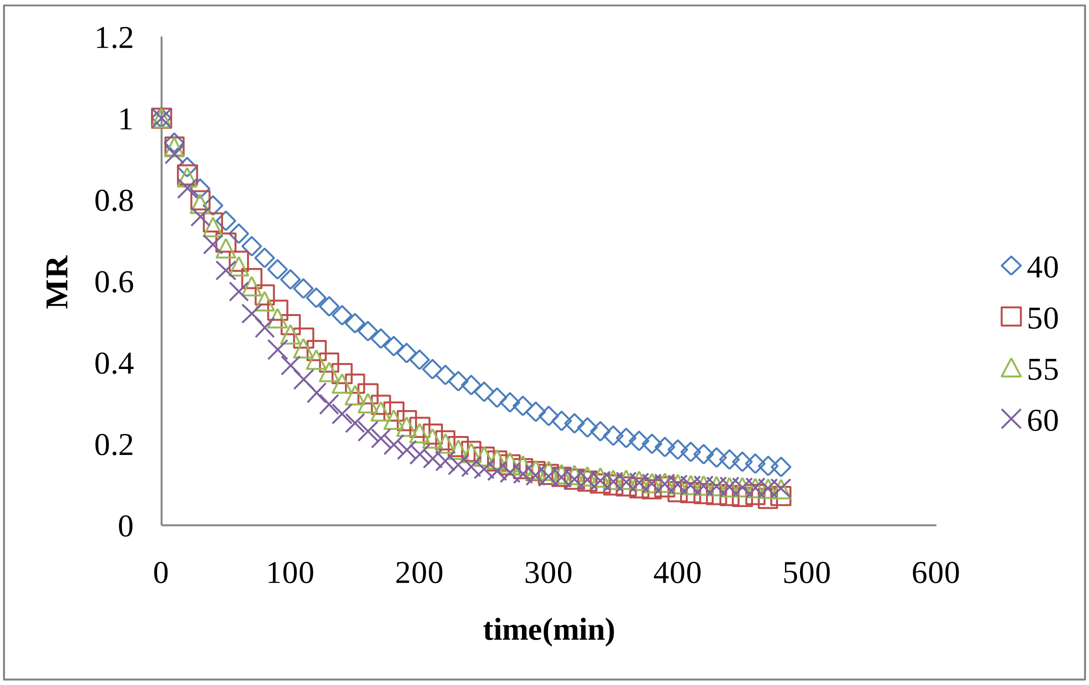

Figure 10 Drying curve of Emir type grape seed at different temperatures

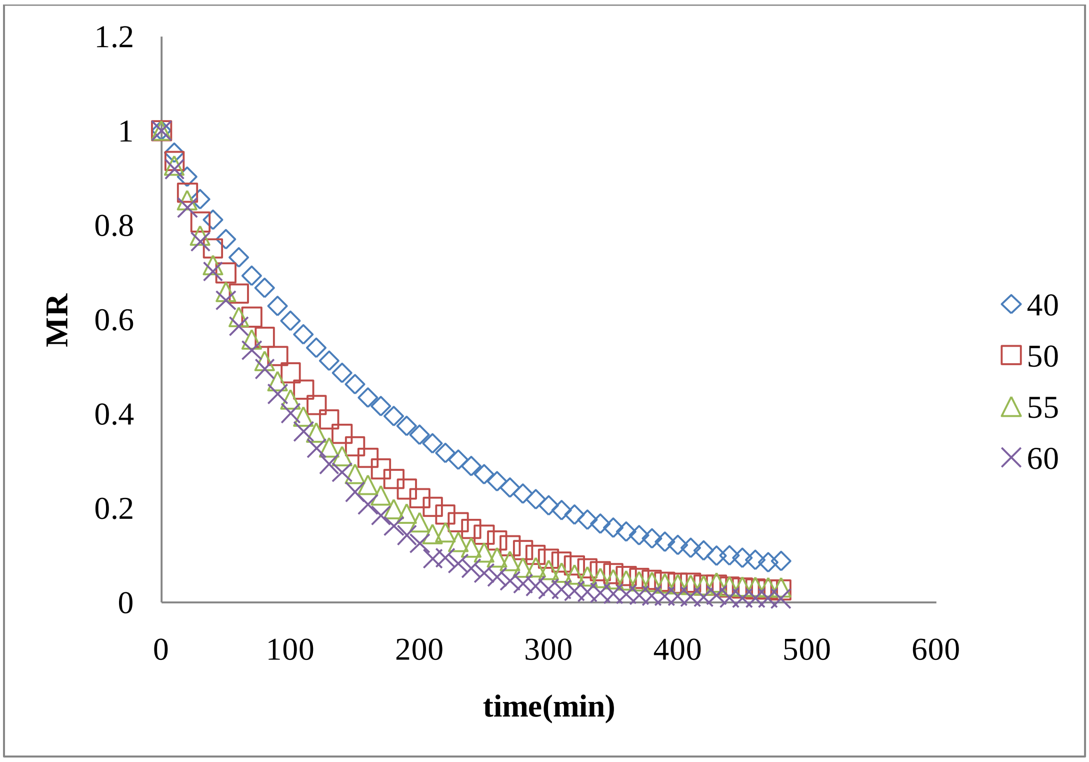

Figure 11 Drying curve of Emir type grape skin at different temperatures

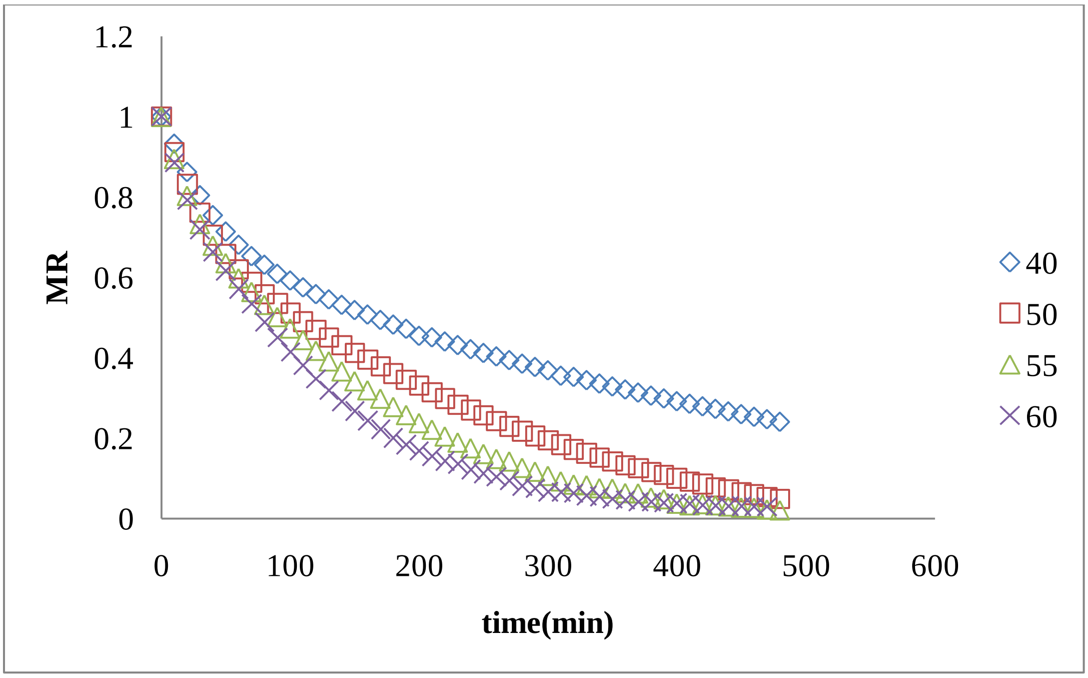

Figure 12 Drying curve of Bogazkere type grape seed at different temperatures

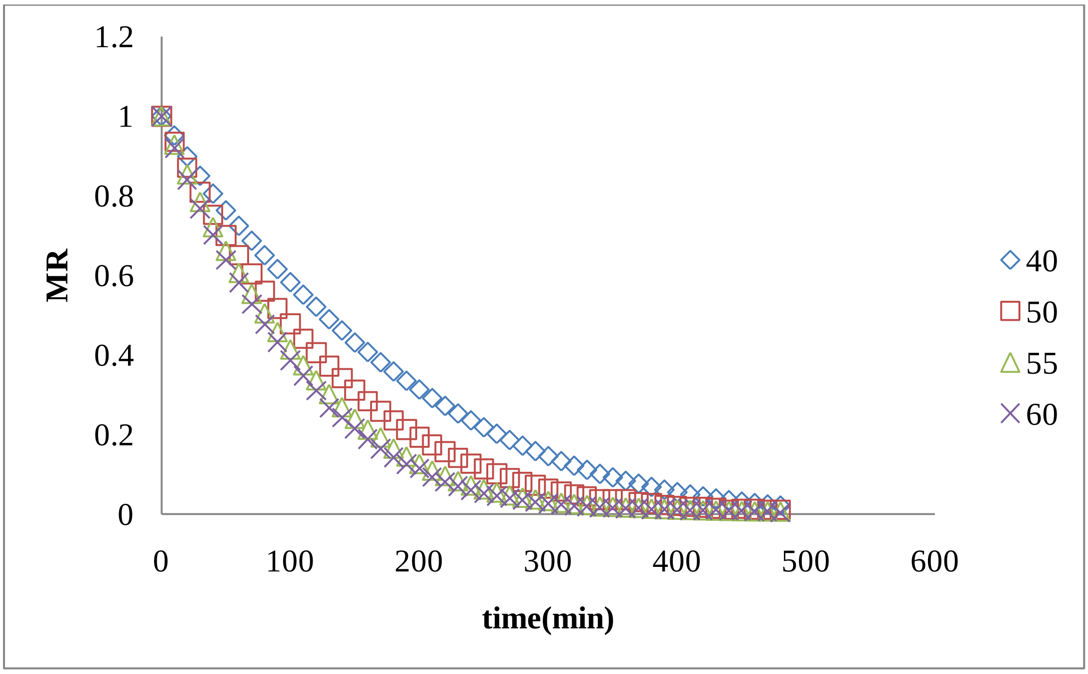

Figure 13 Drying curve Bogazkere type grape skin at different temperatures

3.3 Modeling

In order to explain drying kinetics of grape seeds, thin-layer drying models, which can be defined as simplified models were studied. Four common models of the literature, namely Lewis, Page, Modified Page, Henderson-Pabis, Logarithmic and an additional model, namely Modified Two Term model were selected. The best fit was selected when R^2 had the closest value to one while mean square error was near to zero.

The model constants of each seed and skin variety are tabulated and the results are explained in detail in the following sections.

3.3.1 Emir type grape seeds

Logarithmic model was found as the most appropriate among 6 selected models with R^2 values between 0.9985 and 0.9995 and MSE values between 0.0003 and 0.00008. This model gave the best fit for temperatures 50, 55 and 60°C. For 40°C, although Logarithmic model gave a good fit, the best fit was observed when Modified Two Term model was applied.

For the Logarithmic model, constant “a” ranged between 0.067 and 1.0431. Besides, the model constant “k”, as expected, increased from 0.0050 to 0.0094 while drying temperature increased from 40 to 60°C.

For 40°C, the model constants and statistical parameter values are shown in Table 8. Except for the Newton Model, all the models gave a good fit. Although the Modified Two Term model gave the best fit, since for Emir type grape seeds Logarithmic model was shown to be the most accurate model, it was investigated if it coincided with the experimented values and the overlap is shown in Figure 14.

Table 8 Model constants of Emir type grape seeds drying at 40°C

Model Name	**Model Constants**			**R^2**	**MSE**
Newton	k = 0.0045 ± 0.00005			0.9896	0.00060
Page	k = 0.0095 ± 0.0002	n = 0.8637 ± 0.0038		0.9996	0.00002
Modified Page	k = 0.0045 ± 0.00001	n = 0.8637 ± 0.0038		0.9996	0.00002
Henderson and Pabis	a = 0.9426 ± 0.0058	k = 0.0042 ± 0.00004		0.9965	0.00020
Logarithmic	a = 0.8995 ± 0.0060	k = 0.0050 ± 0.0001	c = 0.0644 ± 0.0069	0.9985	0.00008
Modified Two Term	a =0.0887 ± 0.0051	k1 = 0.0473 ± 0.0048	c = 0.0278 ± 0.0042	0.9999	0.00001
	b = 0.8872 ± 0.0028	k2 = 0.0043 ± 0.00006			

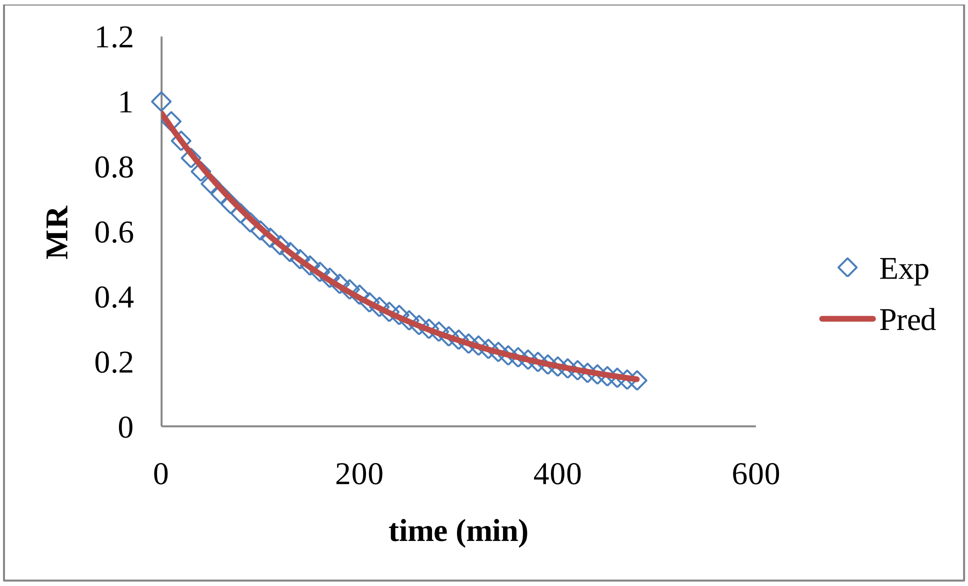

Figure 14 Fitting of Logarithmic model on Emir type grape seeds drying data at 40°C

For 50°C, the model constants and statistical parameter values are shown in Table 9. Although the coefficient of determination was found to be equal for Logarithmic and Modified Two Term model, since the mean square error was smaller, Logarithmic model was selected as the most accurate model and the result is shown in Figure 15.

