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M.Sc. in Food Engineering

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REPUBLIC OF TURKEY

GAZİANTEP UNIVERSITY

GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES

PRODUCTION OF A HEALTHY SNACK BAR

M.Sc. THESIS

IN

FOOD ENGINEERING

BY

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PRODUCTION OF A HEALTHY SNACK BAR

M.Sc. Thesis

in

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Supervisor

Prof. Dr. Fahrettin GÖĞÜŞ

by

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This is to certify that we have read this thesis and that in our consensus/majority opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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

Seda ERASLAN

ABSTRACT

PRODUCTION OF A HEALTHY SNACK BAR

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M.Sc. in Food Engineering
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In this study, a new healthy and nutritious snack bar was produced. Firstly, the candidate ingredients (Pistachio, chia seed, flax seed, quinoa and mulberry molasses / apple concentrate) were selected. During the selection of these components, being nutritional, preservative-free and having minimum amount of sugar were the main criteria. Mucilage (gel-like substance) extracted from the water suspension of chia and flaxseed was used to minimize the level of sugar, which is commonly in use as binding agent and sugar sweetener in the snack bar industry. Molasses and apple juice concentrate were used to obtain a sweet taste and oil seeds were preferred because of their high PUFA, protein and pulp content. Thus, three different possible product formulations were developed. The product, which contains pistachio, chia, flax seed, apple juice concentrate and quinoa formulation, received a higher score (6.93 compared to 7-point hedonic scale) at the sensory analysis. Following the selection of the components, drying methods (atmospheric oven, vacuum oven and vacuum oven combined with microwave oven) and time were studied. Texture profile analysis (hardness, fracturability), color analysis and 7-point hedonic sensory analysis (in terms of fracturability, hardness, chewiness and overall acceptability) performed to determine the appropriate drying method and time to be used in the highest scored product. Finally, energy (594.8 kcal), sugar (15.05g), protein (16.89g), fat (33.17g), ash (2.38g) and total phenolic (2436mg GA) contents were determined for 100g of the final product.

Key Words: Product Development, Healthy Snack Bar, Sensory Analysis, Drying Methods.

ÖZET

SAĞLIKLI BİR ATIŞTIRMALIK BAR ÜRETİMİ

ERASLAN, Seda
Yüksek Lisans Tezi, Gıda Mühendisliği
Danışman: Prof. Dr. Fahrettin GÖĞÜŞ
Temmuz 2019
74 sayfa

Bu çalışmada, sağlıklı ve besleyici bir atıştırmalık bar üretimi yapılmıştır. Öncelikle, ürün içeriğinde kullanılacak aday bileşenler (Antep fıstığı, chia tohumu, keten tohumu, kinoa ve dut pekmezi/elma konsantresi) seçilmiştir. Bu bileşenlerin seçiminde temel kriter olarak besleyicilik, koruyucu madde içermeme ve şeker miktarının minimum olması belirlenmiştir. Atıştırmalık bar endistürisinde yaygın bir şekilde bağlayıcı ajan ve şekerli tat verici olarak kullanılan şeker seviyesini minimuma indirebilmek amacıyla çia ve keten tohumunun su süspansiyonundan ekstrakt edilen musilaj (jel-benzeri madde) kullanılmıştır. Şekerli tat elde etmek için pekmez ve elma suyu konsantresi kullanılmış ve yüksek PUFA, protein ve posa içerikleri sebebiyle yağlı tohumlar tercih edilmiştir. Böylece, üç farklı olası ürün formülasyonu geliştirilmiştir. Bunlardan antepfıstığı, çia, keten tohumu, elma suyu konsantresi ve kinoa içerikli formülasyona sahip olan ürün duyusal analiz sonucunda panalistler tarafıdan diğerlerinden daha yüksek puan (7 noktalı hedonik skalaya göre 6.93) almıştır. Bileşen seçimi çalışmalarını takiben ise kurutma metodları (atmosferik fırın, vakumlu fırın ve mikrodalga fırınla kombinlenmiş vakumlu fırın) ve süresi üzerine çalışılmıştır. Yüksek puanlı üründe kullanılacak uygun kurutma yönteminin ve süresinin belirlenmesi için doku profil analizi (sertlik, kırılabilirlik), renk analizi ve 7 noktalı hedonik duyusal analiz (kırılma, sertlik, çiğnenebilirlik ve genel kabul edilebilirlik bakımından) yapılmıştır. Yapılan analizler sonucunda kurutma şartları vakum fırınında 75 °C de 210dk olarak belirlenmiştir. Son olarak, son ürünün 100g'ı için enerji (594.8 kcal), şeker(15.05g), protein(16.89g), yağ(33.17g), kül(2.38g) ve toplam fenolik(2436mg GA) içeriği bulunmuştur.

Anahtar Kelimeler: Ürün Geliştirme, Sağlıklı Atıştırmalık Bar, Duyusal Analiz, Kurutma Metodları.

"Dedicated to my family"

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CHAPTER 1

INTRODUCTION

A snack can be defined as a small, lightweight food, which is easy to manipulate, ready to eat, accessible and able to satisfy the appetite sensation for a moment [1]. Although the number of conscious consumers has increased in recent years, people are not giving up snack foods. Moreover the snack foods have become an important part of today's human diet. The widespread consumption of snack foods is independent from consumer's social status, age, or gender. As the demand of ready-to-eat food increases, the snack industry has also grown [2].

From past to present, depending on the developments in the food industry, snacks continued to be important even if its production shapes changed with technological developments. Recently times, on the market shelves, ready-to-eat snacks (biscuits, crackers, chips, cakes, etc.) started to be found in addition to traditional products (Turkish delight, pulp, nuts, and dried fruit, etc.). In recent times, consumption trend has turned to the past because of questions that foods overconsumption with low nutritional value. Therefore, industrial snack manufacturers changed some criticized contents with natural ones for new designed snacks and presented them to the market. Another reason for the increase in tendency to healthy snacks was the increase in chronic diseases such as diabetes and obesity. Research has shown that food choices have a great impact on health [3].

The snacks industry is booming and offering various kinds of snacks all around the world. Even if there are no former classification for snack foods, they can be classified according to the production process as fried, dried, baked-roasted and extruded. Snack bars can be classified in dried and extruded snack food group. There are four main categories of bars in the market as granola bars, nutritional/healthy bars, breakfast/cereal bars and diet snack bars. All of the groups are focused on health and convenience on marketing activities. A nutritional bar can be defined as a type of

snacking together with its health benefits. Moreover, they are generally categorized in three groups as high-protein bars, energy bars and healthy snack bars [4].

The snacks industry covers a huge area, including biscuits, crackers, chips, cookies, nuts, chocolates, dried fruits, cereals, and snack bars etc. However the majority of these snacks; It has too fatty, sugary, salty content. For these reasons, there is a need for new healthy snack product designs for satisfy consumer demand.

The aim of this study is to produce a new nutritious (healthy) snack bar by using different valuable ingredients and using different drying methods. To this end, some seeds (flax seed, chia seed, and quinoa), apple juice concentrate/molasses and pistachio powder have been used as omega rich oil source, sugar replacer and flavoring component, respectively. First of all three different snack bar formulations (S1: seeds and pistachio powder with apple juice concentrate; S2: seeds and pistachio powder with molasses and S3: seeds and pistachio powder without apple juice or molasses) were decided to prepare of different combination of these ingredients. Then the sensory analysis was applied using 7-point hedonic scale by expert panelists (n=30) to decide the most acceptable snack combination. Some chemical properties such as titratable acidity and sugar content of the snacks were also determined. The acidity and sugar content of (S1) were determined. The most accepted formulation have been dried by using microwave oven, oven and vacuum oven to obtain the best drying method and time to get a product which has desired hardness, fracturability and color properties. Finally, nutritional parameters (energy, sugar, protein, fat, ash and phenolic) was determined for a healthy snack bar which has gluten-free, preservative-free, artificial-sugar-free.

CHAPTER 2

LITERATURE REVIEW

2.1 History of Snack Foods

Pastéli, known as the first snack bar ever made, gives an idea about the history of snack bars as dating back to the ancient Greece. It was included sesame seeds, honey and nuts [5]. Another snack bar named as Kendal mint cake was created by accident in 1869, whose origins date to prehistoric times. Ingredients of the cake (sweet and marble-like deposits) were created by the unique geological conditions of England's Lake District's caverns. This portable and durable energy source is preferred especially by climbers, runners and cyclists [6].

Figure 2.1 Snack bars of Pastéli (left) and Kendal mint cake (right) [7, 8]

In Anatolia, the first information about the production of snack bar in Turkish cuisine is found in a recipe book, which was written by Mehmet Kamil in 1844. This is the first Turkish cookbook named as Melceü't-Tabbahin (Chefs' Shelter) including many new recipes from Turkish cuisine. There is a recipe named as Rahatü'l hulkum (in other words Turkish delight) in the section of desserts and drinks. Turkish delight has been a popular product which has high energy source by means of its akide sugar (berlingot), nut, starch and fruit contents, since the 15th century. It can be shown as one of the oldest snack bar known in Turkish cuisine [9].

Figure 2.2 Turkish delight and Turkish cookbook Melceü't-Tabbahin [10, 11]

Modern snack bar production history was started in 1973 with the aim of providing both fresh and flavorful foods to astronauts during their space travels. This huge challenge of astronauts was overcame with the development of first snack bars by NASA, U.S. Air Force and Pillsbury Company, called “Space Food Sticks” [12]. In a short time, these snack bars have become popular and started to be used not only by athletes, but also by everyday folks as a healthy food able to replace entire meals [13].

In 1986, together with the release of power bars commercially, protein bars made their athletic appearance. These bars were promising high levels of protein to athletes and were boasting with their unique formulas. One of the example of these snack bars is PowerBar, placed onto market in 1983 by Brian Maxwell. The bar was low in fat and moderate protein, fiber and carbohydrate. The athletes who tasted this bar reported that their performances were improved, and so this bar became popular among athletes [14, 15].

Moreover, they were started to take part in many protein replacement diets of dieters. In the following years, the popularity of these bars continued with new bars released in markets such as The Clif Bar, Deer Valley McHenergy Bar and Trail Hiker Bar [16].

2.2 Healthy Impact of Snack Foods and Snacking

In recent years, the chronic diseases are increasing together with increase in some risk factors such as wrong dietary habits, environmental effects, inadequate physical activities and lifestyle [17]. The snack foods of containing too much fat, salt and sugar can also be considered as a risk factor in this context. It is found that, about three-quarters of these snack foods did not have the nutrients necessary for human health. In a survey research, the effects of snacks on energy balance and diet quality were

investigated by France Bellisle [18]. It was observed that, overweight and unhealthy individuals preferred irregular, high-fatty, salty and sugary snacks, but thinner and healthier individuals regularly preferred low fat snacks and snacks that were rich in carbohydrate.

In terms of prevention, control and treat of type 2 diabetes and obesity, regular physical activity and diet plan can said to be have a critical role [19]. But the diets having planned over long period of times can lead to contribute the risk of chronic diseases [20].

Food reformulation investigations have mainly concentrated on glycemic load reduction together with hunger and satiety regulations, during last 20 years. Blood glucose level can be measured by an important term called as glycemic index, which increases after consumption of foods including carbohydrate. Having a stable blood glucose and consuming foods of suppressing hunger and promoting satiety, has very critical effects on health and provides a protection to non-communicable diseases such as obesity type 2 diabetes [21].

Glycemic index is affected by some components of diet lists such as fibers, sugar, fat and proteins. Dietary fibres of having gel-forming property affects the absorption rate of carbohydrates and causes reduction in blood glucose and insulin responses. In addition, they provide improvement in health and laxation of gut [22]. Moreover, together with its non-glycemic effects, dietary fibers have an impact also on energy density and hunger reduction [23].

Sugar content of a food does not need to have a relationship with the glycemic index. Fructose, glucose, sucrose and lactose have different glycemic index values, where the smallest is fructose and the highest glucose. Therefore, fructose is the most offered for diabetics [24].

Fat addition to a carbohydrate food leads to reduction in glycemic index because of the effects on the delaying gastric emptying and insulin secretion [25]. In addition, carbohydrates and protein has stronger satiety than fat. High fat diets are found to be related with a higher energy intake [3].

The general prediction that protein increase lead to delay in gastric emptying is not correct for all the conditions. The results of the studies have changed depending on different types of proteins and amino acids [24]. The high protein foods have an importance on weight loss and maintenance due to their higher satiety effect resulting in energy intake reduction [26]. Based on the recommendations, dietary protein need to be composed 10-15% of energy intake [20].

2.3 Classification of Snacks

The snacks industry covers a huge area, including biscuits, crackers, chips, cookies, nuts, chocolates, dried fruits, cereals, and snack bars etc. Even if there are no former classification for snack foods, they can be classified according to the production process as fried, dried, baked-roasted and extruded.

2.3.1 Fried Snacks

Frying can be defined as a method of cooking that includes heat transfer by means of fat or oil contacting with food, directly. Corn chips, potato chips, doughnuts, french-fried potatoes, extruded noodles and roasted nuts are the some examples of having frying in their production process.

In frying method, the food contacting oil is as hot as approximately 160-180°C [27]. There are existing two functions of the oil using for deep-fat frying. It provides a medium for heat transfer from thermal source and also it is a part of the finished product [28]. The oil content of the fried products can reach up to 40%. Therefore, regarding to today's knowledge, consumers have still worried about health effects of the fat ingredients of fried products [27].

2.3.2 Dried Snacks

Dried snacks includes drying method in their production process. The principle of drying bases on heat transfer, which can transferred by means of conduction, convection or radiation.

Conductive heat transfer is the heat transmitting process, which can take place in same body or from body to another by means of physical contact. Kinetic energy difference of the molecules of each body takes important role in this heat transfer process. On the other hand, convective heat transfer is the heat transfer method including heat transfer

from one place to another via fluid movements by means of mass transfer. For example, an oven includes both methods of convection and conduction heat transfer. The circulation of heated air molecules and water vapor concludes in contacting solid surfaces and conduction heat transfer. Moreover, convection occurs within the food piece via movement of water vapor and other gases [28].

Radiation heat transfer is a type of an electromagnetic radiation, which is a critical factor in ovens and driers. In this method, there is no need for any medium or exchange of mass. The radiations are not heat, but it is possible to convert them to heat by absorption or interaction with absorbing molecules [28].

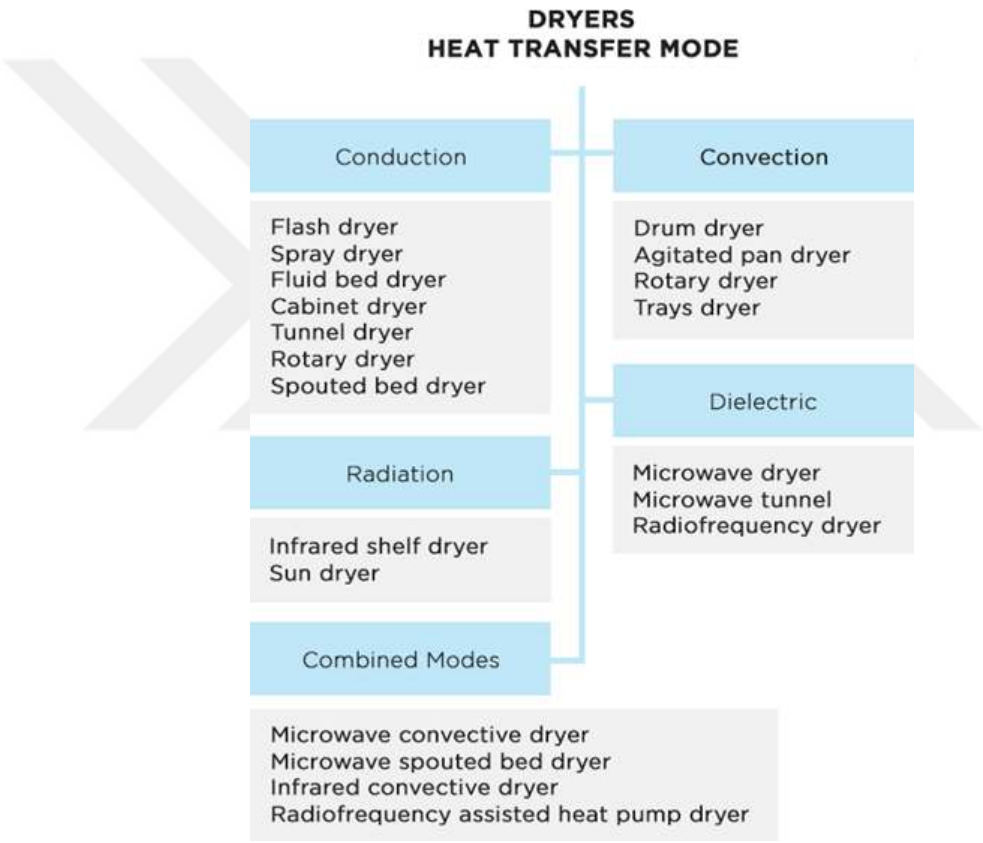

Figure 2.3 Classification of dryers according to heat mode transfer [29]

Drying method can applied on the production of nut-based snacks, dried vegetables, dried fruit snacks, snack bars, and extruded snacks. Recently, dehydrated fruit and vegetable chips are among the snacks produced by using the method of drying as a healthy snack.

Figure 2.4 Some examples of dried vegetables and fruits [30-32]

2.3.3 Baked-Roasted Snacks

In general, the main and common food preparation process composed of frying, baking and roasting. Roasting and baking are the types of cooking by means of hot air, but frying means cooking in oil [27]

Roasting and baking includes both of the conduction, convection and radiation heat transfers. Microwaves has investigated in terms of baking ability and found not to be sufficient in crust formation and surface browning although have enough capacity in providing energy for dough cooking. Consequently, investigation concluded that microwaves need a support of radiation to reach higher efficiency [27].

The common cooking methods for bakery products are cooking with prolonged dry heat in an oven or in hot ashes or on hot stones. Bread is the most popular bakery product among other baked foods.

Bakery product baking is a process of transforming dough into a food having a unique taste mainly starting with flour and water. Some other ingredients can added to product during production process such as sugar, fat, egg or other additives with the aim of having original sensorial features Biscuits, crackers, cakes, cookies etc. are some of the examples of these products [33].

Roasting is a process, mostly made for nuts, where the kernels dehydrated and exposed to browning reaction. Therefore, appearance, texture and flavor of the nut considerably changes [34]. It is possible for a dry roasting of nuts, which done for butter or salted nut production, to be continuous or in batches. By a part of the researchers, the reason for nutty flavor of roasted peanuts is said to be the browning reactions of the Maillard type [27].

2.3.4 Extruded Snacks

Extrusion technology is one of the rising and major methods for food production in recent times [35]. In this process, the food material forced to flow inside a die, which designed for forming, drying or any other purposes, under the conditions of mixing heating or shear [36].

The physical and chemical changes in food material is provided by thermal and shear energy supplied from extruders. Therefore, during extrusion process, complex physicochemical transformations (starch gelatinization, protein denaturation, hydrogen bond rupture etc.) take place [35].

In food industry, there are different types of extruders in use. Not only snacks, but also pet foods, cookie doughs, batters and many other types of bakery products can produced by means of extrusion techniques. For example, macaroni products have produced long before the first snacks produced by means of extrusion techniques. Moreover, with the similar extrusion methods used for snacks, soybean- based meat analogs, croutons, and breakfast cereals can produced [27].

2.4 Classification of Snack Bars

In the market, there are so many types of bars having different aims such as meal replacement and providing the need of nutritiousness for diabetics, children or athletes. There are four main categories of bars in the market as granola bars, nutritional/healthy bars, breakfast/cereal bars and diet snack bars. All of the groups are focused on health and convenience on marketing activities.

Figure 2.5 The change in snack bar consumption of America [37]

A nutritional bar can be defined as a type of snacking together with its health benefits. Moreover, they are generally categorized in three groups as high-protein bars, energy bars and healthy snack bars [4].

2.5 Ingredients

The food design in this project can be categorized as a healthy snack bar. The ingredients of our design have not include preservatives, harmful additives and artificial sweeteners. Although there are so many different contents used in the production of snack bars, for our design, the followings have been used: pistachio, chia seed, flaxseed, quinoa, concentrated apple juice and molasses.

2.5.1 Pistachio

The origin of pistachio, which is commonly grown in Mediterranean countries, is known as central and south-western Asia. In Turkey, archeological records shows that pistachio consumption dates back nearly to 7000 B.C [38, 39]. Pistachio has a fleshy crust like almonds and grow in clusters like grapes. It has a hard exterior shell having nearly 50% weight of its total weight. Its seed has light green flesh, a thin skin and an original taste. The pistachio tree is a desert plant, which can be growth up to 10 meters tall. The ripening of pistachios take place in late summer or early autumn with becoming their hulls rosy and inner shells splitting.

The biggest producers for pistachio is Iran and California with the annual production capacity of several hundred million pound. Turkey is the third biggest country in terms of pistachio trade, and pistachio trees are growing mostly in southeastern region of the country (Pistacia vera L.). Moreover, the wild pistacia species are also grown in different regions of Turkey [40]. The production of pistachio is a cyclical process and yields changes from year to year depending on regions and orchards. In Turkey, the potential of pistachio production is estimated to increase 2-3 times by the Southeastern Anatolia Project [41].