Table 9 Model constants of Emir type grape seeds drying at 50°C

Model Name	Model Constants			R^2	MSE
Newton	k =0,0070 ± 0.00005			0.9969	0.00020
Page	k = 0,0093 ± 0,0005	n = 0,9445 ± 0,0098		0.9981	0.00010
Modified Page	k = 0,0071 ± 0.00004	n = 0,9445 ± 0,0098		0.9981	0.00010
Henderson and Pabis	a = 0,9826 ± 0,0068	k = 0,0069 ± 0.00007		0.9972	0.00020
Logarithmic	a = 0,9683 ± 0,0034	k = 0,0077 ± 0.00007	c = 0,0350 ± 0,0024	0.9994	0.00003
Modified Two Term	a = 0,4907 ± 0,0087	k_1 =0,0077 ± 0,0421	c = 0,0350 ± 0,0168	0.9994	0.00004
	b = 0,4777 ± 0,0169	k_2 = 0,0077 ± 0,7070			

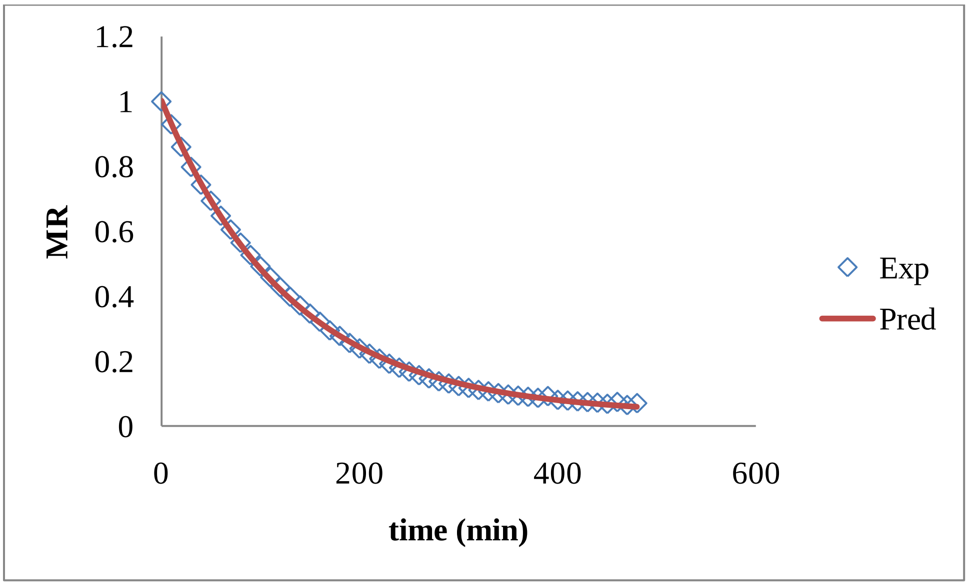

Figure 15 Fitting of Logarithmic model on Emir type grape seeds drying data at 50°C

For 55°C, the model constants and statistical parameter values are shown in Table 10. Except for the Newton Model all the models gave a good fit. The coefficient of determination and mean square error was observed to be the same for Logarithmic and Modified Two Term model but since the standard errors of the model constants of the Logarithmic model is less than the other. It was found as the best fit and overlapping of the predicted values on the experimented data is represented in Figure 16.

Table 10 Model Constants of Emir type grape seeds drying at 55°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0071 ± 0,0001			0.9875	0.00080
Page	k = 0,0132 ± 0,0011	n =0,8801 ± 0,0159		0.9939	0.00040
Modified Page	k = 0,0073 ± 0.00009	n =0,8801 ± 0,0159		0.9939	0.00040
Henderson and Pabis	a = 0,9641 ± 0,0131	k = 0,0069 ± 0,0001		0.9891	0.00070
Logarithmic	a = 0,0671 ± 0,0019	k = 0,0087 ± 0.00007	c = 0,0671 ± 0,0019	0.9995	0.00003
Modified Two Term	a = 0,4800 ± 163773 b = 0,4624 ± 163773	k_1 = 0,0087 ± 37,4992 k_2 = 0,0087 ± 38,9252	c = 0,0671 ± 0,0048	0.9995	0.00003

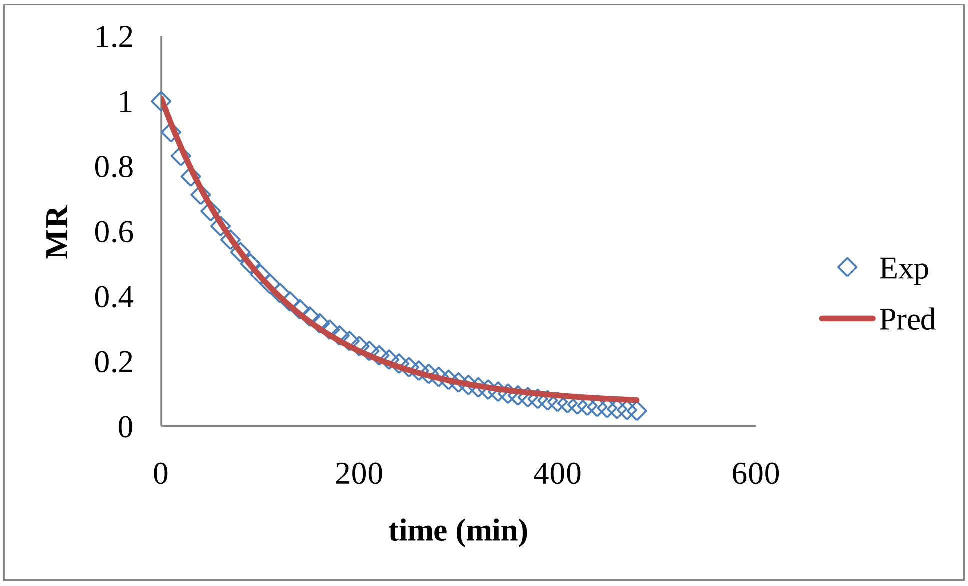

Figure 16 Fitting of Modified Two Term model on Emir type grape seeds drying data at 55°C

For 60°C, the model constants and statistical parameter values are shown in Table 11. The situation that holds for 55°C was valid here also and the model accuracy is plotted in Figure 17.

Table 11 Model Constants of Emir type grape seeds drying at 60°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0085 ± 0,0002			0.9670	0.00190
Page	k = 0,0216 ± 0,0026	n = 0,8098 ± 0,0238		0.9838	0.00100
Modified Page	k = 0,0088 ± 0,0002	n = 0,8098 ± 0,0238		0.9838	0.00100
Henderson and Pabis	a = 0,9445 ± 0,0218	k = 0,0079 ± 0,0003		0.9706	0.00170
Logarithmic	a = 1,0431 ± 0,0077	k = 0,0094 ± 0,0002	c = -0,0201 ± 0,0041	0.9991	0.00005
Modified Two Term	a = 0,4778 ± 0,0098	k_1 = 0,0112 ± 0,0423	c = 0,0844 ± 0,0195	0.9991	0.00005
	b = 0,4546 ± 0,0164	k_2 = 0,0112 ± 0,4469			

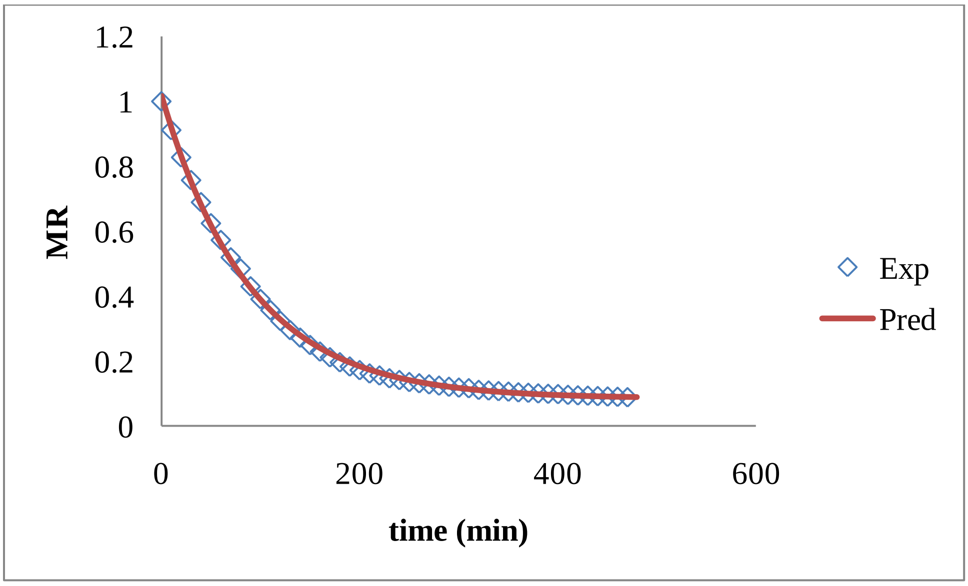

Figure 17 Fitting of Modified Two Term model on Emir type grape seeds drying data at 60°C

3.3.2 Emir type grape skins

Modified Page model was found as the most appropriate one among 6 selected models with R^2 values between 0.9989 and 0.9999 and MSE values between 0.000006 and 0.00008. For Emir type grape skins, it was observed that different models gave the best fit for different temperatures but Modified Page model was shown to be sufficient for all of the drying temperatures.

For the Modified Page model, constant "n" ranged between 1.0112 and 1.1247. Besides, the model constant "k", as expected, was increased from 0.0052 to 0.0095 while drying temperature was increased from 40 to 60°C.

For 40°C, the model constants and statistical parameter values are shown in Table 12. The Logarithmic model and the Modified Page model was at the same level of accuracy in terms of R^2 and MSE but the standard errors of the model constants was smaller in the Modified Page model thus it was investigated if the latter model describes the drying curve and the overlap is shown in Figure 18.

Table 12 Model Constants of Emir type grape skins drying at 40°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0052 ± 0,000008			0.9999	0.00001
Page	k = 0,0049 ± 0,00006	n = 1,0112 ± 0,0023		0.9999	0.000006
Modified Page	k = 0,0052 ± 0,000007	n = 1,0112 ± 0,0023		0.9999	0.000006
Henderson and Pabis	a = 1,0194 ± 0,0013	k = 0,0076 ± 0,00001		0.9992	0.00006
Logarithmic	a = 1,008 ± 0,0016	k = 0,0051 ± 0,00002	c = -0,0076 ± 0,0018	0.9999	0.000006
Modified Two Term	a = 0,5134 ± 0,0036 b = 0,4946 ± 0,0084	k1 = 0,0051 ± 0,0189 k2 = 0,0051 ± 0,5255	c = -0,0076 ± 0,0070	0.9999	0.000007

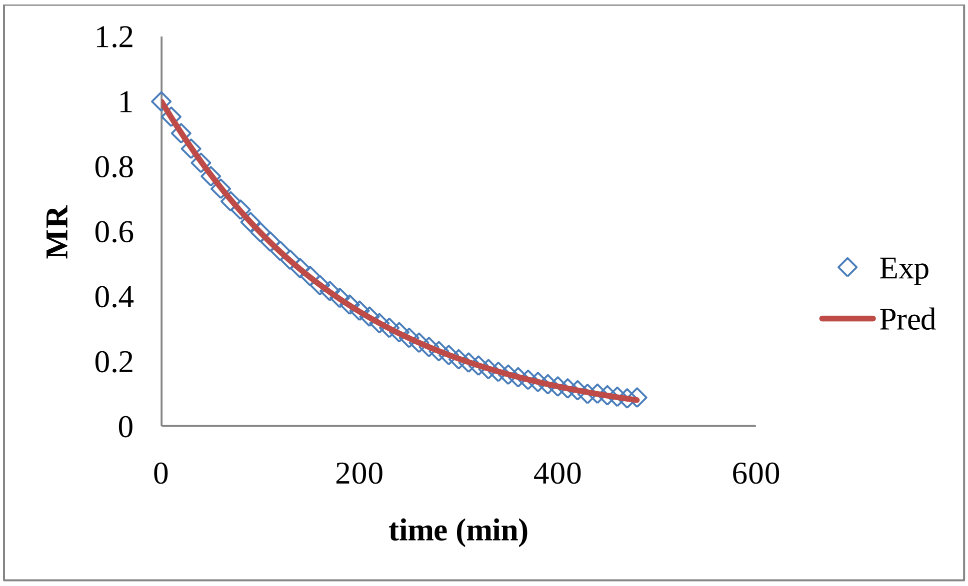

Figure 18 Fitting of Modified Page model on Emir type grape skins drying data at 40°C

For 50°C, the model constants and statistical parameter values are shown in Table 13.The Modified Page model gave the best fit and the overlap of the predicted values and experimental data is shown in Figure 19.