Table 2.1 Key nutrients and phytochemicals per 1.0 ounce (28.35 g) of pistachios [39]

Nutrient	Pistachios (dry roasted/salted)
Calories (kcal)	160
Total lipid content (g)	12.7
Monounsaturated fat (g)	6.7
Polyunsaturated fat (g)	3.8
Saturated fat (g)	1.5
Protein (g)	5.9
Dietary fiber (g)	2.8
Potassium (mg)	285
Magnesium (mg)	31-34
Vitamin K (mg)	3.7
Vitamin E (a-tocopherol) (mg)	0.7
Total phenols (mg)	470
g-Tocopherol (mg)	6.7
Lutein + zeaxanthin (mg)	329
Total phytosterols (mg)	61-82

Pistachio has so many nutrients beneficial for heart health such as protein, dietary fiber, potassium, magnesium, vitamin K, g-tocopherol and some phytochemicals. Pistachio's lutein and anthocyanin content induces to its original green and purple kernel colors. Rather than other nuts, the highest potassium, g-tocopherol, vitamin K, phytosterols and xanthophyll carotenoids contents come together in pistachio.

Pistachio have healthy contributions like helping to maintain healthy antioxidant and anti-inflammatory activities. Moreover, it may help controlling body weight by means of its satiety and satiation effects together with reducing net metabolizable energy content. A study including statistics of a weight-loss program demonstrated that pistachio consuming subjects has lower levels of body mass index and triglyceride rather than others consuming isocaloric pretzel snack. Recent studies have shown that the usage of pistachios in high-glycemic meals can contribute to lower the overall postprandial glycemic response. Moreover, it has been suggested that pistachios can be beneficial for reducing oxidative and inflammatory stress, promoting vascular health and providing glycemic and weight controls [39].

Pistachio's oil content generally higher than 55% and this oil contains linoleic acids, which are essential for human diet [42, 43]. These fatty acids able to reduce the

cholesterol level in blood and provides higher prevention of cardiovascular diseases than other oils [42]. In addition, they have a usage area on cosmetics and pharmaceutical industries [44].

Consumption of pistachio kernels are taken place generally as snacks, roasted, salted or flavored and additionally they can be included in other various food products.

The production process of pistachio starts with its arrival to processing plant. At the beginning, de-hulling process takes place with the aim of separating soft hull from pistachio. Later on, the separation of small branches, remaining shells and leaves from pistachios is carried out. Unpeeled and unripe pistachio separation continues with the high-pressure sprayed water washing. Drying process aims to decrease moisture contents of pistachios, which have nearly 40% moisture content, to appropriate levels. Separation of split nuts from non-split ones continues with sizing, salting, roasting and processes with separated split nuts. On the other hand, non-split nuts are broken with shearer and its kernel is used as snack after the separation [45]. Lastly, kernels chop and sieved with the aim of using in different products such as ice cream, bakery products or snacks.

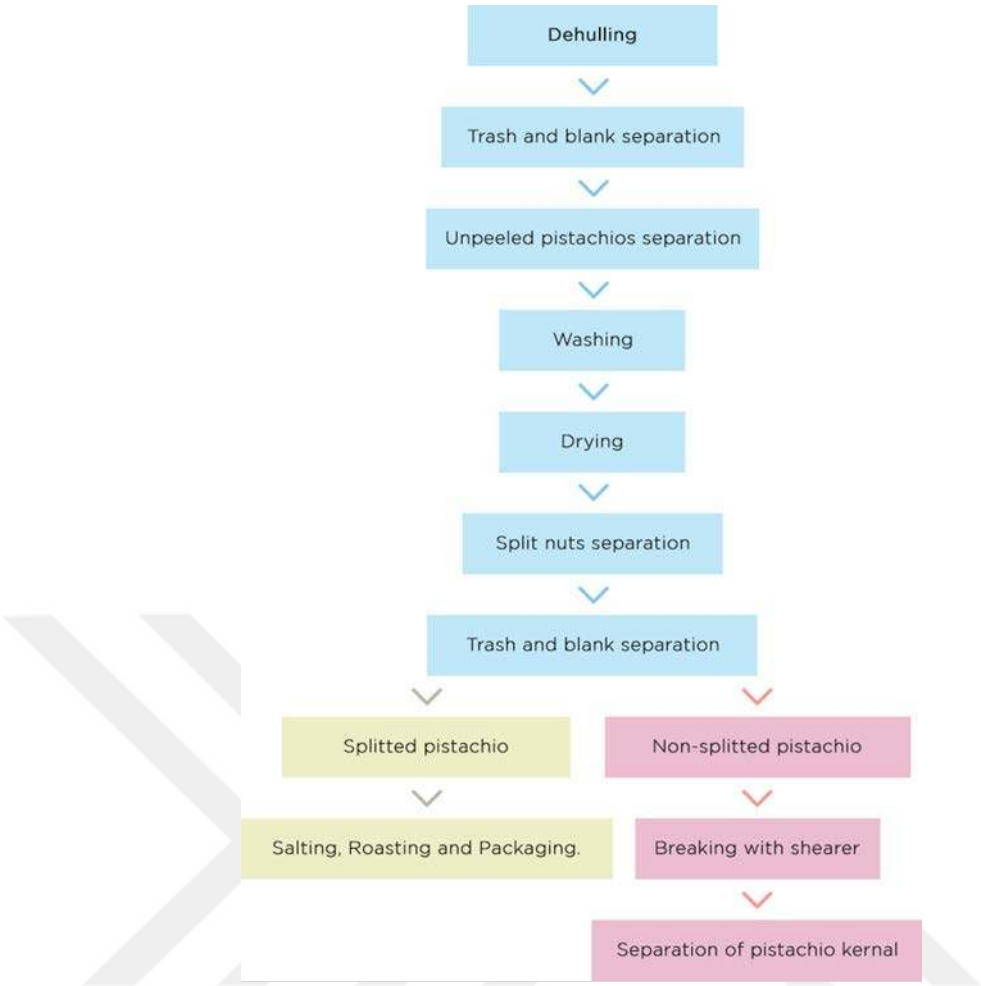

Figure 2.6 Pistachio production flow chart

During the pistachio chopping process; pistachio grains are chopped in different sizes and classified by the help of sieves with different sizes. However, the pistachio powder under the sieve, with the size lower than 0,5mm, is not generally preferred by commercial companies and also it has half the price compared to other pistachios. In this study, with the aim of evaluating as a high-added value product, this powder was preferred to use in a new snack product to be developed.

2.5.2 Chia Seed

Chia plant's seeds are round shaped, black or gray colored and have a diameter of 1.5-2 mm in average. They have oil, protein, antioxidant and dietary fiber contents, and so the seeds have been greatly investigated and recommended [46]. A chia seed includes high amount of antioxidants and it is composed of approximately 15-25 % protein, 30-33% fats, 26-41% carbohydrates, 18-30% high dietary fiber, 4-5% ash, minerals, vitamins and 90-93% dry matter [47]. The most important feature of this seed is its

being gluten-free [48]. In addition, it is capable of holding water up to 27 times of its weight [49]. Chia seed also has the property of gelation by means of being capable of forming mucilage. The chia seed gel have a use on food formulations as a thickening and emulsifying agent and also stabilizer (for frozen food products) [50].

Today's commercial chia grower countries are Mexico, Bolivia, Ecuador, Argentina and Guatemala [46]. Aztec tribes have been using chia seeds as an important part of their foods, medicine and paints. Although it is not well known in European countries, chia seed is very popular and is being consumed traditionally in Mexico and southwestern United States [51].

The demand for functional foods has become inevitable due to the worldwide increase in public health awareness. With the aim of preventing today's diseases of diabetes, obesity, cardiovascular problems...etc., the usage of medicinal food from folk medicine have been increasing its popularity among the public [52]. Correspondingly, chia (Salvia hispanica L.), as a traditional food from central and southern America, have been increasing its consumption rate due to its various health benefits. For instance, its phenolic acid and omega 3/6 oil content contributes maintaining healthy serum lipid level. The studies about safety and efficacy of the chia seed are still limited, thus, this medicinal food or natural product need to be validated by means of scientific researches, although the health benefits of its ingredients warranted [53].

2.5.3 Flaxseed

Flaxseed have a smooth and shiny color gradient changing from dark to yellow together with an oval shape and a pointed tip. Based on measured different commercial flaxseeds, its dimensions are approximately 2.5 x 5 x 1.5 mm [54].

During the last decade, the flaxseed production has reached approximately 2.3 million metric tons with a stable capacity increase. Canada, China, Ethiopia, Russia, United States, Kazakhstan and India are flaxseed-growing countries for oil and fibre. Canada is the world's largest flaxseed producer with its stock capacity, which reaches up to 80% of flaxseed global trade [54].

The main reason of flax (sometimes called as linseed) cultivation is actually its seeds and fiber. A flaxseed contains averagely 41% fat, 28% dietary fiber and 21% protein. Fat content point of view, it includes low, moderate and high amounts of saturated,

monounsaturated and polyunsaturated fats, respectively [55]. Moreover, it is rich in essential omega-3 fatty acid and alpha-linolenic acid, lignans and fiber components [56]. The flaxseed lignans can said to be natural source of useful biologically active components together with their health promoting properties. On the other hand, phenolic molecules have critical effects such as preventing oxidative stress and stimulating collagen synthesis, which provides benefits to skin, by means of their antioxidant activity [57].

Seed coats have epidermal cells, who provides high amount of mucilage of surrounding the seed with a gel-like capsule. The flaxseed mucilage, which has health benefits and commercial utility, has a mixture of arabinoxylans and strongly acidic rhamnose-containing polymers [58]. Even small dose of flaxseed fiber has a suppressing effect on appetite and energy intake [59].

Flaxseed hulls has a gum at their outermost layer named as flaxseed gum. This gum forms the seed's approximately 8% of dry mass and easily released when contacted with water by its water-soluble property. Flaxseed gum is capable of stabilizing oil-in-water emulsions and its proteins have a critical role on its emulsification properties. Moreover, this gum has thought to have benefits on preventing diabetes and heart disease as a functional food ingredient [54]. Consequently, the flaxseed gum will provide important advantages such as keeping the ingredients together, improving textural property and health benefits, for our new product design.

2.5.4 Quinoa

World's biggest quinoa producers, in terms of their export capacity, are Bolivia and Peru with 88% of the worldwide export followed by United States of America with 6% [60]. South America (Andean region) generally cultivates quinoa for its seed [61].