Table 13 Model Constants of Emir type grape skins drying at 50°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0075 ± 0,00004			0.9988	0.00009
Page	k = 0,0056 ± 0,0001	n = 1,0581 ± 0,0038		0.9998	0.00001
Modified Page	k = 0,0074 ± 0,00002	n = 1,0581 ± 0,0038		0.9998	0.00001
Henderson and Pabis	a = 1,0194 ± 0,0042	k = 0,0076 ± 0,00005		0.9992	0.00006
Logarithmic	a = 1,0264 ± 0,0031	k = 0,0073 ± 0,00006	c = -0,0155 ± 0,0024	0.9996	0.00003
Modified Two Term	a = 0,5218 ± 162084	k1 = 0,0073 ± 15,2803	c =-0,0155 ± 0,0074	0.9996	0.00003
	b = 0,5046 ± 162084	k2 = 0,0073 ± 15,7973			

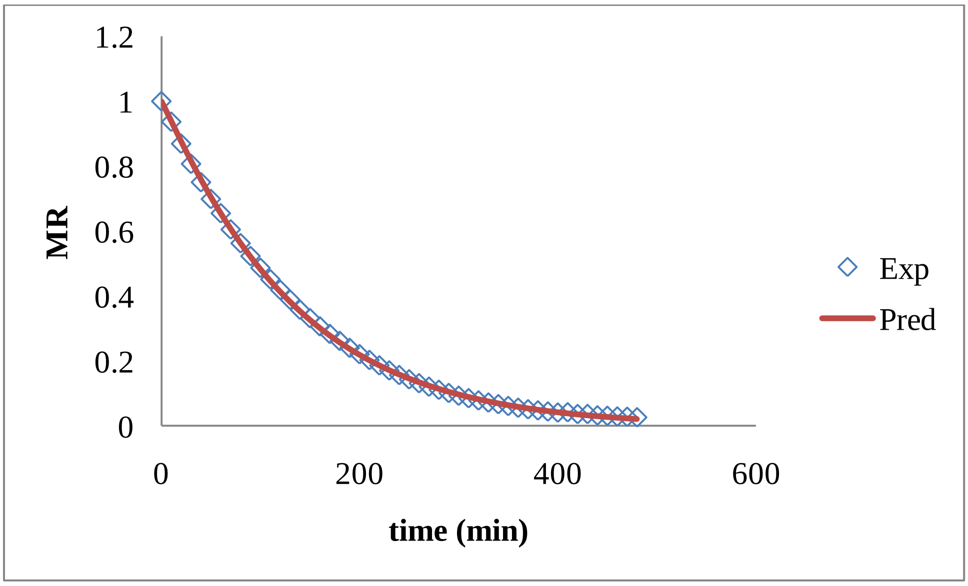

Figure 19 Fitting of Modified Page model on Emir type grape skins drying data at 50°C

For 55°C, the model constants and statistical parameter values are shown in Table 14. Although the Logarithmic model gave the best fit, since for Emir type grape skins Modified Page model was shown to be the most accurate model, it was investigated if it coincides with the experimented values and the overlap is shown in Figure 20.

Table 14 Model Constants of Emir type grape skins drying at 55°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0086 ± 0,00005			0.9988	0.00008
Page	k = 0,0076 ± 0,0003	n =1,0252 ± 0,0085		0.9990	0.00007
Modified Page	k = 0,0086 ± 0,00004	n =1,0252 ± 0,0085		0.9990	0.00007
Henderson and Pabis	a = 1,0119 ± 0,0048	k = 0,0087 ± 0,00006		0.9989	0.00007
Logarithmic	a = 1,0096 ± 0,0047	k = 0,0089 ± 0,0001	c = 0,0065 ± 0,0027	0.9991	0.00007
Modified Two Term	a = 0,5152 ± 0,0116	k1 = 0,0089 ± 0,0558	c = 0,0065 ± 0,0227	0.9991	0.0032
	b = 0,4944 ± 0,0212	k2 = 0,0089 ± 0,7961			

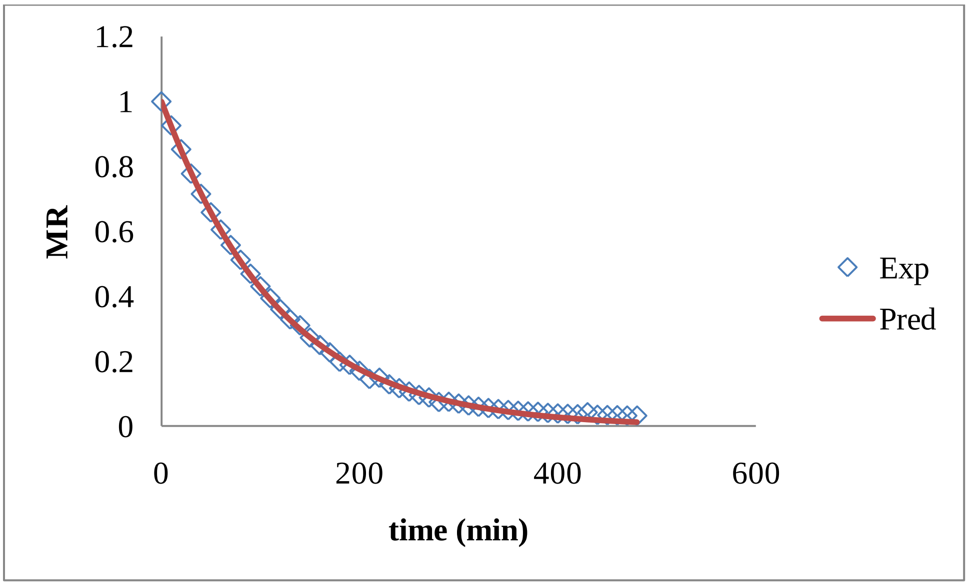

Figure 20 Fitting of Modified Page model on Emir type grape skins drying data at 55℃

For 60℃, the model constants and statistical parameter values are shown in Table 15. Although the Modified Two Term model gave the best fit, since for Emir type grape skins Modified Page model was shown to be the most accurate model, it was investigated if it coincides with the experimented values and the overlap is shown in Figure 21.

Table 15 Model Constants of Emir type grape skins drying at 60°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0097 ± 0,0001			0.9953	0.0004
Page	k = 0,0053 ± 0,0003	n = 1,1247 ± 0,0108		0.9989	0.00008
Modified Page	k = 0,0095 ± 0.00005	n = 1,1247 ± 0,0108		0.9989	0.00008
Henderson and Pabis	a = 1,0353 ± 0,0097	k = 0,0100 ± 0,0001		0.9963	0.0003
Logarithmic	a = 1,0431 ± 0,0077	k = 0,0094 ± 0,0002	c = -0,0201 ± 0,0041	0.9977	0.0002
Modified Two Term	a = 0,5385 ± 0,0188 b = 0,5046 ± 0,0335	k1 = 0,0094 ± 0,0905 k2 = 0,0094 ± 1,2092	c = -0,0201 ± 0,0367	0.9991	0.00007

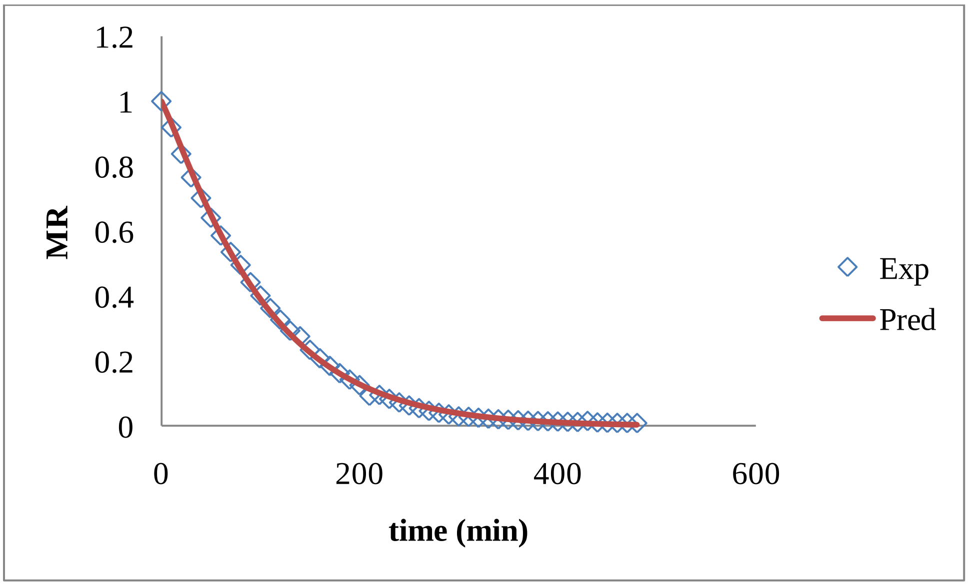

Figure 21 Fitting of Modified Page model on Emir type grape skins drying data at 60°C

3.3.3 Bogazkere type grape seeds

Modified Two Term model was found as the best model among 6 selected models with R^2 values between 0.9990 and 0.9998 and MSE values between 0.000006 and 0.00007. This model gave the best fit for temperatures 40, 50 and 55°C. For 60°C, although Modified Two Term model gave a good fit, the best fit was observed when Logarithmic model was applied.

For the Modified Two Term model, the model constant "k_1" was increased from 0.0245 to 0.0761 and "k_2" was increased from 0.0017 to 0.0083 while drying temperature was increased from 40 to 60°C.

For 40, 50 and 55°C, the model constants and statistical parameter values are shown in Table 16-18. Modified Two Term model had the best accuracy and the plots of the coincide of predicted values with experimental data is shown in Figures 22-24

Table 16 Model Constants of Bogazkere type grape seeds drying at 40°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0036 ± 0,0001			0.8777	0.0043
Page	k = 0,0261 ± 0,0011	n = 0,6432 ± 0,0074		0.9969	0.0001
Modified Page	k = 0,0034 ± 0.00002	n = 0,6432 ± 0,0074		0.9969	0.0001
Henderson and Pabis	a = 0,8537 ± 0,0142	k = 0,0029 ± 0.00009		0.9597	0.0014
Logarithmic	a = 0,6963 ± 0,0131	k = 0,0060 ± 0,0003	c = 0,2323 ± 0,0130	0.9851	0.0005
Modified Two Term	a = 0,3173 ± 0,0069	k1 = 0,0245 ± 0,0007	c = -0,1181 ± 0,0368	0.9998	6.409E-06
	b = 0,8080 ± 0,0300	k2 = 0,0017 ± 0,0001			

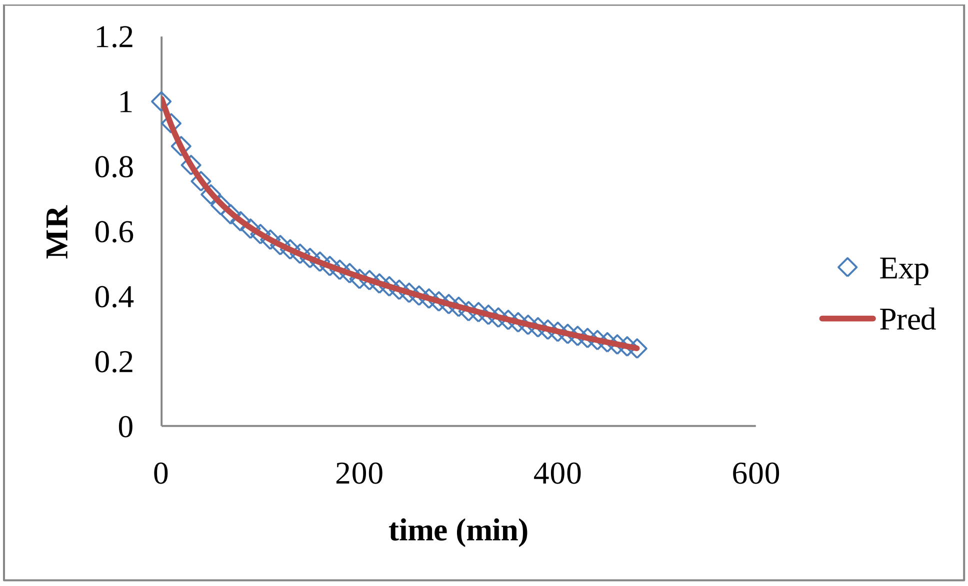

Figure 22 Fitting of Modified Two Term model on Bogazkere type grape seeds drying data at 40°C

Table 17 Model Constants of Bogazkere type grape seeds drying at 50°C

Model Name	**Model Constants**			R^2	**MSE**
Newton	k = 0,0075 ± 0,0002			0.9784	0.0013
Page	k = 0,0162 ± 0,0017	n = 0,8489 ± 0,0203		0.9895	0.0007
Modified Page	k = 0,0078 ± 0,0001	n = 0,8489 ± 0,0203		0.9895	0.0007
Henderson and Pabis	a = 0,9114 ± 0,0130	k = 0,0068 ± 0,0001		0.9889	0.0007
Logarithmic	a = 0,9233 ± 0,0142	k = 0,0062 ± 0,0003	c = -0,0246 ± 0,0134	0.9896	0.0007
Modified Two Term	a = 0,2718 ± 0,0083 b = 0,8617 ± 0,0045	k1 = 0,0445 ± 0,0024 k2 = 0,0041 ± 0,0001	c = -0,1250 ± 0,0078	0.9997	2.046E-05

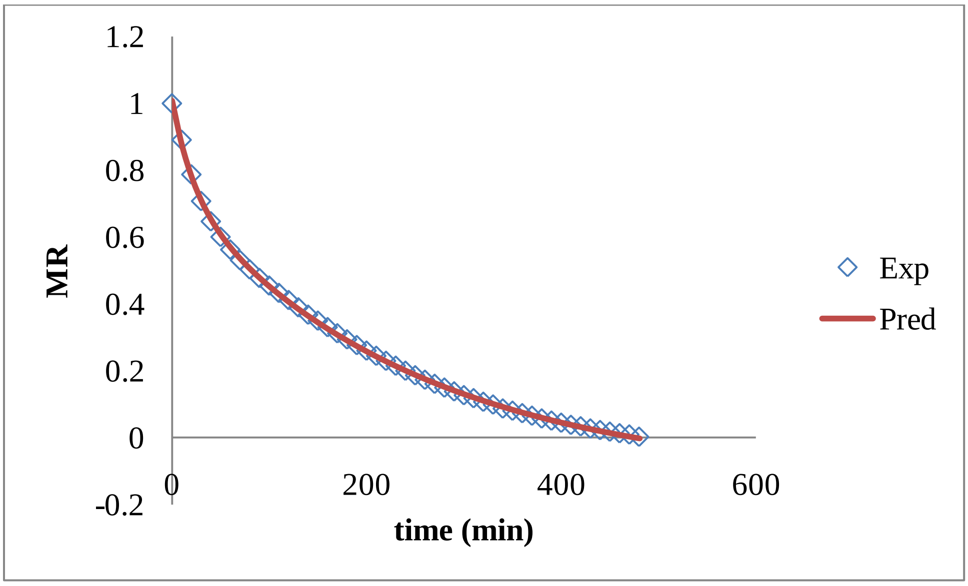

Figure 23 Fitting of Modified Two Term model on Bogazkere type grape seeds drying data at 50°C

Table 18 Model Constants of Bogazkere type grape seeds drying at 55°C

Model Name	**Model Constants**			**R^2**	**MSE**
Newton	k = 0,0075 ± 0,00008			0.9932	0.0005
Page	k = 0,0112 ± 0,0008	n = 0,9223 ± 0,0146		0.9956	0.0003
Modified Page	k = 0,0077 ± 0.00008	n = 0,9223 ± 0,0146		0.9956	0.0003
Henderson and Pabis	a = 0,9483 ± 0,0078	k =0,0071 ± 0,00008		0.9965	0.0002
Logarithmic	a = 0,9569 ± 0,0078	k = 0,0067 ± 0,0002	c = -0,0183 ± 0,0067	0.9970	0.0002
Modified Two Term	a = 0,1255 ± 0,0099 b = 0,9201 ± 0,0060	k1 = 0,0761 ± 0,0120 k2 = 0,0059 ± 0,0001	c = -0,0417 ± 0,0046	0.9994	0.00004

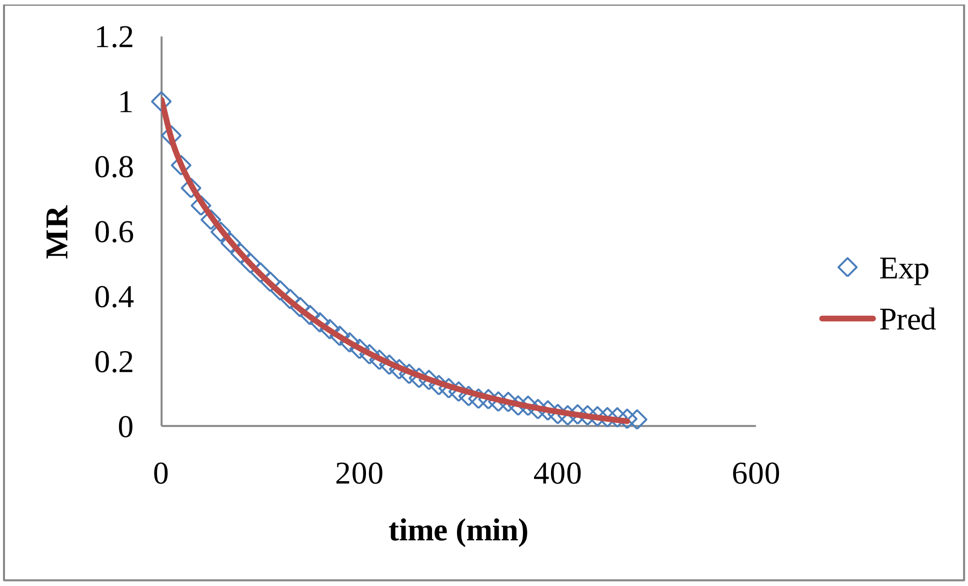

Figure 24 Fitting of Modified Two Term model on Bogazkere type grape seeds drying data at 55°C

For 60°C, the model constants and statistical parameter values are shown in Table 19. The coefficient of determination and mean square error was observed to be the same for Logarithmic and Modified Two Term model. Although the standard errors of the model constants of the Modified Two Term model had large values, it was observed from the Figure 25 that this model can be used in order to describe the drying kinetics for Bogazkere type grape seeds.

Table 19 Model Constants of Bogazkere type grape seeds drying at 60°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0084 ± 0.00006			0.9976	0.0002
Page	k = 0,0114 ± 0,0004	n = 0,9404 ± 0,0078		0.9989	7.549E-05
Modified Page	k = 0,0086 ± 0,00004	n = 0,9404 ± 0,0078		0.9989	7.652E-05
Henderson and Pabis	a = 0,9656 ± 0,0046	k = 0,0081 ± 0,00005		0.9989	7.652E-05
Logarithmic	a = 0,9635 ± 0,0046	k = 0,0083 ± 0,0001	c = 0,0057 ± 0,0030	0.9990	7.142E-05
Modified Two Term	a =0,4699 ± 410851	k1 = 0,0083 ± 9,4624	c = 0,0057 ± 0,0079	0.9990	0.0000747
	b = 0,4936 ± 410851	k2 = 0,0083 ± 8,9891			

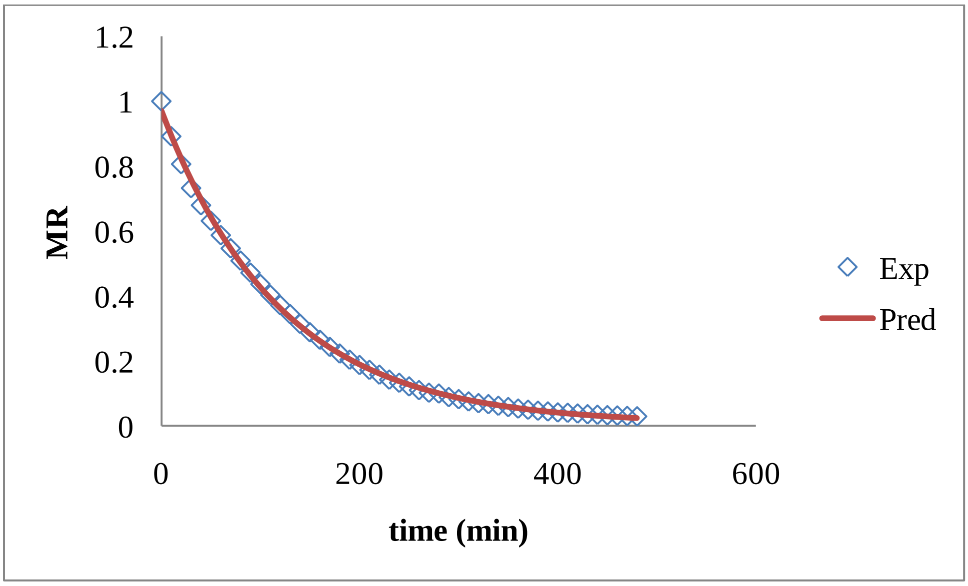

Figure 25 Fitting of Modified Two Term model on Bogazkere type grape seeds drying data at 60°C

3.3.4 Bogazkere type grape skins

Modified Page model was found as the best model among 6 selected models with R^2 values between 0.9982 and 0.9994 and MSE values between 0.000046 and 0.0005. This model gave the best fit for temperatures 50, 55 and 60°C. For 40°C, although Modified Page model gave a good fit, the best fit was observed when Logarithmic model was applied.

For the Modified Page model, the model constant "k" increased from 0.0059 to 0.0098 as expected and "n" ranged between 1.1423 and 1.1627 while drying temperature increased from 40 to 60°C.

For 40°C, the model constants and statistical parameter values are shown in Table 20. Although Logarithmic model gave the best fit with R^2 value being 0.9995 and MSE being 0.00003, the Modified Page model was investigated if it satisfactorily defines the drying curve since this model was observed to give a better fit for Bogazkere type grape skins and the model fit is shown in Figure 26.

Table 20 Model Constants of Bogazkere type grape skins drying at 40°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0060 ± 0,00008			0.9915	0.0337
Page	k = 0,0027 ± 0,0002	n = 1,1529 ± 0,0124		0.9982	0.0002
Modified Page	k = 0,0059 ± 0.00003	n = 1,1529 ± 0,0124		0.9982	0.0002
Henderson and Pabis	a = 1,0423 ± 0,0111	k = 0,0063 ± 0,0001		0.9936	0.0005
Logarithmic	a =1,1015 ± 0,0041	k = 0,0050 ± 0,00005	c = -0,0940 ± 0,0047	0.9995	0.00003
Modified Two Term	a = 0,5661 ± 0,0086 b = 0,5355 ± 0,0207	k1 = 0,0050 ± 0,0482 k2 = 0,0050 ± 1,4274	c = -0,0940 ± 0,0169	0.9995	0.00004

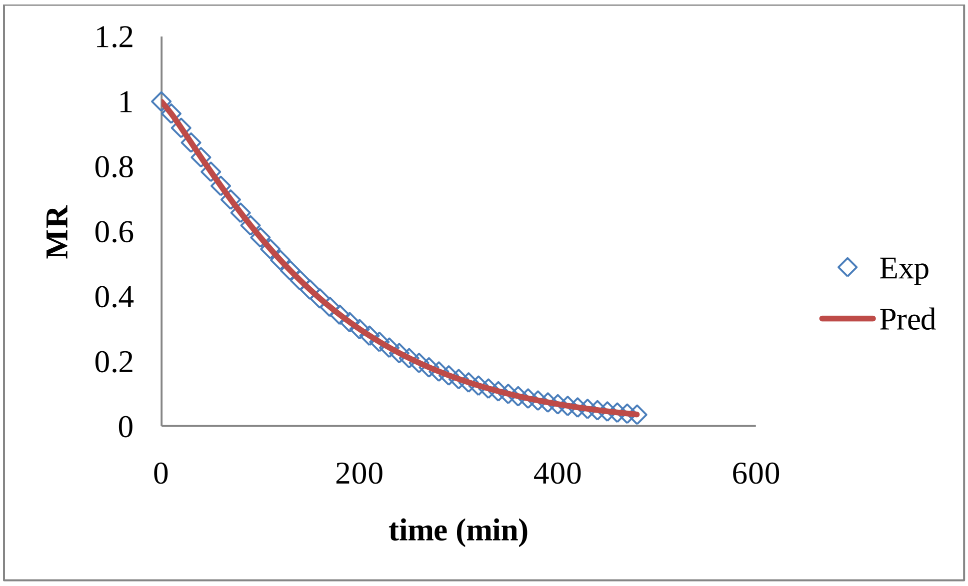

Figure 26 Fitting of Modified Two Term model on Bogazkere type grape skins drying data at 40°C

For 50, 55 and 60 °C, the model constants and statistical parameter values are shown in Table 21-23. Page and Modified Page models showed the same accuracy in terms of R^2 and MSE, while the constant "k" in the Modified Page model had a smaller value of standard error, it was chosen to describe the drying kinetics and the predicted values over experimented data is shown in figures 27-29.

Table 21 Model Constants of Bogazkere type grape skins drying at 50°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0080 ± 0,00009			0.9943	0.0005
Page	k = 0,0039 ± 0,0002	n = 1,1403 ± 0,0081		0.9993	0.00005
Modified Page	k = 0,0078 ± 0.00003	n = 1,1403 ± 0,0081		0.9993	0.00005
Henderson and Pabis	a = 1,0425 ± 0,0097	k = 0,0083 ± 0,0001		0.9960	0.0003
Logarithmic	a = 1,0594 ± 0,0058	k = 0,0075 ± 0,0001	c = -0,0369 ± 0,0043	0.9986	0.0001
Modified Two Term	a = 0,5454 ± 520445	k1 = 0,0075 ± 60,1400	c = -0,0369 ± 0,0129	0.9986	0.0001
	b = 0,5140 ± 520445	k2 = 0,0075 ± 63,8218			

Table 22 Model Constants of Bogazkere type grape skins drying at 55°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0094 ± 0,0001			0.9936	0.0005
Page	k = 0,0043 ± 0,0002	n = 1,1627 ± 0,0082		0.9994	0.00005
Modified Page	k = 0,0092 ± 0.00003	n = 1,1627 ± 0,0082		0.9994	0.00005
Henderson and Pabis	a = 1,0494 ± 0,0107	k = 0,0099 ± 0,0001		0.9957	0.0003
Logarithmic	a = 1,0588 ± 0,0083	k = 0,0092 ± 0,0002	c = -0,0233 ± 0,0046	0.9974	0.0002
Modified Two Term	a = 0,5506 ± 0,0204	k1 = 0,0092 ± 0,1004	c = -0,0233 ± 0,0399	0.9974	0.0002
	b = 0,5081 ± 0,0368	k2 = 0,0092 ± 1,3715			

Table 23 Model Constants of Bogazkere type grape skins drying at 60°C

Model Name	Model Constants			R^2	MSE
Newton	k = 0,0101 ± 0,0001			0.9946	0.000400
Page	k = 0,0049 ± 0,0002	n = 1,1484 ± 0,0082		0.9994	0.000045
Modified Page	k = 0,0098 ± 0.00004	n = 1,1484 ± 0,0082		0.9994	0.000045
Henderson and Pabis	a = 1,0443 ± 0,0100	k = 0,0105 ± 0,0001		0.9963	0.000300
Logarithmic	a = 1,0513 ± 0,0082	k = 0,0099 ± 0,0002	c = -0,0184 ± 0,0041	0.9975	0.000200
Modified Two Term	a = 0,5458 ± 394684 b = 0,5056 ± 394684	k1 = 0,0099 ± 213,65 k2 = 0,0099 ± 230,65	c = -0,0184 ± 0,0088	0.9975	0.000200