Quinoa has an advantage of hardness, which provides itself to be able to tolerate drought, high altitude and poor, sandy soils. It includes more protein, lysine, fibre and fat than common cereals [62]. The content of quinoa embryo includes sugar (43%), protein (23.5%), dietary fiber (18.9%), fat (10.2%) and mineral (4.3%) [63]. Moreover, the total composition of quinoa includes protein (10-18%), crude fat (4.5-8.75%), carbohydrates (54.1-64.2%), for ash (2.4-3.65%) and crude fibre (2.1-4.9%) [60].

Quinoa seed found to include very high phenolic and flavonoid content. Although the seeds are baked or cooked, the total phenolic content was found to exist in the final product [64]. In addition, in the seed coat, quinoa contains saponins, which have a bitter taste and also tendency of foaming inside aqueous solutions [60, 61]. Therefore, in order to get rid of the bitter-taste, quinoa need to be processed [62].

Today, so many studies are existing about the health benefits of quinoa in diet. In a study, it was shown that, quinoa seed has an elimination effect on the adverse effects of fructose on lipid profile and glucose level [65]. In another study, it was indicated that quinoa seed has an anti-obesity activity and it is possible to use as a nutritional supplement to prevent obesity and obesity-associated disorders [66].

Quinoa seed is not only commonly used on biscuits, pastries, noodles but also as a moisture preserver and intended flavor provider on baked foods. Moreover, starch granules isolated from quinoa can be used as an emulsion stabilizer. In a study, it was demonstrated that, these granules can be used not only on food applications, but also in cosmetics and pharmaceutical formulations [67].

2.5.5 Concentrated Apple Juice

Apple is one of the most popular kind of fruit in terms of consumption. Among the apple producers, Turkey is the fourth in the world by means of its geographical location and climatic features [68].

Turkish Food Codex defines fruit juice concentrate as a product, which has obtained physically from fruit juices in determined proportions by water evaporation methods. This concentrated fruit juice process includes heating, evaporation and storage stages, respectively. From the apple juice point of view, the parameters of growing region, cultivar, climate, cultural practice and maturity affects its chemical composition [69]. The average nutritious content of apple is very similar with apple juice except for its protein, fiber, natural vitamin C contents [70].

The dietary phenolic compounds, which have found commonly in fruits, have antioxidant activity and may have benefits on health [71].

Table 2.2 Average nutrient contents of apple and apple juice (per 100g fresh weight) [70]

Nutrient	Apple Juice	Apples
Water (g)	88.1	85.3
Energy (kcal/kJ)	48/203	54/227
Protein (g)	0.07	0.3
Fat (g)	N/A	0.6
Carbohydrates (g)	11.1	11.4
Fibre (g)	0.77	2
Potassium (mg)	116	144
Calcium (mg)	4.2	7
Magnesium (mg)	6.9	6
Phosphorus (mg)	7	12
Vitamin C (mg)	1.4	12
Organic Fruit acids (g)	0.74	0.5
Energy (kcal/kJ))	48/203	54/227
Protein (g)	0.07	0.3

The widespread biological activities of apple or apple products have proved to have positive contribution against so many diseases such as cancer, cardiovascular diseases, diabetes, obesity, pulmonary dysfunction and asthma [70].

2.5.6 Molasses

Molasses can defined as a concentrated fruit juice produced by means of boiling to approximately 70-80% soluble dry matter content and includes different kinds of fruits. The production of molasses, which requires minimum processing, can include grape, fig, watermelon, plum, apple, sugar beet, carob, mulberry, juniper and sugarcane as its raw material [72, 73]

The mulberry production of Turkey is approximately 65000 tons per year. Most of the fruits dried or processed into fresh products rather than direct consuming [74]. On the other hand, the molasses production of Turkey is approximately 250000 tons per year [75]. In Turkey, mulberry molasses comprises the large part of consumed mulberry products.

Fresh fruits, which have a short shelf life, may have considerable losses takes place because of deterioration in storage. Therefore, production of molasses from these fresh fruits is wise in terms of conservation of nutritional values for a longer time [75]. The

production includes traditional methods rather than technological and scientific concepts.

Mulberry molasses has a brown or dark yellow color due to the exposure of nonenzymatic browning reaction [74]. Moreover, a final product of mulberry molasses has a pH of 5.7 and solid content of approximately 70% (w/v). Its long shelf life based on its protein (0.88%) and high sugar (62.86%) content [74]. In addition, as a snack, mulberry molasses has healthy benefits also due to polyphenol intake [75]. It is a significant nutritious product for human due to its sugar, mineral, and organic acid contents [76].

2.6 Snack Bar Production Process

In the market, there are so many types of bars which aims meal replacement or nutrition serving for diabetics, children, athletes or women [4]. Even the content of these bars changes from product to product, their production processes are generally similar. The steps of this process includes formulation, mixing, forming, drying, cooling, cutting and packaging.

2.6.1 Formulation

A product developer need to handle so many tasks during a nutritional bar production. For instance, the ingredients of the product should provide certain nutritional requirements and final product should meet the convenience and health benefits of the consumers. Therefore, correct ingredients need to be determined by formulators for the production of a bar having acceptable sensory attributes and nutritional content. In the market, some of the bars still not have acceptable tastes and sensory attributes, even though a large number of formulation/receipt trials made for them. In terms of proper acceptability and exceptional quality, it is important to optimize sensory and functional properties together during the processing of new products.

2.6.2 Mixing

A nutrient bar is mainly based on the determination of its ingredients such as protein, carbohydrate, fat and natural sweetener. Following the preparing recipe of the snack bar, dry ingredients are pre-mixed by means of a mixer.

Later on, with the aim of forming a mass, liquid ingredients fed to mixer by means of a pump. This process continues until having a homogenous mixture. It is critical to have a good mixing process in order to have a homogenous snack bar dough.

Figure 2.7 Mixing machine

2.6.3 Spreading and Forming

The distribution of the granola mix, which comes from the elevating conveyor, across the width of the oven is done by feeder spreader unit. This unit includes a hopper and contra-rotating feed rolls with the aim of creating a constant thickness loose sheet laying on the oven band as shown in Figure 2.8. Moreover, there is a compression roll, which provides the desired thickness of the product by means of a final press and gauging of the sheet before feeding onto oven.

Figure 2.8 Processes of contra-rotating rolling, spreading and final-pressing

2.6.4 Drying and Drying Equipment

Drying or dehydration can be defined as a process of lowering a product's water activity by means of water removal. It is the oldest method of food preservation in order to have a longer use of products. In order to realize drying process, after supplying heat to wet feedstock and liquid vaporization occurs. Convective industrial dryers (over 85%) uses hot air or combustion gases as the drying medium. In this study, during the drying process, ovens were used on snack bar production.

Ovens are used for baking cookies, crackers, pretzels, and other similar types of snack foods. Band ovens are usually classified in accordance with the type of their heating systems. They may, for instance, be classified as being heated by gas, electricity, oil, or other means. In this study, the electric ovens were used, which can be categorized as conventional, microwave and vacuum ovens.

i. Conventional Atmospheric Oven;

The heating of dough starts from its outer surface and goes inward by conductive and radiative heat transfer. During this process, some structural differences occurs for dough such as volume increase, water evaporation, crust formation, starch gelatinization, protein denaturation, non-enzymatic browning [77].

It is possible to provide more uniform heating and shortening the cooking time with the new types of convection ovens having fan forced air circulation [78]. Microwave ovens are not able to induce browning on bread surface as their main difference with convection ovens. In addition, microwave ovens are not able to produce Maillard's reactions, which are responsible for producing so many flavored and colored compounds. The reason is the cool ambient temperature inside the microwave oven causing surface cooling of products [79].

From past to present, convective drying is still the most extensive method in use for food product drying due to its lower investment costs and effectiveness at the beggining of the drying process, even though it has some disadvantages and limitations. For instance, shrinkage effect including a hard texture leads to lower product quality. In addition, in convective drying, hot air causes some oxidation processes and makes some chemical differences including content of the thermolabile

biologically active compounds occur on profile. In summary, the conventional drying method leads to change in taste, color and nutritional deterioration of products [80].

ii. Microwave Ovens;

Microwave systems are the most common electronic ovens used in homes and restaurants, which provides faster heating of kinds of foodstuffs. On products, heat generation of these ovens occurs by means of molecular vibrations generated from high frequency electromagnetic radiation absorption.

iii. Vacuum ovens;

Vacuum drying method can be defined as drying an object in a closed container with venting air and reducing the pressure with a vacuum pump. The aim of this pressure drop is increasing water vapor partial pressure difference artificially. Moreover, vacuum ovens are the equipment, where this process carried out.

In the use of vacuum ovens, the materials take place in trays inside the vacuum dryer during pressure reduction by vacuum pump. In order to realize conduction heat transfer, the steam is let to be travelled between trays and jacket after the dryer door is safely closed. Condenser takes the water vapors coming from the feed and, in the end, the process ends with disconnection of drying vacuum pump, and product collection from trays.

For food materials, vacuum drying is in use for many years due to its lower temperature induced effects. When compared with conventional atmospheric drying, its moisture removal pressure is lower. Vacuum drying have faster mass transfer in the drying chamber by means of produced high pressure gradient, which provides object to dry faster. They can also be used on drying heat sensitive hygroscopic and toxic materials. Even if the material to dry is a solution, it is possible for them to carry out the process with the ability of recovering the solvent by condensation [81].

By means of the ability to expand air and water vapor inside the foods, it is possible for vacuum drying to have higher drying rate, lower drying temperature and oxygen-free processing environment [82].

Effect of Drying Methods on Snacks

Drying process can conclude in some physicochemical changes on food products and affect the final product quality. These changes can take place on product's optical, structural, textural, sensory or nutritional characteristics. On the other hand, the process could improve some quality indices such as flavor and digestibility while able to decrease others such as vitamin and aroma.

Products can be critically damaged in terms of their color, flavor and nutrients because of the conventional drying methods with high air temperatures together with long drying times. Therefore, in order to eliminate these effects, there exists different dehydration processing scheme proposals. For instance, convective drying, convective-solar drying, air-infrared radiation (IR) heating, vacuum drying and vacuum-microwave are some of these schemes [83].

2.6.5 Cooling

Cooling process follows the drying process when the moisture content reduced to desired level. In order to have a crispy feature, the product is cooled to room temperature. If the hot product is packaged before the dehydration is not ended, the product will have softer structure because of the moisture content inside the package. Moreover, this condition could lead to microbial growths.

2.6.6 Cutting

The cutting process of compressed product carried out by gauged blades with desired dimensions. This process is mainly based on the customer demands and requirements.

Figure 2.9 Cutting process

2.6.7 Packaging

Today, energy and protein bars are the most common snack foods have instantly consumption. There are so many types of snack bars in terms of their flavor, ingredients or packaging. The popularity and fast growing tendency of energy bar market have lead producers to have a need for effective packaging designs. Versatile snack bar packaging products, which have high technology production and superior quality materials, are in product by package manufacturers, nowadays. From producer to consumer, the desired protection of energy bars products can be provided by cold or heat seal packaging.

Basically, food packaging have some major functions such as retarding product deterioration, extending shelf-life, maintaining the quality and safety of food and retaining the beneficial effects of processing. These functions of packaging involves the protection of foods chemically, biologically and physically from external effects[84].

The foil laminated (metalized or aluminum) snack bars packaging rolls are able to protect texture, freshness and taste of the products by means of providing a shield, which is blocking moisture, oxygen and other contamination [85].

With the aim of increasing the durability and tear resistance of the rolls, packaging manufacturers use some superior grade plastic materials. The most common films used are Linear Low-density Polyethylene (LLDPE), Polyethylene (PE), and oriented polypropylene (BOPP) etc.[86].

Packaging Systems for Snack Bars

Packaging types of foods differs from product to product depending on their protection requirements and their specifications. For instance, single or double twist packaging is commonly used on candies or chocolate products because their long shelf-life is already provided by their high sugar-content.

Today, the most common packaging system for snack bars is flow wrappers. These systems mainly divided into two categories as vertical and horizontal. Horizontal type systems are mainly used on nuts and similar dense products, while vertical types used

on snack industry. Their capacities change approximately up to 400 units/min and suitable for different container sizes and configurations.

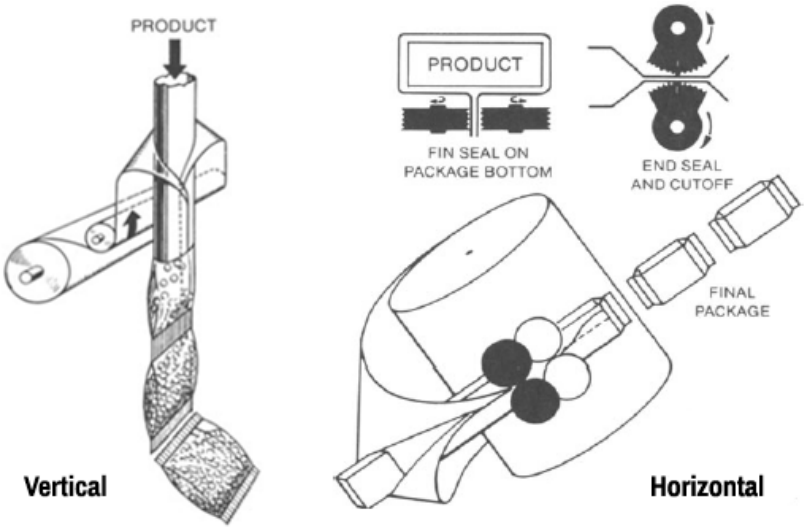

Figure 2.10 Illustrations of vertical and horizontal flow wrappers

The main usage area of this system is soft cakes, sweet goods, crackers, cookies, baked health food products and candy bars. In this type of packaging, the flowpack style is optional such as pillow, gusseted, zig zag and hole punch as shown in Figure 2.6. Maximum and minimum bar dimensions are changing depending on the model of the machine [28]. They can pack up to 400 units/min and accommodate a wide range of container sizes and configurations; they are recommended for use with soft cakes, sweet goods, cookies, crackers, baked health food products, and candy bars.

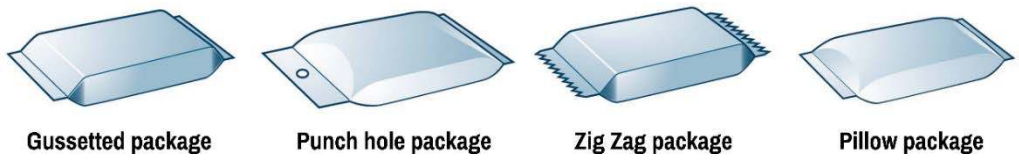

Figure 2.11 Some of the snack bar packaging types [87]

The biggest fault with the packaging equipment is the packaging challenges due to the sticky characteristics of the snack bars especially rice and granola bars. Equipment need to be stopped every two to three hours due to the extensive accumulate of damaged products. The reason of this problem is the property of products as being sticky and vulnerable to breakage.

The non-contact infeed of new bar-packaging line forwards the snack bar with minimal breakage, provides the system to run at double the speed than the old line and up to

eight hours before cleaning. The bars travel to the flow wrapper which is an electronically controlled servo wrapper equipped with cold-seal film. Thanks to this systems, amount of output product and production time are increased.

On the other hand, easy and extensive cleaning has a great importance to eliminate all traces of potentially allergy-causing ingredients because of the packaging of different products on the same system by packaging equipment.

2.7 Marketing

The tendency of people to change their meal patterns and increase their snack consumption lead energy bar producers to change their way of promotion and positioning nutrition bars. It is a challenge for food industry that consumer and health organization demands are increasing towards healthy, high quality foods and health promotion. Therefore, the increase in development of new food products will make it easier for consumers to make healthy choices. For instance, nowadays, protein bars have market appeal thanks to their natural content.

In 2003, the worldwide snack food market had a capacity of $66 billion, where United States have one third of this capacity. While the other parts of the world were westernizing, the global demand for snack food is increasing and developing [88]. From 1950 to 2000, American manufacturers introduced so many varying snack products to market including basic ingredients such as sugar, salt and fat. During this time interval, they become a snack production nation. When it comes to 1980s, snack foods were very popular among the people and they were consuming at home, work, school and even in car. Figure 2.12 shows the increase in snacks from 1970 to 1993 for some different food products. On the other hand, the popularity and easy access of snack food also caused people to question whether these products make any contribution to losing healthy eating models and consumption of products with low nutrition content [89].

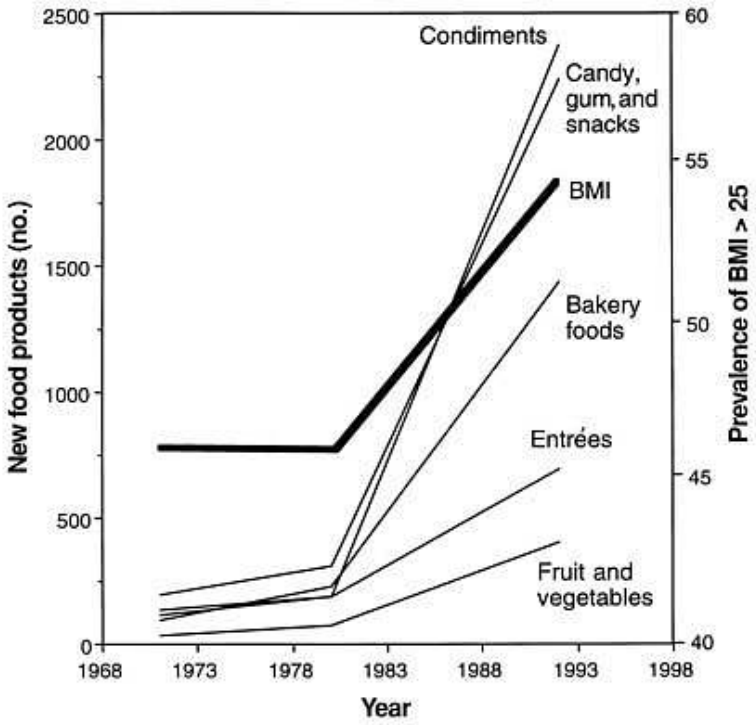

Figure 2.12 The change in snack bar consumption of America [90]

The new trend of the market is targeting the consumption of snack bars regarding to specific periods of day. Some brands focuses on main meals to appeal snacking habits of consumers. In terms of breakfast, lunch and dinner times of the day, cereal bars are very popular in breakfast, but in the progressing times of the day, its usage decreases. For these parts of the day, especially for lunch and dinner, granola, energy/protein and diet bars reach higher consumption rates as shown in Figure 2.13 [91].

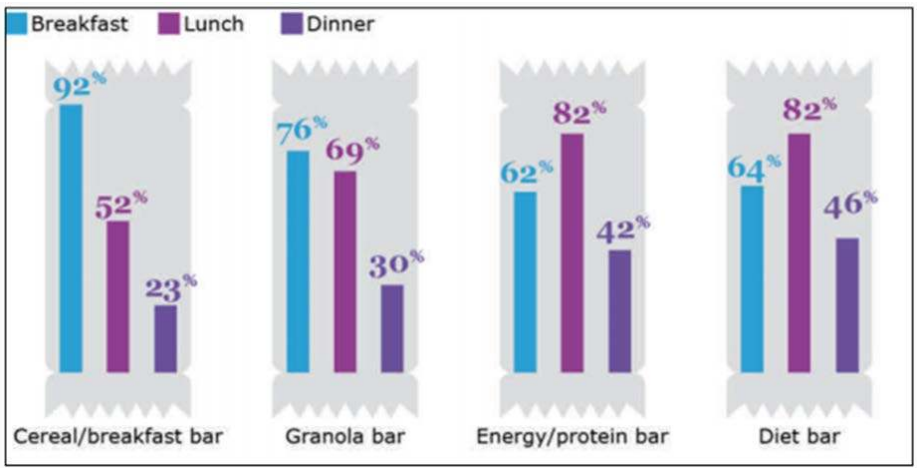

Figure 2.13 Snack bar usage of United States in 2009 based on time of the day [91]

Nielsen Company [2] made a categorization of healthy eating trends as healthy, semi-healthy and indulgent. Due to the study, healthy category includes foods such as dairy-based shakes, fruit, sports drinks, tea, vegetables, water and yogurt. Moreover, indulgent category includes carbonated soft drinks, chips, chocolate and cookies/biscuits and semi-healthy category includes bread, cheese, cereal, granola bars, juice, popcorn and pretzels as totally shown in Figure 2.14

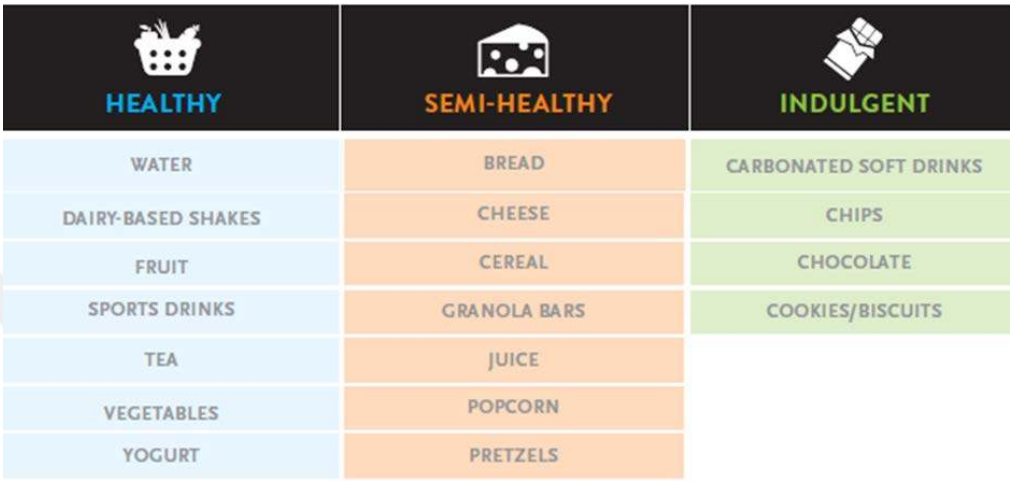

Figure 2.14 Classification of healthy, semi-healthy and indulgent foods [2]

In Figure 2.15, it can be obtained that, the healthy selection wanting of consumers may not always coincide with their actual behaviors. From 2012 to 2014, healthy and indulgent category sales are seen as increased worldwide, but healthy category is seen as out of this trend. Healthy category is seen as make its most growth in developing regions around the world. In North America and Europe the only growing categories are healthy and indulgent categories, respectively. The growth of indulgent category under the same conditions is seen as slower than healthy category [2].