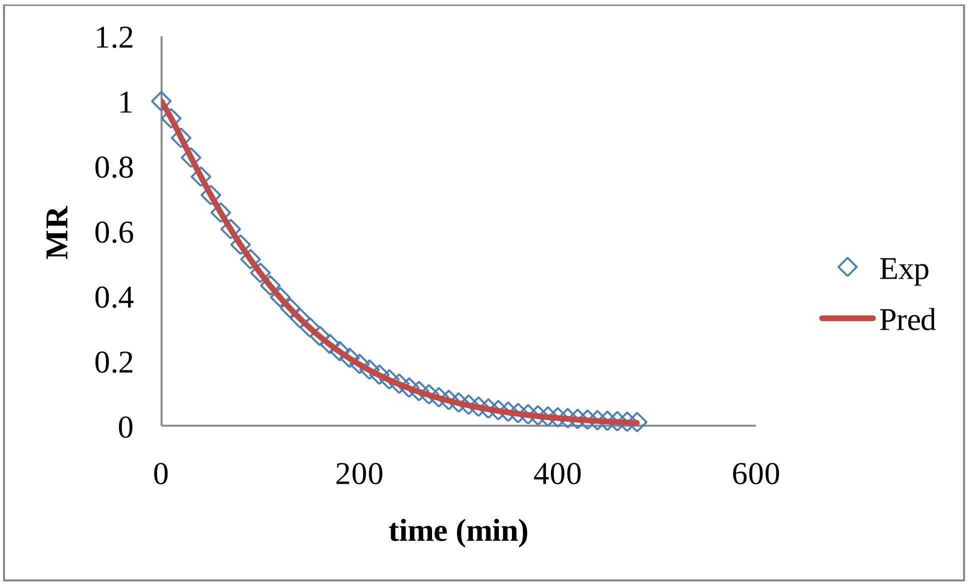

Figure 27 Fitting of Modified Two Term model on Bogazkere type grape skins drying data at 50°C

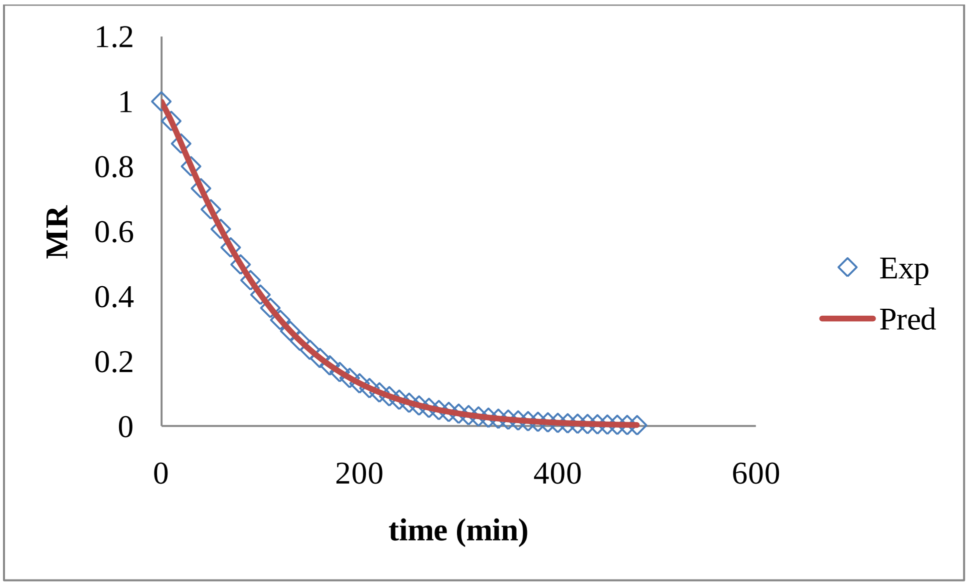

Figure 28 Fitting of Modified Two Term model on Bogazkere type grape skins drying data at 55°C

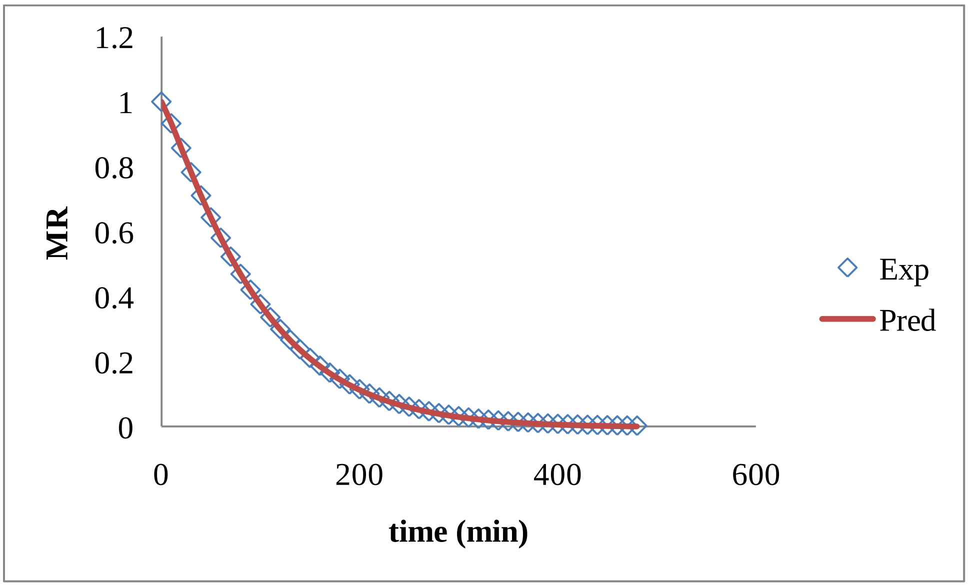

Figure 29 Fitting of Modified Two Term model on Bogazkere type grape skins drying data at 60°C

3.4. Effective Moisture Diffusivity

Effective moisture diffusivity (D_{eff}) was calculated by using two different approaches. First approach was based on the solution of the diffusion equation for infinite slab. The reduced form of the equation when dimensionless Fourier number, i.e. D_{eff} .t/L^2 is greater than 0.1 is

— ——— (3)

Here, L represents a characteristic thickness of the slab. Since in the experiments, the characteristic thickness cannot be determined neither for seeds nor for skins it was decided to report D_{eff} in terms of D_{eff}/L^2. The straight slope of the plot in terms of ln(M_R) versus time was used to calculate the values of D_{eff}/L^2. The numerical values are given in Table 24.

Table 24 Effective moisture Diffusivities according to the first approach

Sample	Temp (°C)	Deff/L^2 (1/s)(10^{-5})
	40	0.7
	50	1.2
	55	1.2
Emir Type Grape Seeds	60	1.4
	40	0.9
	50	1.3
	55	1.5
Emir Type Grape Skins	60	1.9
	40	0.2
	50	1.1
	55	1.3
Bogazkere Type Grape Seeds	60	1.4
	40	1.2
	50	1.7
	55	1.9
Bogazkere Type Grape Skins	60	2.1

Although this approach is widely used in the literature, it is disadvantageous due to having too many assumptions. These assumptions may not be valid throughout the drying process. For this reason, another approach was tried. This second approach was to calculate the effective moisture diffusivity by means of constant "k" of the drying kinetics models that were found to give the best fit. Since these models were valid in whole drying period, this can be considered as a better approach. The effective moisture diffusivities of the samples are presented in Table 25.

Table 25 Effective moisture diffusivities according to the second approach

Sample	Temp (°C)	Deff/L^2 (1/s)(10^{-5})
	40	0.8
	50	1.3
	55	1.5
Emir Type Grape Seeds	60	1.6
	40	0.9
	50	1.2
	55	1.5
Emir Type Grape Skins	60	1.6
	40	0.3
	50	0.7
	55	1.0
Bogazkere Type Grape Seeds	60	1.4
	40	1.0
	50	1.3
	55	1.6
Bogazkere Type Grape Skins	60	1.7

According to the both of the calculation methods, it was observed that D_{eff}/L^2 is increased with increasing temperature as expected. This second approach, however, has a negative aspect that it is hard to compare the values with each other since the best fit models were different for different samples.

The D_{eff}/L^2 values are higher for grape skins than grape seeds. This can be explained by the difference of the outer surface of the seeds and skins. Since the seeds have a hard surface, it is reasonable that the D_{eff}/L^2 parameter is less than that of skins. This hard surface causes a tough barrier to the removal of moisture compared to the soft skins.

Activation energy was estimated by Equation 14. The results for each sample are presented in Table 26 for the D_{eff}/L^2 values calculated by the first approach and in Table 27 for the values calculated by the second approach.

Table 26 Activation Energies (first approach)

Sample	$(D_{eff}/L^2)_0$	**Ea (kj/mol)**	R^2
Emir type grape seeds	0.875	3.048	0.9013
Emir type grape skins	2.692	32.848	0.9948
Bogazkere type grape seeds	$76.533*10^9$	99.411	0.8587
Bogazkere type grape skins	0.15	24.517	0.9861

Table 27 Activation Energies (second approach)

Sample	$(D_{eff}/L^2)_0$	**Ea (kj/mol)**	R^2
Emir type grape seeds	0.416	28.037	0.9644
Emir type grape skins	0.247	26.627	0.9914
Bogazkere type grape seeds	970920	69.059	0.998
Bogazkere type grape skins	0.064	22.809	0.9867

It was observed that the findings of the second approach had a better fit to an Arrhenius type equation than the first approach. This may be due to the validity difference of the approaches. The values calculated by the second approach resembles the activation energy values that have been calculated in literature such as 40.14 kj/mol of red grape seeds of variety Riesling, 30.45 and 31.47 kj/mol of white grape seeds of Concord and Cab Franc.(Roberts,2008) Furthermore, the results are comparable with grape pulp and marc activation energies of 25.41 and 13.74 kj/mol, respectively. (Doymaz,2009)

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

In Turkey, grape is produced at high amount of more than four million tons a year. It is harvested not only for table use but also for juice and wine production and grape pomace is a waste byproduct. In the light of the results obtained in this study the followings can be concluded:

- Owing to the beneficial health effects of this by-product, it is utilized after various processes such as separation, drying, pressing or milling whereas drying temperature is a critical part of the treatments.

- Drying rate was observed to increase with the air temperature and only falling rate drying period is seen. For this period, it was found that the drying kinetics can be explained accurately by the thin-layer drying models. Of these models it was seen that for Bogazkere seeds, Modified Two Term Model, for Bogazkere and Emir skins Modified Page Model and for Emir skins Logarithmic Model gave the best prediction.

- It was found that D_{eff} / L^2 values are larger for grape skins than grape seeds.

- D_{eff} / L^2 values of each type found for each temperature increased with increasing temperature and this dependence was described by application of an Arrhenius type equation.

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APPENDIX A

DRYING CONDITIONS

Table 28 Drying conditions of grape pomace varieties

Grape Pomace Variety	Tray Dryer Temperature			
Emir Type	40℃	50℃	55℃	60℃
Seeds	xxx	xxx	xxx	xxx
Skins	xxx	xxx	xxx	xxx
Bogazkere Type	40℃	50℃	55℃	60℃
Seeds	xxx	xxx	xxx	xxx
Skins	xxx	xxx	xxx	xxx

x represents replications.

APPENDIX B

INITIAL MOISTURE CONTENT DATA

Table 29 Initial moisture content data for Emir type grape seeds

	Moisture Content (g water/g dry solid)
1	0.72
2	0.68
3	0.70
4	0.69
5	0.71
6	0.69
7	0.65
8	0.70
9	0.72
10	0.61
11	0.67
12	0.66

Table 30 Initial moisture content data for Emir type grape skins

	Moisture Content (g water/g dry solid)
1	2.20
2	2.13
3	2.23
4	2.20
5	2.21
6	1.99
7	2.16
8	2.19
9	2.08
10	2.17
11	2.19
12	2.72

Table 31 Initial moisture content data for Bogazkere type grape seeds

	Moisture Content (g water/g dry solid)
1	1.16
2	1.05
3	1.12
4	1.09
5	1.12
6	1.13
7	1.06
8	1.06
9	1.19
10	1.01
11	1.19
12	1.08

Table 32 Initial moisture content data for Bogazkere type grape skins

	Moisture Content (g water/g dry solid)
1	5.91
2	5.51
3	5.72
4	6.03
5	5.46
6	5.65
7	5.61
8	5.74
9	5.58
10	6.01
11	5.47
12	5.56

APPENDIX C

SEED DIMENSIONS

Table 33 Emir type grape seed dimensions

	L (mm)	a (mm)
1	6.0	4.0
2	7.0	4.0
3	6.2	3.5
4	6.5	4.0
5	6.3	3.8
6	5.0	3.0
7	6.0	3.0
8	7.0	4.0
9	6.5	4.0
10	6.0	3.0

Table 34 Bogazkere type grape seed dimensions

	L (mm)	a (mm)
1	6.5	4.0
2	7.0	4.0
3	6.7	3.5
4	6.3	3.2
5	6.7	4.0
6	6.0	4.0
7	6.9	3.8
8	6.5	4.0
9	7.0	4.0
10	6.3	4.0

APPENDIX D

EQUILIBRIUM MOISTURE CONTENT DATA

Table 35 Equilibrium moisture contents of Emir type grape seeds

Temperature	Me (g water/g dry solid)
40	0.073 ± 0.006
50	0.066 ± 0.006
55	0.035 ± 0.006
60	0.021 ± 0.006

Table 36 Equilibrium moisture contents of Emir type grape skins

Temperature	Me (g water/g dry solid)
40	0.071 ± 0.003
50	0.061 ± 0.003
55	0.056 ± 0.003
60	0.038 ± 0.005

Table 37 Equilibrium moisture contents of Bogazkere type grape seeds

Temperature	Me (g water/g dry solid)
40	0.061 ± 0.003
50	0.042 ± 0.003
55	0.035 ± 0.006
60	0.032 ± 0.003

Table 38 Equilibrium moisture contents of Bogazkere type grape skins

Temperature	Me (g water/g dry solid)
40	0.068 ± 0.009
50	0.059 ± 0.008
55	0.044 ± 0.007
60	0.036 ± 0.009