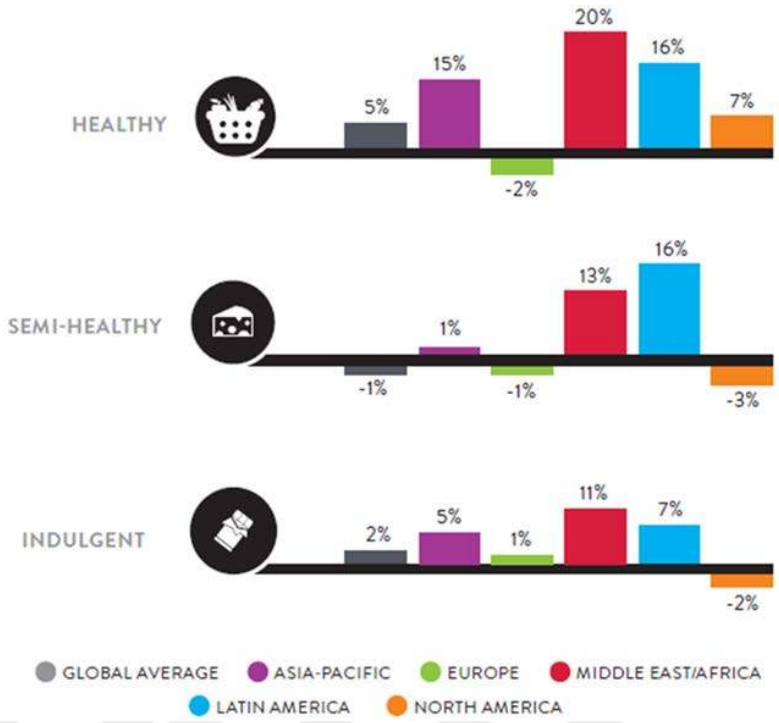

Figure 2.15 Sales changes of healthy, semi-healthy and indulgent categories between2012-2014 in different regions of the world together with global average [2]

According to a study about healthy snack market report prepared by Grand View Research [92] the largest product segment is estimated as to be cereal and granola bar, which is expected to increase its share thanks to its better taste, filling capacity and portability. Its popularity among the athletes is also increasing due to its instant energy providing capacity and nutrition.

The demand for nuts and seed snacks increasing by vegetarians is expected to enhance the growth of the industry. Moreover, protein-rich content of this type of snack, which is expected to increase its demand from 2017 to 2025, is providing a sustainable product option for also non-vegetarian consumers. For instance, it is a good option for pre-workout snacking [92].

The people living in Europe, Asia Pacific and North America regions have an increasing awareness, which is expected to have positive results on industry.

For so many countries, healthy snack is a very new sector progressing its development. It is expected for healthy snack market to reach 32.8 billion dollars by 2025 [92]. Product based global healthy snack market revenue in 2015 is shown in Figure 2.16.

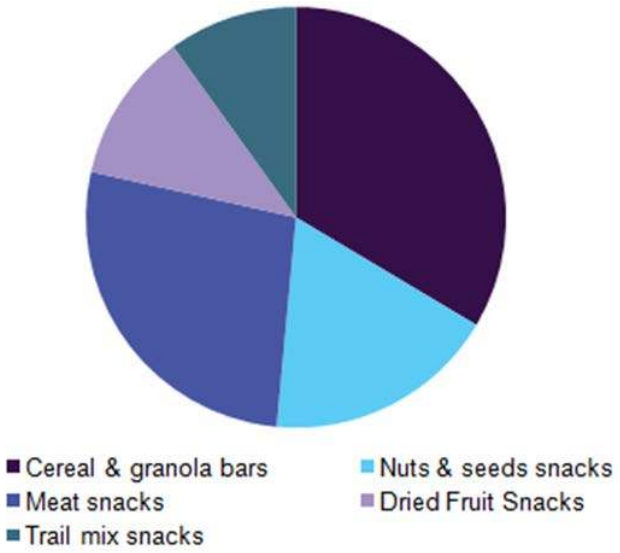

Figure 2.16 Global healthy snack market revenue (%) of 2015 depending on product type [92]

Snack foods provide price flexibility, portion size option and portability, to consumers. Moreover, thanks to them, consumers are able to have chance to compose an eating occasion fitting their specific needs. The study carried out by NPD Group in 2017 shown that snack consumption increased from 21% to 24% over the last 5 years. The predictions also figure that it will be reach up to 36% by 2024 [93].

The increasing demand for healthy foods and foods associated with disease prevention forced food manufacturers to reformulate their established brand products. The challenges on healthy food product marketing success includes taste appeal, valid health claims and sustainable ingredients.

A study investigating purchasing preferences of the mother who gives more value to the healthy nutrition of their children included how they decide a snack is healthy or not. The result of the study shown that, their decisions mainly depend on the ingredient list and amount of sugar that product includes, rather than brand of the product [94].

Another study investigating the snack acceptance of consumers shown the unrecognition of protein and seed bars and their needs on sensorial improvement. In addition, the predictions about the next 5 years expects an increase in fruit and nut bars about 7.2% and cereal bars and other snack bars less than 1% [95]. Therefore, this study has aimed to design a healthy and tasty snack bar, which is more nutritious and functional [96].

CHAPTER 3

MATERIAL AND METHOD

3.1 Material

The ingredients, manufacturers, nutrient information and other details for components, which were used in this study for a design of an experimental healthy snack bar were given in Table 3.1. The pistachio powder under the sieve with the size lower than 0.5 mm was supplied from local commercial companies with the aim of evaluating as a high-added value product. Moreover, concentrated apple juice (70brix) was provided by a local cooperative. All of the other ingredients bought from retail supermarkets. No chemicals and/or preservatives were used as ingredients.

Sodium hydroxide (NaOH), DNS (3,5-dinitrosalicylic acid), sodium potassium tartrate ($KNaC_4H_4O_6$), hydrochloric acid (HCl), methanol, folin-ciocalteu´s phenol reagent, sodium carbonate (Na_2CO_3), copper sulfate ($CuSO_4$) were purchased from Sigma-Aldrich. Potassium sulfate (K_2SO_4) and n-hexane were purchased from Isolab. All other used reagents and solvents were supplied from the analytical laboratory class.

Table 3.1 Product, manufacturer, nutrient information and other information for components of healthy snack bars.

Product	Manufacturer	Nutrient information and other comments	
Pistachio Powder	Local cooperative	Per 100 g	**Energy** 597 kcal **Carbohydrate** 4.6g **Fat** 56.8g **Protein** 21.9g
Chia Seed	Yayla Agro Gıda A.Ş.	Uncooked per 100 g	**Energy** 434kcal **Carbohydrate** 35.8g **Fat** 29.3g **Protein** 22.9g
Flaxseed	Yayla Agro Gıda A.Ş.	Uncooked per 100 g	**Energy** 509kcal **Carbohydrate** 20.1g **Fat** 32g **Protein** 23.9g
Quinoa	Hünkar Gıda A.Ş.	Uncooked per 100 g	**Energy** 337 kcal **Carbohydrate** 20.1g **Fat** 32g **Protein** 23.9g
Concentrated Apple Juice	Local cooperative	Per 100 g	**Energy** 280kcal **Carbohydrate** 70g **Fat** 0.44g **Protein** 0.6g
Molasses	Dutpınar Gıda	Per 100 g	**Energy** 294 kcal **Carbohydrate** 68.1g **Fat** 0.46g **Protein** 0.88g

3.2 Method

The method, which was used for the snack bar production in this study, includes identifying potential ingredients, development trials, investigation of candidate recipes, determination of drying conditions, determination of drying time for final product and final product composition, as given in Figure 3.1.

Figure 3.1 Flow chart of the snack bar production process

3.2.1 Identification of Potential Ingredients

The first step of the methodology of our study is potential ingredients identification. The selection was carried out by means of taking some specifications of materials into consideration. These specifications are having high-nutritional value and low-sugar content, being high-protein source, high-essential fatty acid source, high fiber source, gluten-free and artificial-sugar-free. In conclusion, the selected materials, which are chia seed, flax seed, quinoa, concentrated apple juice, molasses and pistachio powder, were shown in Figure 3.2.

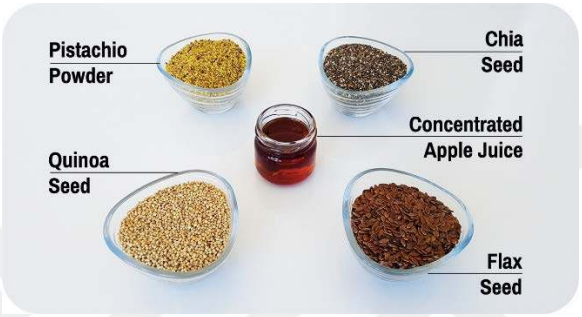

Figure 3.2 The selected potential ingredients

3.2.2 Preliminary Trials

In the trial development step, different combination of ingredients were tried with the aim of finding most ideal recipe, but some problems have arisen during these trials as given below:

- Challenge in obtaining a suitable dough structure without using processed sugar, which is generally used as binding agent.

- The difficulty in determining which kind and what amount of material should be added as ingredient.

- The difficulty in obtaining an easy cuttable, formable and non-dispersive texture.

In order to overcome these problems, some experiments were carried out and the following solutions were found:

- Mucilage property of flaxseed and chia seed were used to overcome the problem of obtaining suitable dough structure.

- Chia, flaxseed and water ratios were determined with the help of preliminary trials and, the holding time in water was determined by considering the amount of water-soluble solids.

- Thanks to the gel-like substance that takes place as a binding agent, the difficulty of cutting was handled. Thus, a non-dispersing structure was obtained during cutting process.

3.2.2.1 Investigation of Mucilage Extraction from Chia seed and Flaxseed

Flax and chia seed coat epidermal cells release a high amount of mucilage, which forms gel-like structure when mixed with water. It is important to wait enough time in the water before mixing other ingredients in order to provide adequate amount of water-to-seed ratio to obtain possible maximum gel-like material. Therefore, different water-to-seed ratios were studied and the most perfect ratio was determined depending on dough structure's formability.

The suspension solution shown in Figure 3.3 was obtained from soaking the chia seed and flaxseed in the water. But, the immersion time should be determined for enough mucilage extraction before mixing other ingredients. For this purpose, the soluble dry matter determination was performed. The immersion time was increased until the soluble dry matter ratio was fixed.

Figure 3.3 Obtained suspension solution (flaxseed, chia and water)

3.2.2.2 Production of Snack Bar Prototype

The difference of our snack bar formulation from the typical snack bars was not only its proportions of ingredients applied on initial product combination but also its method of preparation.

As a preliminary process, after mixing chia and flaxseed in water, a suspension was formed. In order to obtain maximum possible gel formation, it was kept in water for 30 minutes. Then, following the addition of other ingredients to this mixture and dough formation, the processes of spreading, pressing, cutting, drying and cooling ware carried out following the flowchart shown in Figure 3.4.

While these processes carried out, three different prototype snack bar formulations (designated as S1, S2 and S3) were developed by means of changing ingredients as followings:

Table 3.2 Snack bar prototypes and their ingredients

Snack Bar Prototypes	Ingredients
S1	Seeds and pistachio powder with apple juice concentrate
S2	Seeds and pistachio powder with molasses
S3	Seeds and pistachio powder without apple juice or molasses

Sensorial analysis was performed to select the most liked among these three snack bar prototypes. The next step, which is defining drying methods, was carried out with the selected snack bar.

3.2.3 Drying Method

After determining the most preferred formulation of the snack bar by sensory analysis, the changes in texture, moisture content and color were investigated to determine one of the drying methods of oven, vacuum oven and microwave oven combined with vacuum oven. (Figure 3.5)

In this study, prepared three snack bars dried with three different drying methods of oven drying, vacuum oven drying and microwave combined with vacuum oven drying. Later on, texture analysis of each samples, which were dried with different methods, were carried out and compared in terms of fracturability and hardness.

In oven drying, the sample was prepared and dried at 75°C until the moisture content become approximately 6%. The drying procedure was taken 415 minutes, but the texture analysis could not be carried out for the first 105 minutes because of the sample's inadequate fracturability and hardness.

Figure 3.4 Oven dryer, vacuum-oven dryer and microwave-oven dryer

In vacuum oven drying, the sample was prepared and dried at 75 ºC until the moisture content become approximately 6%. The drying procedure was taken 210 minutes, but the texture analysis could not be carried out for the first 90 minutes because of the sample's inadequate fracturability and hardness as it is in the oven drying.

In microwave oven combined with vacuum oven drying, the sample was prepared and dried firstly in microwave oven during 1 minute at 80% power (640W). Later on, the sample was cooled in desiccator and put into vacuum oven to dry for 50 minutes. During the vacuum oven drying, texture analysis was performed at determined time intervals.

Figure 3.5 Some microwave oven drying trials

After drying method determination, the drying time was studied. In order to determine the best drying time, sensory analysis was performed with the samples dried for 180, 195 and 210 minutes.

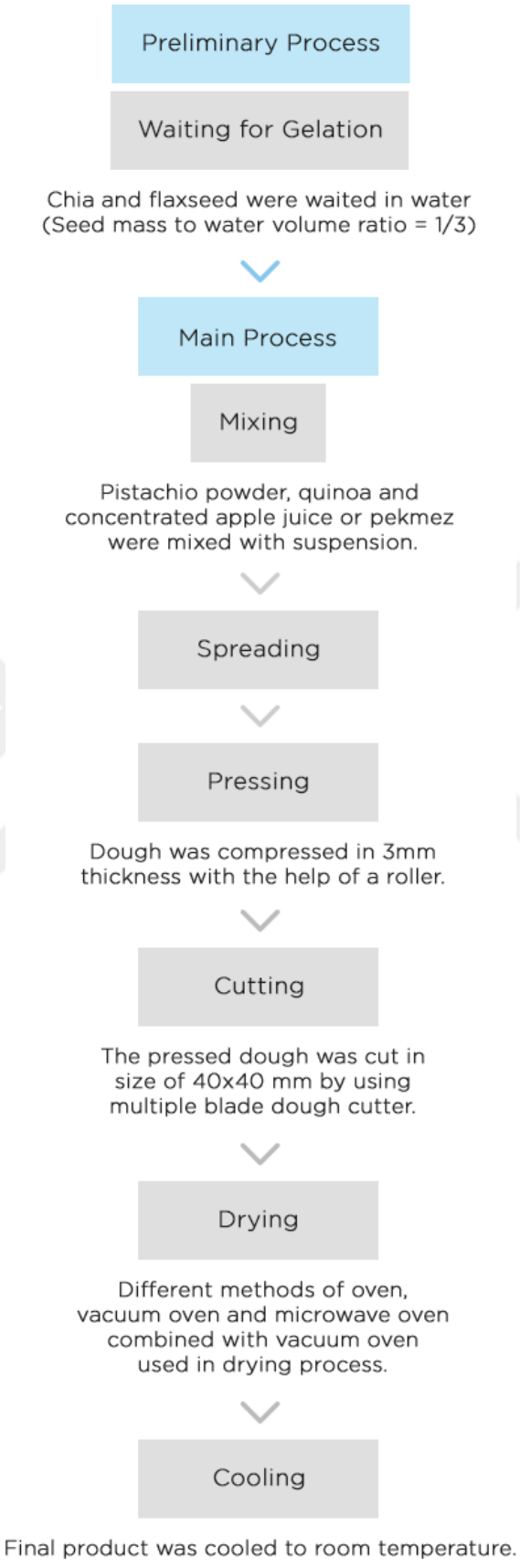

Figure 3.6 Snack bar process flow diagram used in this study.

3.2.4 Analysis

3.2.4.1 Mucilage Extraction

Water-to-sample ratios were used as 1:10 for mucilage extraction. Immersion time (starting from 5 minutes) was increased with 5 minutes intervals until dry matter is constant. The mixture was then centrifuged at 2000 rpm for 3 minutes. The mucilage layer was collected, and the seeds were accumulated at the bottom.

3.2.4.2 Determination of Soluble Dry Matter

Mucilage extract was dried at 105 ℃, until constant mass, in an oven. The mass difference between after and before drying process was used for calculating the dry matter of gel extract.

3.2.4.3 Sensory Analysis

Descriptive, discriminatory and affective sensory analysis techniques were mainly carried out with the aim of evaluating sensorial characteristics such as texture, flavor, hardness, chewiness etc.

In this study, sensory analysis was used in two stages. In first stage, sensory analysis was applied on three snack bar candidate product samples to predict consumer acceptability. 7 point hedonic scale (a scale have scores varying from 7 = 'like extremely' to 1 = 'dislike extremely') was applied for candidate of three different snack bar formulation. The candidate samples were evaluated in terms of their overall flavor acceptability. The samples were coded with three-digit random numbers, presented in white plastic dishes and served in a random order. Tasting test was carried out in the Sensory Analysis Laboratory of the Food Engineering Department at the University of Gaziantep (Turkey) in individual booths.

In second stage, snack bars were evaluated for fracturability, hardness, chewiness and overall acceptability on a seven-point hedonic scale for determination of drying time. Each of the attribute was scored on a scale varying from 7 = 'like extremely' to 1 = 'dislike extremely'. Samples were presented in white plastic dishes coded with three-digit random numbers and served in a random order.

The obtained data was analyzed by means of one-way analysis of variance (ANOVA), by SPSS Statistics, to determine if there is a significant difference between snack bars.

The data were presented as the mean ± SD of each treatment. Mean values were calculated according to Tukey tests ($p < 0.05$).

3.2.4.4 Titratable Acidity (TA)

In order to determine the sour taste caused by acidic content, the acidity value of each snack sample were measured. Titratable acidity was determined according to the AOAC official method 942.15 (AOAC 2000). Five grams of snack food was blended and diluted in 25 ml of distilled water and titrated by 0.1N sodium hydroxide (NaOH) to pH 8.1. The titratable acidity was indicated as g citric acid/100g of sample, according to Equation (3.1), where 0.1 is the normality of NaOH (N), 0.064 is the conversion factor for citric acid, V is the volume of NaOH required (mL) and m is the mass of snack bar sample used (g).

$$\text{Titratable acidity (g citric acid/100g of sample)} = (V \times 0.1 \times 1000 \times 0.064)/m \quad (3.1)$$

3.2.4.5 Texture Analysis

Texture, whose parameters can be assessed by sensory evaluation techniques or instrumental measurements, have a critical importance on product quality. Texture profile analysis (TPA), which has an aim to imitate the action of the jaw, has become most popular among the instrumental texture analysis methods. It is possible for a single TPA test, where the sample compressed twice, to measure so many textural characteristics such as hardness, cohesiveness, springiness, factorability, adhesiveness, chewiness and gumminess. The results of the test are in good agreement with various sensory ratings.

Figure 3.7 Texture profile analyzer

The most common parameter derived from a TPA curve is the maximum load (newtons) during the first cycle of compression, which called as hardness. Fracturability or brittleness can be defined as the force value (newtons), where the first break in the TPA curve occurs, during the first compression cycle. Cohesiveness (Nxmm) can be defined as the ratio of areas under the curve for first and second compression. Moreover, the required work to pull the plunger away from the sample is called as adhesiveness (Nxmm). Springiness (mm) can be defined as the length of the height, which the sample recovers during the time between end of the first compression cycle and start of the second. In addition, gumminess (newtons) can be calculated as hardness times cohesiveness, and chewiness (Nxmm) can be calculated in terms of hardness, cohesiveness and springiness.

The peak force (PF) was measured by using three point bend test by means of a three point bending rig. A break test was performed on the snack bars obtained at different drying times using a TA-XT2i Texture Analyzer (Texture Technologies Corp., Scarsdale, NY, USA). The speed of the test was specified as 5 mm/s and the distance between two supports was 6 mm. The analysis and record of the curve was carried out by Texture Exponent 32 software program (version 6.1.4.0). The slope (S) (N/mm) and distance (Di) (mm) of the break were measured from the force-distance curve and the evaluation carried out in terms of hardness and factorability. Hardness and fracturability were evaluated on samples dried at different drying methods and drying times, corresponding to different levels of moisture content for each condition. Three measurements were performed on each sample. For good experimental application, all tests were run on the same day the snack bars were processed.