APPENDIX E

DRYING DATA

Table 39 Drying data of Emir type grape seeds at 40 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9358	0.9375	0.9439	0.9391
20	0.8716	0.8778	0.8885	0.8793
30	0.8133	0.8250	0.8412	0.8265
40	0.7717	0.7803	0.8034	0.7851
50	0.7367	0.7405	0.7655	0.7476
60	0.7046	0.7103	0.7331	0.7160
70	0.6747	0.6774	0.7034	0.6851
80	0.6448	0.6506	0.6743	0.6566
90	0.6120	0.6245	0.6486	0.6284
100	0.5945	0.5943	0.6223	0.6037
110	0.5697	0.5758	0.5986	0.5813
120	0.5478	0.5531	0.5750	0.5586
130	0.5259	0.5346	0.5520	0.5375
140	0.5047	0.5119	0.5304	0.5157
150	0.4843	0.4934	0.5108	0.4962
160	0.4646	0.4756	0.4898	0.4767
170	0.4464	0.4570	0.4723	0.4586
180	0.4274	0.4392	0.4533	0.4400
190	0.4114	0.4213	0.4364	0.4230
200	0.3968	0.4035	0.4195	0.4066
210	0.3756	0.3740	0.4006	0.3834
220	0.3603	0.3589	0.3885	0.3692

Table 39 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
230	0.3450	0.3458	0.3709	0.3539
240		0.3321	0.3567	0.3444
250	0.3209	0.3204	0.3425	0.3280
260	0.3063	0.3060	0.3283	0.3136
270	0.2954	0.2943	0.3162	0.3020
280		0.2833	0.3033	0.2933
290	0.2742	0.2724	0.2898	0.2788
300	0.2648	0.2621	0.2790	0.2686
310	0.2502	0.2518	0.2675	0.2565
320	0.2422		0.2587	0.2504
330	0.2298	0.2408	0.2506	0.2404
340	0.2225	0.2312	0.2391	0.2309
350	0.2181	0.2223		0.2202
360	0.2108	0.2113	0.2216	0.2145
370	0.2035	0.2065	0.2121	0.2074
380	0.1977	0.1989	0.2040	0.2002
390	0.1911	0.1879	0.1979	0.1923
400	0.1853	0.1831	0.1898	0.1861
410	0.1809	0.1756	0.1844	0.1803
420	0.1758	0.1694	0.1790	0.1747
430	0.1692	0.1639		0.1666
440	0.1648	0.1564	0.1641	0.1618
450	0.1612	0.1495	0.1580	0.1562
460	0.1554	0.1461	0.1533	0.1516
470	0.1481	0.1413	0.1486	0.1460
480	0.1488	0.1385	0.1432	0.1435

Table 40 Drying data of Emir type grape seeds at 50 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9303	0.9249	0.9332	0.9295
20	0.8593	0.8505	0.8705	0.8601
30	0.7964	0.7868	0.8117	0.7983
40	0.7392	0.7330	0.7589	0.7437
50	0.6883	0.6838	0.7102	0.6941
60	0.6412	0.6366	0.6668	0.6482
70	0.5979	0.5941	0.6247	0.6056
80	0.5564	0.5543	0.5853	0.5653
90	0.5187	0.5171	0.5459	0.5272
100	0.4810	0.4832	0.5139	0.4927
110	0.4445	0.4520	0.4811	0.4592
120	0.4138	0.4194	0.4524	0.4285
130	0.3823	0.3915	0.4224	0.3987
140	0.3547	0.3636	0.3977	0.3720
150	0.3270	0.3410	0.3730	0.3470
160	0.2988	0.3164	0.3509	0.3220
170	0.2780	0.2932	0.3149	0.2954
180	0.2548	0.2746	0.3055	0.2783
190	0.2341	0.2527	0.2835	0.2567
200	0.2171	0.2374	0.2648	0.2398
210	0.2008	0.2201	0.2501	0.2237
220	0.1869	0.2042	0.2341	0.2084
230	0.1712	0.1909	0.2167	0.1929
240	0.1574	0.1809	0.2034	0.1806
250	0.1467	0.1690	0.1900	0.1686
260	0.1354	0.1597	0.1773	0.1575
270	0.1254	0.1504	0.1673	0.1477
280	0.1184	0.1397	0.1580	0.1387
290	0.1109	0.1351	0.1499	0.1320
300	0.1040	0.1278	0.1406	0.1241
310	0.0996	0.1218	0.1339	0.1184
320	0.0927	0.1158	0.1279	0.1121
330	0.0877	0.1132	0.1226	0.1078

Table 40 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.0826	0.1072	0.1172	0.1023
350	0.0782	0.1039	0.1119	0.0980
360	0.0751	0.1005	0.1079	0.0945
370	0.0732	0.0959	0.1039	0.0910
380	0.0694	0.0939	0.1005	0.0879
390		0.0906	0.0959	0.0932
400	0.0644	0.0873	0.0932	0.0816
410	0.0625	0.0846	0.0912	0.0794
420	0.0600	0.0826	0.0885	0.0770
430	0.0581	0.0806	0.0852	0.0746
440	0.0569	0.0779	0.0838	0.0729
450	0.0550	0.0746	0.0785	0.0694
460		0.0740	0.0765	0.0752
470	0.0500	0.0713	0.0758	0.0657
480		0.0693	0.0738	0.0716

Table 41 Drying data of Emir type grape seeds at 55 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9298	0.9296	0.9267	0.9287
20	0.8502	0.8579	0.8546	0.8542
30	0.7793	0.7952	0.7927	0.7890
40	0.7157	0.7442	0.7361	0.7320
50	0.6609	0.6925	0.6854	0.6796
60	0.6081	0.6537	0.6443	0.6354
70	0.5552	0.6091	0.5949	0.5864
80	0.5178	0.5678	0.5627	0.5494
90	0.4750	0.5303	0.5174	0.5076
100	0.4389	0.4857	0.4793	0.4680
110	0.4021	0.4521	0.4471	0.4338
120	0.3713	0.4276	0.4185	0.4058
130	0.3399	0.3966	0.3899	0.3754
140	0.3165	0.3681	0.3565	0.3470
150	0.2937	0.3430		0.3183
160	0.2710	0.3203	0.3047	0.2987
170	0.2536	0.2977	0.2844	0.2786
180	0.2329	0.2777	0.2642	0.2582
190	0.2161	0.2615	0.2451	0.2409
200	0.2034	0.2447	0.2267	0.2249
210	0.1914	0.2273	0.2171	0.2119
220	0.1780	0.2165	0.2040	0.1995
230	0.1673	0.2015	0.1838	0.1842
240	0.1606	0.1872	0.1808	0.1762
250	0.1519	0.1808	0.1716	0.1681
260	0.1426	0.1743	0.1647	0.1605
270	0.1378	0.1685	0.1534	0.1532
280	0.1312	0.1575	0.1480	0.1456
290	0.1258		0.1426	0.1342
300	0.1212	0.1369	0.1385	0.1322
310	0.1165	0.1317		0.1241
320	0.1138	0.1272	0.1254	0.1221
330	0.1105	0.1226	0.1230	0.1187

Table 41 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.1085	0.1201	0.1194	0.1160
350	0.1051		0.1152	0.1102
360	0.1018	0.1181	0.1117	0.1105
370	0.0984	0.1149	0.1099	0.1077
380	0.0957		0.1087	0.1022
390	0.0937	0.1097	0.1057	0.1031
400	0.0924	0.1052	0.1009	0.0995
410	0.0917	0.1007	0.0997	0.0974
420	0.0911	0.0987	0.0986	0.0961
430	0.0891	0.0974	0.0980	0.0948
440	0.0877	0.0962		0.0919
450	0.0864	0.0955	0.0944	0.0921
460	0.0850	0.0949	0.0902	0.0900
470	0.0824	0.0942	0.0890	0.0885
480	0.0797	0.0936	0.0884	0.0872

Table 42 Drying data of Emir type grape seeds at 60 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9591	0.8983	0.9249	0.9116
20	0.9074	0.8152	0.8404	0.8278
30	0.8533	0.7379	0.7773	0.7576
40	0.8035	0.6678	0.7117	0.6897
50	0.7548	0.6047	0.6454	0.6250
60	0.7085	0.5480	0.5987	0.5734
70	0.6661	0.4926	0.5476	0.5201
80	0.6237	0.4675	0.5034	0.4855
90	0.5832	0.4044	0.4574	0.4309
100	0.5455	0.3638	0.4202	0.3920
110	0.5085	0.3304	0.3855	0.3579
120	0.4727	0.2962	0.3533	0.3248
130	0.4416	0.2666	0.3255	0.2961
140	0.4096	0.2467	0.2996	0.2732
150	0.3801	0.2235	0.2776	0.2505
160	0.3509	0.2035	0.2574	0.2304
170	0.3240	0.1861	0.2397	0.2129
180	0.3015	0.1720	0.2233	0.1976
190	0.2746	0.1597	0.2094	0.1846
200	0.2513	0.1488	0.1981	0.1734
210	0.2330	0.1404	0.1861	0.1632
220	0.2143	0.1359	0.1779	0.1569
230	0.2143	0.1269	0.1697	0.1483
240	0.1828	0.1217	0.1640	0.1429
250	0.1680	0.1160	0.1577	0.1368
260	0.1524	0.1134	0.1526	0.1330
270	0.1407	0.1089	0.1501	0.1295
280	0.1291	0.1056	0.1457	0.1257
290	0.1201	0.1031	0.1413	0.1222
300	0.1108	0.1005	0.1388	0.1196
310	0.1034	0.0986	0.1369	0.1177
320		0.0921	0.1331	0.1126
330	0.0890	0.0902	0.1312	0.1107

Table 42 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.0839	0.0889	0.1287	0.1088
350	0.0796	0.0876	0.1268	0.1072
360	0.0722	0.0850	0.1249	0.1050
370	0.0683	0.0844	0.1230	0.1037
380	0.0668	0.0838	0.1198	0.1018
390	0.0637	0.0825	0.1186	0.1005
400	0.0625	0.0812	0.1179	0.0996
410	0.0598	0.0793	0.1154	0.0973
420	0.0578	0.0773	0.1141	0.0957
430	0.0555	0.0767	0.1129	0.0948
440	0.0539	0.0754	0.1116	0.0935
450	0.0504	0.0747	0.1097	0.0922
460	0.0497	0.0741	0.1085	0.0913
470	0.0485	0.0735	0.1066	0.0900
480	0.0473	0.0735	0.1059	0.0897

Table 43 Drying data of Emir type grape skins at 40 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9533	0.9536	0.9516	0.9528
20	0.9077	0.9005	0.8976	0.9019
30	0.8629	0.8522	0.8476	0.8543
40	0.8225	0.8066	0.8029	0.8107
50	0.7846	0.7648	0.7589	0.7694
60	0.7471	0.7249	0.7208	0.7309
70	0.7133	0.6800	0.6827	0.6920
80	0.6810	0.6517		0.6663
90	0.6508	0.6189	0.6139	0.6279
100	0.6225	0.5850	0.5821	0.5966
110	0.5950	0.5556	0.5525	0.5677
120	0.5689	0.5258	0.5233	0.5393
130	0.5431	0.4972	0.4952	0.5119
140	0.5189	0.4697	0.4697	0.4861
150	0.4957	0.4444	0.4460	0.4621
160	0.4623	0.4169	0.4220	0.4337
170	0.4509	0.3954	0.4006	0.4156
180	0.4310	0.3747	0.3776	0.3945
190	0.4104	0.3532	0.3573	0.3736
200	0.3910	0.3344	0.3395	0.3550
210	0.3722	0.3170	0.3207	0.3366
220	0.3472	0.2989	0.3029	0.3164
230	0.3369	0.2824	0.2870	0.3021
240	0.3266	0.2677	0.2715	0.2886
250	0.3035	0.2530	0.2571	0.2712
260	0.2880	0.2371	0.2438	0.2563
270	0.2733	0.2247	0.2308	0.2430
280	0.2590	0.2126	0.2186	0.2301
290	0.2461	0.2009	0.2075	0.2182
300	0.2336	0.1855	0.1964	0.2052
310	0.2211	0.1776	0.1865	0.1951
320	0.2105	0.1685	0.1779	0.1857
330	0.1969	0.1595	0.1683	0.1749

Table 43 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.1884	0.1501	0.1609	0.1665
350	0.1785	0.1429	0.1524	0.1579
360	0.1686	0.1342	0.1461	0.1497
370	0.1598	0.1271	0.1391	0.1420
380	0.1517	0.1210	0.1328	0.1352
390	0.1440	0.1142	0.1262	0.1281
400	0.1355	0.1086	0.1199	0.1213
410	0.1285	0.1022	0.1151	0.1153
420	0.1219	0.0973	0.1095	0.1096
430		0.0916	0.1055	0.0985
440	0.1098	0.0864	0.1014	0.0992
450	0.1043	0.0811	0.0970	0.0941
460	0.0984	0.0773	0.0936	0.0898
470	0.0932	0.0709	0.0896	0.0846
480	0.0888		0.0859	0.0873

Table 44 Drying data of Emir type grape skins at 50 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9360	0.9350	0.9391	0.9367
20	0.8671	0.8655	0.8747	0.8691
30	0.8057	0.8028	0.8127	0.8070
40	0.7498	0.7444	0.7571	0.7504
50	0.6991	0.6912	0.7058	0.6987
60	0.6518		0.6579	0.6548
70	0.6066	0.5963	0.6119	0.6049
80	0.5644	0.5531	0.5698	0.5624
90	0.5252	0.5124	0.5307	0.5228
100	0.4900	0.4773	0.4924	0.4866
110	0.4560	0.4415	0.4567	0.4514
120	0.4241	0.4083	0.4238	0.4187
130	0.3949	0.3776	0.3927	0.3884
140	0.3609	0.3492	0.3617	0.3573
150	0.3379	0.3226	0.3341	0.3315
160	0.3135	0.2971	0.3081	0.3062
170	0.2909	0.2746	0.2832	0.2829
180	0.2698	0.2535	0.2610	0.2614
190	0.2487	0.2328	0.2384	0.2400
200	0.2287	0.2144	0.2188	0.2206
210	0.2110	0.1970	0.2000	0.2027
220	0.1943	0.1807	0.1832	0.1861
230	0.1788	0.1656	0.1671	0.1705
240	0.1640	0.1519	0.1529	0.1563
250	0.1507	0.1394	0.1395	0.1432
260	0.1388	0.1275	0.1272	0.1312
270	0.1277	0.1172	0.1165	0.1205
280	0.1173	0.1080	0.1073	0.1109
290	0.1081	0.0987	0.0966	0.1011
300	0.1000	0.0899	0.0882	0.0927
310	0.0914	0.0836	0.0801	0.0851
320	0.0844	0.0773	0.0728	0.0782
330	0.0774	0.0703	0.0675	0.0717

Table 44 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.0729	0.0651	0.0617	0.0666
350	0.0663	0.0600	0.0568	0.0610
360	0.0615	0.0555	0.0502	0.0557
370	0.0574	0.0518	0.0433	0.0509
380	0.0541	0.0481	0.0399	0.0474
390	0.0504	0.0448	0.0372	0.0441
400	0.0467	0.0415	0.0341	0.0408
410	0.0444	0.0389		0.0417
420	0.0411	0.0367	0.0307	0.0362
430	0.0393	0.0334		0.0363
440	0.0374	0.0315	0.0273	0.0321
450	0.0356	0.0300	0.0265	0.0307
460	0.0337	0.0289	0.0234	0.0287
470	0.0326	0.0278	0.0230	0.0278
480	0.0307	0.0263	0.0215	0.0262

Table 45 Drying data of Emir type grape skins at 55 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9247	0.9271	0.9232	0.9259
20	0.8461	0.8591	0.8525	0.8526
30	0.7759	0.7792	0.7897	0.7776
40	0.7144	0.7160	0.7368	0.7152
50	0.6591	0.6575	0.6875	0.6583
60	0.6087	0.6017	0.6404	0.6052
70	0.5619	0.5532	0.5979	0.5576
80	0.5174	0.5066	0.5572	0.5120
90	0.4766	0.4619	0.5175	0.4692
100	0.4391	0.4219	0.4818	0.4305
110	0.4035	0.3849	0.4486	0.3942
120	0.3705	0.3502	0.4165	0.3603
130	0.3390	0.3187		0.3289
140	0.3104		0.3579	0.3104
150	0.2833	0.2622	0.3308	0.2727
160	0.2588	0.2403	0.3050	0.2496
170	0.2366	0.2178	0.2815	0.2272
180		0.1982	0.2597	0.1982
190	0.1976	0.1797	0.2379	0.1887
200	0.1784	0.1623	0.2179	0.1703
210		0.1453	0.1983	0.1453
220	0.1490		0.1818	0.1490
230	0.1364	0.1209	0.1640	0.1287
240	0.1249	0.1087	0.1490	0.1168
250	0.1134	0.0994	0.1343	0.1064
260	0.1034	0.0883	0.1204	0.0959
270	0.0964	0.0802	0.1075	0.0883
280		0.0743	0.0954	0.0743
290	0.0819	0.0680	0.0840	0.0749
300	0.0763	0.0624	0.0740	0.0694
310	0.0708	0.0565	0.0636	0.0637
320	0.0663	0.0528	0.0554	0.0596
330	0.0622	0.0491	0.0479	0.0557

Table 45 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.0593	0.0454	0.0404	0.0524
350	0.0563	0.0428	0.0347	0.0496
360	0.0533	0.0410	0.0290	0.0472
370	0.0515	0.0391	0.0243	0.0453
380	0.0526	0.0354	0.0201	0.0440
390	0.0478	0.0336	0.0172	0.0407
400	0.0459	0.0321	0.0136	0.0390
410	0.0452	0.0303	0.0111	0.0377
420	0.0437	0.0295	0.0086	0.0366
430	0.0426		0.0068	0.0426
440	0.0422	0.0273	0.0040	0.0348
450	0.0411	0.0269	0.0029	0.0340
460	0.0404	0.0266	0.0018	0.0335
470	0.0389	0.0262	0.0004	0.0325
480	0.0389	0.0258		0.0324

Table 46 Drying data of Emir type grape skins at 60 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9273	0.9198	0.9108	0.9193
20	0.8532	0.8344	0.8257	0.8377
30	0.7867	0.7609	0.7482	0.7653
40	0.7276	0.6978	0.6799	0.7017
50	0.6722	0.6328	0.6178	0.6409
60	0.6226	0.5738	0.5615	0.5860
70	0.5745	0.5218	0.5092	0.5352
80	0.5294		0.4613	0.4953
90	0.4864	0.4223	0.4177	0.4421
100	0.4460	0.3814	0.3755	0.4010
110	0.4089	0.3417	0.3363	0.3623
120	0.3719	0.3079	0.3004	0.3267
130	0.3377	0.2741	0.2669	0.2929
140	0.3069	0.2444		0.2756
150	0.2779	0.2177	0.2058	0.2338
160	0.2500	0.1932	0.1800	0.2077
170	0.2258	0.1713	0.1559	0.1843
180	0.2008	0.1516	0.1334	0.1619
190	0.1802	0.1330	0.1137	0.1423
200	0.1604	0.1189	0.0959	0.1251
210		0.1052	0.0798	0.0925
220	0.1263	0.0933	0.0651	0.0949
230	0.1116	0.0825	0.0540	0.0827
240	0.0991	0.0725	0.0439	0.0718
250	0.0874	0.0643	0.0356	0.0624
260	0.0778	0.0562	0.0285	0.0542
270	0.0686	0.0499	0.0188	0.0458
280	0.0606	0.0439	0.0151	0.0399
290	0.0539	0.0387	0.0121	0.0349
300	0.0477		0.0097	0.0287
310	0.0418	0.0317	0.0087	0.0274
320	0.0382	0.0283	0.0077	0.0247
330	0.0334	0.0261	0.0061	0.0218

Table 46 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.0297	0.0242	0.0057	0.0199
350	0.0275	0.0220	0.0057	0.0184
360	0.0253	0.0209	0.0044	0.0169
370	0.0231	0.0194	0.0034	0.0153
380	0.0216	0.0183	0.0034	0.0144
390	0.0198	0.0179	0.0030	0.0136
400	0.0183	0.0179	0.0024	0.0129
410	0.0165	0.0172	0.0024	0.0120
420	0.0158	0.0164	0.0020	0.0114
430	0.0139	0.0157		0.0148
440	0.0136	0.0153	0.0014	0.0101
450	0.0128	0.0135	0.0014	0.0092
460	0.0121	0.0131	0.0010	0.0087
470	0.0117	0.0127	0.0010	0.0085
480	0.0114	0.0127	0.0010	0.0084

Table 47 Drying data of Bogazkere type grape seeds at 40 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9196	0.9576	0.9206	0.9326
20	0.8488	0.8866	0.8514	0.8623
30	0.7900	0.8281	0.7945	0.8042
40	0.7377	0.7787	0.7471	0.7545
50	0.6950	0.7389	0.7075	0.7138
60	0.6608	0.7061	0.6754	0.6808
70	0.6317	0.6787	0.6469	0.6524
80	0.6081	0.6540		0.6310
90	0.5885	0.6325	0.6042	0.6084
100	0.5719	0.6159	0.5874	0.5917
110	0.5568	0.5960	0.5711	0.5746
120	0.5402	0.5767	0.5564	0.5578
130	0.5262	0.5643	0.5436	0.5447
140	0.5131	0.5487	0.5314	0.5311
150	0.5000	0.5342	0.5197	0.5180
160	0.4880	0.5251	0.5075	0.5069
170	0.4759	0.5090	0.4953	0.4934
180	0.4643	0.4961	0.4851	0.4819
190	0.4528	0.4864	0.4750	0.4714
200	0.4427		0.4648	0.4538
210	0.4317	0.4633	0.4551	0.4500
220	0.4216	0.4520	0.4454	0.4397
230	0.4131	0.4424	0.4368	0.4308
240	0.4020	0.4316	0.4276	0.4204
250	0.3930	0.4220	0.4185	0.4111
260	0.3840	0.4134	0.4103	0.4025
270	0.3754	0.4032	0.4017	0.3934
280	0.3664	0.3935	0.3935	0.3845
290	0.3578	0.3860	0.3849	0.3762
300	0.3498	0.3768	0.3768	0.3678
310	0.3422	0.3666		0.3544
320	0.3347	0.3580	0.3615	0.3514
330	0.3262	0.3500	0.3539	0.3433

Table 47 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.3181	0.3408	0.3457	0.3349
350	0.3111	0.3333	0.3386	0.3277
360	0.3036	0.3258	0.3310	0.3201
370	0.2955	0.3177	0.3238	0.3124
380	0.2890	0.3097	0.3157	0.3048
390	0.2814	0.3027	0.3091	0.2977
400	0.2749	0.2952	0.3025	0.2909
410	0.2679	0.2893	0.2964	0.2845
420	0.2613	0.2834	0.2898	0.2782
430	0.2553	0.2769	0.2831	0.2718
440	0.2498	0.2705	0.2760	0.2654
450	0.2423	0.2645	0.2689	0.2586
460	0.2357	0.2581	0.2623	0.2520
470	0.2302	0.2517	0.2562	0.2460
480	0.2242	0.2447	0.2501	0.2396

Table 48 Drying data of Bogazkere type grape seeds at 50 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.8900	0.9113	0.8916	0.8908
20	0.7881	0.8316	0.7863	0.7872
30	0.7092	0.7611	0.7058	0.7075
40	0.6479	0.7051	0.6456	0.6468
50	0.5992	0.6587	0.6014	0.6003
60	0.5580	0.6199	0.5666	0.5623
70	0.5244	0.5877	0.5368	0.5306
80	0.4952	0.5584	0.5104	0.5028
90	0.4686	0.5347	0.4856	0.4771
100	0.4455	0.5116	0.4632	0.4544
110	0.4234	0.4899	0.4414	0.4324
120	0.4018	0.4692	0.4205	0.4111
130	0.3807	0.4506	0.3976	0.3892
140	0.3576	0.4314	0.3772	0.3674
150	0.3410	0.4123	0.3579	0.3495
160	0.3225	0.3951	0.3375	0.3300
170	0.3049	0.3780	0.3186	0.3117
180	0.2878	0.3608	0.2992	0.2935
190	0.2702	0.3452	0.2823	0.2763
200	0.2557	0.3306	0.2639	0.2598
210	0.2406	0.3135	0.2480	0.2443
220	0.2265	0.2983	0.2321	0.2293
230	0.2120	0.2832	0.2172	0.2146
240	0.1979	0.2696	0.2013	0.1996
250	0.1833	0.2560	0.1884	0.1859
260	0.1708	0.2424	0.1745	0.1726
270	0.1587	0.2293	0.1620	0.1604
280	0.1487	0.2172	0.1496	0.1491
290	0.1376	0.2051	0.1377	0.1377
300	0.1251	0.1940	0.1277	0.1264
310	0.1175	0.1834	0.1173	0.1174
320	0.1070	0.1713	0.1064	0.1067
330	0.0985	0.1617	0.0984	0.0984

Table 48 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.0884	0.1517	0.0845	0.0865
350	0.0789	0.1421	0.0810	0.0799
360	0.0718	0.1325	0.0731	0.0725
370	0.0638	0.1249	0.0661	0.0650
380	0.0553	0.1159	0.0581	0.0567
390	0.0487	0.1083	0.0517	0.0502
400	0.0422	0.1002	0.0457	0.0440
410	0.0352	0.0917	0.0398	0.0375
420	0.0312	0.0856	0.0353	0.0332
430	0.0236	0.0776	0.0298	0.0267
440	0.0191	0.0710	0.0248	0.0220
450	0.0146	0.0655	0.0199	0.0172
460	0.0096	0.0589	0.0154	0.0125
470	0.0055	0.0539	0.0119	0.0087
480	0.0020	0.0483		0.0020

Table 49 Drying data of Bogazkere type grape seeds at 55 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.8979	0.8897	0.8982	0.8953
20	0.8048	0.8000	0.8059	0.8036
30	0.7339	0.7343	0.7325	0.7336
40	0.6825	0.6817	0.6748	0.6797
50	0.6418	0.6386	0.6279	0.6361
60	0.6036	0.6035	0.5881	0.5984
70	0.5688	0.5699	0.5545	0.5644
80	0.5361	0.5369	0.5242	0.5324
90	0.5045	0.5078	0.4939	0.5020
100	0.4753	0.4787	0.4669	0.4736
110	0.4461	0.4496	0.4390	0.4449
120	0.4184	0.4221	0.4139	0.4181
130	0.3902	0.3960	0.3893	0.3918
140	0.3641	0.3700	0.3666	0.3669
150	0.3384	0.3449	0.3438	0.3424
160	0.3148	0.3223	0.3225	0.3199
170	0.2932	0.3013	0.3026	0.2990
180	0.2730	0.2802	0.2818	0.2784
190	0.2509	0.2607	0.2633	0.2583
200	0.2313		0.2454	0.2383
210	0.2132	0.2236	0.2288	0.2218
220	0.1966	0.2061	0.2122	0.2049
230	0.1810	0.1910	0.1975	0.1898
240	0.1669	0.1765	0.1838	0.1757
250	0.1523	0.1619	0.1701	0.1614
260	0.1392	0.1494	0.1587	0.1491
270		0.1374	0.1483	0.1428
280	0.1171	0.1264	0.1374	0.1269
290	0.1065	0.1173	0.1284	0.1174
300	0.0949	0.1073	0.1189	0.1071
310	0.0884	0.0983		0.0933
320	0.0808	0.0898		0.0853
330	0.0723	0.0827	0.0958	0.0836

Table 49 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.0658	0.0742	0.0891	0.0764
350		0.0672	0.0830	0.0751
360	0.0532	0.0612	0.0778	0.0640
370		0.0557	0.0711	0.0634
380	0.0431	0.0497	0.0664	0.0531
390	0.0386	0.0457	0.0626	0.0490
400	0.0336	0.0422		0.0379
410	0.0305	0.0371		0.0338
420	0.0265	0.0331	0.0508	0.0368
430	0.0235	0.0301	0.0479	0.0338
440	0.0200	0.0271	0.0456	0.0309
450	0.0180	0.0246	0.0418	0.0281
460	0.0159		0.0394	0.0277
470	0.0129	0.0191	0.0380	0.0233
480	0.0109	0.0171	0.0356	0.0212

Table 50 Drying data of Bogazkere type grape skins at 60 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.8984	0.8909	0.8858	0.8917
20	0.8262	0.7999	0.7925	0.8062
30	0.7684	0.7088	0.7196	0.7323
40	0.7179	0.6571	0.6633	0.6794
50	0.6627	0.6144	0.6169	0.6313
60	0.6194	0.5703	0.5715	0.5871
70	0.5802	0.5257	0.5336	0.5465
80	0.5394	0.4968	0.4892	0.5085
90	0.5013	0.4627	0.4503	0.4714
100	0.4647	0.4299	0.4143	0.4363
110	0.4306	0.3986	0.3804	0.4032
120	0.3971	0.3688	0.3480	0.3713
130	0.3698	0.3417	0.3191	0.3435
140	0.3357	0.3137	0.2916	0.3137
150	0.3094	0.2858	0.2672	0.2875
160	0.2842	0.2668	0.2432	0.2647
170	0.2599	0.2459	0.2223	0.2427
180	0.2393	0.2265	0.2008	0.2222
190	0.2187	0.2075	0.1839	0.2033
200	0.2016	0.1909	0.1684	0.1870
210	0.1862	0.1753	0.1544	0.1720
220	0.1702	0.1582	0.1430	0.1571
230		0.1482	0.1355	0.1419
240	0.1434	0.1326	0.1210	0.1323
250	0.1305		0.1115	0.1210
260	0.1191	0.1065	0.1031	0.1096
270	0.1098		0.0936	0.1017
280	0.1006	0.0975		0.0990
290	0.0923	0.0908	0.0811	0.0881
300	0.0866	0.0837	0.0746	0.0817
310	0.0799	0.0776	0.0667	0.0747
320	0.0737		0.0652	0.0694
330	0.0686	0.0671	0.0632	0.0663

Table 50 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.0639	0.0629	0.0572	0.0613
350	0.0588	0.0586	0.0547	0.0573
360	0.0552	0.0543	0.0487	0.0527
370	0.0505	0.0515	0.0457	0.0492
380	0.0480	0.0486	0.0417	0.0461
390	0.0459	0.0448	0.0407	0.0438
400		0.0429	0.0387	0.0408
410	0.0412	0.0406	0.0372	0.0397
420	0.0382	0.0377	0.0362	0.0374
430	0.0371	0.0358	0.0327	0.0352
440	0.0356		0.0317	0.0337
450	0.0335	0.0325	0.0307	0.0322
460	0.0320	0.0306		0.0313
470	0.0304	0.0297	0.0297	0.0299
480	0.0284	0.0287	0.0292	0.0288

Table 51 Drying data of Bogazkere type grape skins at 40 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9487	0.9524	0.9518	0.9510
20	0.8949	0.9025	0.8980	0.8985
30	0.8442	0.8552		0.8497
40	0.7970	0.8118	0.8059	0.8049
50	0.7512	0.7717	0.7658	0.7629
60	0.7102	0.7351	0.7268	0.7241
70	0.6702	0.6994	0.6898	0.6865
80	0.6329	0.6646	0.6526	0.6500
90	0.5954	0.6310	0.6190	0.6152
100	0.5599	0.6007	0.5864	0.5823
110	0.5267	0.5704	0.5557	0.5509
120	0.4981	0.5410	0.5227	0.5206
130	0.4660	0.5124	0.4892	0.4892
140	0.4362	0.4859	0.4608	0.4610
150	0.4102	0.4580	0.4238	0.4307
160	0.3833	0.4339	0.4035	0.4069
170	0.3581	0.4069	0.3783	0.3811
180	0.3343	0.3840	0.3556	0.3580
190	0.3114	0.3599	0.3324	0.3346
200	0.2893	0.3376	0.3109	0.3126
210	0.2682	0.3156	0.2894	0.2910
220	0.2493	0.2951	0.2699	0.2714
230	0.2306	0.2752	0.2513	0.2524
240	0.2138	0.2573	0.2338	0.2349
250	0.1971	0.2386	0.2174	0.2177
260	0.1820	0.2216	0.2008	0.2015
270	0.1671	0.2056	0.1845	0.1857
280	0.1536	0.1904	0.1704	0.1715
290	0.1407	0.1762	0.1567	0.1579
300	0.1290	0.1628	0.1438	0.1452
310	0.1170	0.1491	0.1317	0.1326
320	0.1064	0.1366	0.1206	0.1212
330	0.0966	0.1259	0.1094	0.1106

Table 51 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
330	0.0966	0.1259	0.1094	0.1106
340	0.0878	0.1149	0.0991	0.1006
350	0.0795	0.1054	0.0905	0.0918
360	0.0720	0.0962	0.0810	0.0831
370	0.0643	0.0876		0.0759
380	0.0577	0.0801	0.0658	0.0679
390	0.0508	0.0727	0.0592	0.0609
400	0.0457	0.0658	0.0526	0.0547
410	0.0402	0.0593	0.0469	0.0488
420	0.0357	0.0543	0.0420	0.0440
430	0.0305	0.0486	0.0371	0.0387
440	0.0271	0.0436	0.0331	0.0346
450	0.0233	0.0397	0.0297	0.0309
460	0.0202	0.0355	0.0260	0.0272
470	0.0170	0.0317	0.0225	0.0237
480	0.01447	0.02809	0.0199	0.0208

Table 52 Drying data of Bogazkere type grape skins at 50 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9462	0.9258	0.9350	0.9356
20	0.8876	0.8595	0.8641	0.8704
30	0.8338	0.7936	0.8005	0.8093
40	0.7823	0.7331	0.7417	0.7524
50	0.7352	0.6766	0.6891	0.7003
60	0.6913	0.6238	0.6377	0.6509
70	0.6471	0.5736	0.5913	0.6040
80	0.6061	0.5282	0.5467	0.5603
90	0.5663	0.4818	0.5039	0.5174
100	0.5283	0.4432	0.4637	0.4784
110	0.4917	0.4032	0.4273	0.4407
120	0.4595	0.3666	0.3919	0.4060
130	0.4262	0.3325	0.3588	0.3725
140	0.3963	0.3010	0.3284	0.3419
150	0.3665	0.2710	0.2991	0.3122
160	0.3381	0.2422	0.2728	0.2844
170	0.3097	0.2173	0.2483	0.2584
180	0.2845	0.1968	0.2249	0.2354
190	0.2600	0.1760	0.2037	0.2132
200	0.2368	0.1570	0.1850	0.1930
210	0.2149	0.1401	0.1679	0.1743
220	0.1941	0.1243	0.1523	0.1569
230	0.1757	0.1101	0.1369	0.1409
240	0.1593	0.0973	0.1239	0.1268
250	0.1432	0.0851	0.1118	0.1134
260	0.1280	0.0759	0.1014	0.1018
270	0.1145	0.0658	0.0917	0.0907
280	0.1017	0.0584	0.0828	0.0810
290	0.0911	0.0513	0.0748	0.0724
300	0.0815	0.0450	0.0674	0.0647
310	0.0721	0.0394	0.0612	0.0576
320	0.0636	0.0349		0.0493
330	0.0563	0.0308	0.0485	0.0452

Table 52 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340		0.0290	0.0435	0.0363
350	0.0437	0.0269	0.0385	0.0364
360	0.0399		0.0341	0.0370
370	0.0358	0.0234	0.0305	0.0299
380	0.0320	0.0207	0.0267	0.0265
390	0.0285	0.0171	0.0237	0.0231
400	0.0259	0.0154	0.0214	0.0209
410	0.0235	0.0139	0.0190	0.0188
420	0.0215	0.0124	0.0169	0.0169
430	0.0200	0.0112	0.0143	0.0152
440		0.0100	0.0134	0.0117
450	0.0183	0.0094	0.0119	0.0132
460	0.0174	0.0079	0.0107	0.0120
470	0.0168	0.0070	0.0098	0.0112
480	0.0165	0.0064	0.0089	0.0106

Table 53 Drying data of Bogazkere type grape skins at 55 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9320	0.9304	0.9230	0.9285
20	0.8604	0.8532	0.8484	0.8540
30	0.7945	0.7825	0.7773	0.7848
40	0.7335	0.7185	0.7128	0.7216
50	0.6768	0.6584	0.6512	0.6621
60	0.6226	0.6021	0.5958	0.6069
70	0.5724	0.5481	0.5419	0.5542
80	0.5245	0.4983	0.4931	0.5053
90	0.4786	0.4500	0.4463	0.4583
100	0.4340	0.4055	0.4043	0.4146
110	0.3970	0.3642	0.3637	0.3750
120	0.3591	0.3259	0.3270	0.3373
130	0.3248	0.2902	0.2923	0.3025
140	0.2902	0.2578	0.2613	0.2698
150	0.2618	0.2286	0.2316	0.2407
160	0.2331	0.2018	0.2056	0.2135
170	0.2074	0.1930	0.1813	0.1939
180	0.1820	0.1570	0.1591	0.1660
190	0.1616	0.1370	0.1396	0.1460
200	0.1406	0.1199	0.1212	0.1272
210	0.1222	0.1045	0.1052	0.1107
220	0.1069	0.0919	0.0925	0.0971
230	0.0924	0.0801	0.0800	0.0842
240	0.0797	0.0704	0.0697	0.0732
250	0.0687	0.0615	0.0602	0.0635
260	0.0596	0.0547	0.0525	0.0556
270	0.0513	0.0482	0.0463	0.0486
280	0.0457	0.0424	0.0401	0.0427
290	0.0403	0.0376	0.0368	0.0383
300	0.0356	0.0332		0.0344
310	0.0318	0.0297	0.0282	0.0299
320	0.0291	0.0264	0.0250	0.0268
330	0.0264	0.0235	0.0223	0.0241

Table 53(continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340		0.0211	0.0199	0.0205
350	0.0223	0.0185	0.0179	0.0195
360	0.0208	0.0167	0.0161	0.0179
370	0.0196	0.0146		0.0171
380	0.0187	0.0129	0.0137	0.0151
390	0.0179	0.0114	0.0125	0.0139
400	0.0164	0.0102	0.0114	0.0127
410	0.0158	0.0093	0.0105	0.0119
420	0.0152	0.0082	0.0096	0.0110
430	0.0146	0.0073	0.0087	0.0102
440	0.0137	0.0064	0.0084	0.0095
450	0.0134	0.0061	0.0072	0.0089
460	0.0128	0.0055	0.0069	0.0084
470	0.0125	0.0055	0.0066	0.0082
480	0.0122	0.0052	0.0060	0.0078

Table 54 Drying data of Bogazkere type grape seeds at 60 ºC at air velocity of 1 m/s.

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
0	1	1	1	1
10	0.9205	0.9257	0.9154	0.9205
20	0.8410	0.8475	0.8334	0.8406
30	0.7688	0.7768	0.7598	0.7685
40	0.7031	0.7120	0.6897	0.7016
50	0.6432	0.6493	0.6250	0.6392
60	0.5886	0.5937	0.5647	0.5823
70	0.5373	0.5399	0.5077	0.5283
80	0.4889	0.4914	0.4522	0.4775
90	0.4440	0.4462	0.4083	0.4328
100	0.4026	0.4025	0.3548	0.3867
110	0.3612	0.3583	0.3233	0.3476
120	0.3260	0.3187	0.2850	0.3099
130		0.2822	0.2512	0.2667
140	0.2603	0.2492	0.2209	0.2435
150	0.2321	0.2200	0.1933	0.2152
160	0.2057	0.1921	0.1669	0.1882
170	0.1822	0.1674	0.1443	0.1647
180	0.1602	0.1454	0.1229	0.1429
190	0.1403	0.1261	0.1101	0.1255
200	0.1224	0.1086		0.1155
210	0.1063	0.0937	0.0813	0.0938
220	0.0922	0.0803	0.0710	0.0812
230	0.0798	0.0696	0.0609	0.0701
240	0.0690	0.0604	0.0525	0.0607
250	0.0593	0.0527	0.0457	0.0526
260	0.0514	0.0467	0.0389	0.0457
270	0.0443	0.0417	0.0332	0.0398
280	0.0382	0.0378	0.0285	0.0348
290	0.0332	0.0340	0.0243	0.0305
300	0.0288	0.0313	0.0214	0.0272
310	0.0247	0.0289	0.0181	0.0239
320	0.0217	0.0265	0.0157	0.0213
330		0.0248	0.0137	0.0192

Table 54 (continued)

Time (min)	MR Sample 1	MR Sample 2	MR Sample 3	MR Average
340	0.0173	0.0233	0.0122	0.0176
350	0.0156	0.0212	0.0110	0.0159
360	0.0141	0.0203	0.0095	0.0146
370	0.0129	0.0185		0.0157
380	0.0121	0.0176	0.0083	0.0127
390	0.0112	0.0167	0.0077	0.0119
400	0.0106	0.0155	0.0071	0.0111
410	0.0097	0.0146	0.0062	0.0102
420	0.0091	0.0143	0.0056	0.0097
430	0.0085	0.0135		0.0110
440	0.0083	0.0132	0.0050	0.0088
450	0.0077	0.0126	0.0047	0.0083
460	0.0074	0.0120	0.0042	0.0078
470	0.0068	0.0117	0.0039	0.0074
480	0.0065	0.0000	0.0036	0.0033