3.2.4.6 Determination of Moisture Content

During and after the drying process, some samples were taken at determined time intervals and moisture contents were measured. The measurement was carried out with the oven method complying with standard procedures of AOAC (1990). The measurements were expressed as the mean (±SD) of triplicate analysis.

3.2.4.7 Determination of Color Change

The color measurements of the snack bars was performed by means of HunterLab ColorFlex (A60-1010-615 Model Colorimeter, HunterLab, and Reston VA, USA)

during the different drying times with different drying methods (vacuum oven, oven and microwave oven). The color changes were expressed in terms of L*a*b* color space (also referred to as CIELAB). The color values were expressed as L* (darkness/whiteness), a* (greenness/redness), b* (blueness/yellowness) values and yellowness index (YI). The instrument calibration was made against the standard reference white tiles (L*= 93.41, a* =-1.12, b* =1.07).

The total color differences ΔE (a larger ΔE denotes greater color change from the reference material) were calculated from the Hunter L*, a*, b* values with the Equation (3.2).

$$\Delta E = \sqrt{(L - L_0)^2 + (b - b_0)^2 + (a - a_0)^2} \quad (3.2)$$

Figure 3.8 HunterLab ColorFlex

3.2.4.8 Sugar Determination

Sample preparation

Among the snack bar formulations (S1, S2 and S3) prepared with water, molasses, flaxseed, chia, quinoa, concentrated apple juice and pistachio powder, the formulation containing only apple juice (S1) was found to be the favorite sample according to sensory analysis.

With the aim of having a gel property, the sample preparation of the S1 formulation starts with the mixing of chia seed and flaxseed in water for 30 minutes. Later on, pistachio powder, concentrated apple juice and quinoa have added into the mixture and waited for 20 minutes. The mixture was spreaded and pressed by means of a roller.

Then the samples were cutted in a size of 40x40x3mm and dried with vacuum oven at 75 °C. Lastly, the samples were homogenized with the help of a grinder.

Figure 3.9 Sample preparation

Determination of sugar was achieved by DNS (dinitrosalicylic acid) method. This method tests for the presence of free carbonyl group (C=O), the so-called reducing sugars.

Preparation of DNS reagent

DNS reagent was prepared according to Coughlan & Moloney [97]. 10 g of dinitrosalicylic acid (DNS) in 200 ml of 2N NaOH and 300 g of sodium potassium tartrate in 500 ml of distilled water were mixed gently to dissolve the reagents. The final volume was to 1.0 L with distilled water.

Procedure

The samples were prepared in appropriate dilution (0.5g sample and dilute to 100 ml with distilled water). Solution was homogenized and filtered to remove precipitates. 1 mL samples and 1 drop of 37% HCl acid were added in each tubes and they incubated in oven for 5min at 90°C. 3 drops of 5N KOH solution were added to neutralize the acid. Then 3mL DNS reagent were added to all the tubes and they were mixed well. Tubes were placed in boiling water for 5 minute. After that tubes were cooled by placing them in water bath at 25 °C and 6mL of distilled water was added in each tubes. Finally absorbance was measured against a blank reagent at 540 nm, using Optima SP-3000 spectrophotometer (Figure 3.11).

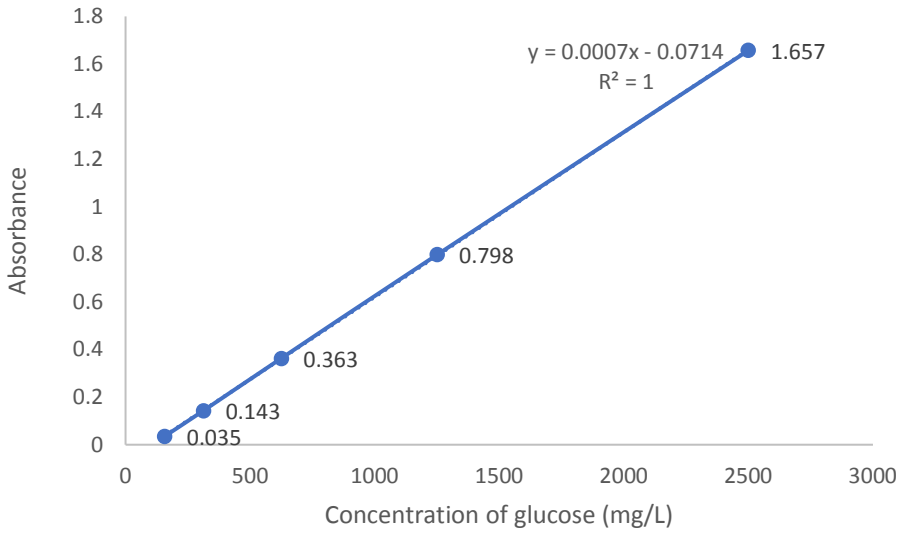

Figure 3.10 Glucose calibration curve at 540 nm

Glucose standard solutions ranging from 156.25-2500 mg/L were prepared for calibration curve. (Figure 3.10) The amount of reducing sugar present in test tubes was calculated from the standard curve of glucose and expressed as g/100 g of sample.

3.2.4.9 Protein Determination

The protein content of snack bar was determined by the Kjeldahl method. The nitrogen rate of snack bar sample was measured, the obtained number of sample was multiplied by protein factor 6.25 and the amount of protein in sample was calculated by using standard procedures of AOAC (1990). The results were expressed as the mean (±SD) of triplicate analysis.

3.2.4.10 Fat Determination

The fat content of snack bar was determined according to TS 973 EN ISO 659 (Turkish Standard, 2000) using Solvent extractor (Ser 148-6, Velp Scientifica, Italy). The results were expressed as the mean (±SD) of triplicate analysis.

3.2.4.11 Ash Determination

The total ash content of the snack bar samples were determined using the dry ashing method (AOAC, 2000). About 2 g (dry weight basis) of the sample was weighed into a porcelain crucible. The crucibles containing the samples were placed in a high

temperature muffle furnace heated to 800°C for 6 h. The ash content was then calculated by using in Equation (3.3).

$$Percentage\ ash = \frac{mass\ of\ ash}{mass\ of\ dry\ sample} \times 100 \quad (3.3)$$

3.2.4.12 Determination of Total Phenolic Content

The extraction of phenolic contents:

The samples were ground in an electric grinder to obtain a fine powder (110–120 mesh). The samples were defatted with hexane (1:5 w/v, 5 min thrice), dried for evaporation of hexane at 40 °C for 24 h. Sample was divided into two part as fat and defatted parts.

Defatted sample (1g) further was extracted with methanol (60%, 1:10 w/v) at room temperature for 60 min and was mixed at 25°C for 40 minutes in a stirrer (New Brunswick Scientific, Innova 40, USA). Samples were filtered using Whatman filter paper (No. 1). 100 microliters phenol extract was diluted with water to a total volume of 10 mL [98].

Fat (2.5g) of sample were dissolved with n-hexane (1:2 w/v) to remove oil, extracted with methanol (60%, 1:2 w/v) at room temperature for 60 min and mixed with stirrer. Followed by, phenolic compounds extraction was carried out with centrifugation at 3,500 rpm for 10 min [99].

Procedure:

2,25ml of FC reagent which previously diluted with distilled water to 1:9 (v/v), was added on a 450 µL sample extract or blank. After equilibration for 5 min, the extract was then mixed with 1.8 mL of sodium carbonate solution (7%), incubated for 90 min at room temperature in the dark. Absorbance of the mixture was read at 760 nm (Optima SP-3000 nano UV-Vis Spectrophotometer OPTIMA Tokio, Japan) and the results were expressed as µg of gallic acid equivalents (GAE) per gram of sample.

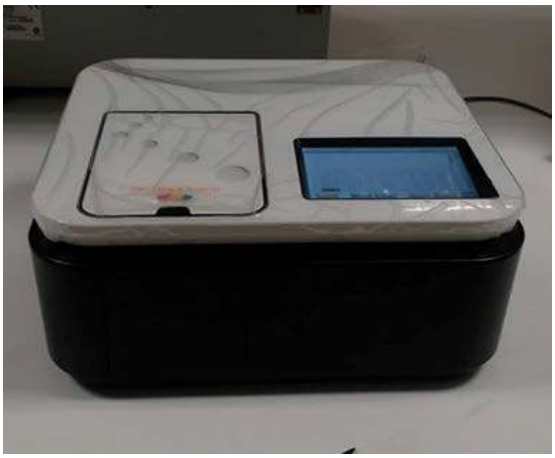

Figure 3.11 SP-3000 spectrophotometer

3.2.5.13 Determination of Calorific Value of Snack Bar

Determination of calorific value of snack bar can be performed by means of ASTM D 5865 Gross Calorific Value of Coal and Cake method. In this study, Leco AC 500 (automatic calorimeter) was used. Firstly, oxygen tube and the computer, which was connected to the equipment have started. The internal pressure was regulated as 420–450 psi by means of a regulator. The bomb was taken into bomb preparation unit and after opening its cover; fuse wire was connected to electrodes. The sample was weighed at a range of (0.8–1.2 g). Later on, the sample plate was located into the bomb and contact wire was connected to electrodes. Oxygen was supplied to the bomb unit via the automatic filling hand port. The water pump was opened and 2L of water accumulated into the pipet was taken to the container where the bomb was placed. The water container was placed in its unit. The prepared bomb was then placed in water. Electrical connection was made. After writing all necessary information (method, wight, sample code etc.) to the computer, the cover of the equipment was closed and the analysis was performed.

3.2.5 Statistical Analysis

The data of sensory analysis was subjected to one way analysis of variance (ANOVA) by using SPSS Statistics software version 25, to determine if there is a significant difference between snack bars. Statistics were calculated in the same program and excel. The data reported in all the tables were an average of triplicate observations unless otherwise specified. The results of the analysis was expressed in mean values ± standard deviation. The data were presented as the mean ± SD of each treatment. Mean values were calculated according to Tukey tests ($p < 0.05$).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Determination of Soluble Dry Matter in Mucilage Extraction

Over the years, different ingredients have been used for replacement of fat in foods, such as gums, fibers or mucilage. Chia mucilage has been recently studied as a possible fat replacer. Chia mucilage might provide hydration, viscosity development and conservation of freshness, especially for baked goods, therefore, presenting a potential as fat substitute. A research by Felisberto et al. showed that viscous mucilaginous external layer of chia seed can usable to evaluate its potential as fat substitute in bakery products and technologically feasible in pound cakes, with no significant alterations on their quality characteristics [100]. Therefore, the use of seeds with mucilage was preferred in this study. However, seeds should be kept in water for immersion time to release mucilage.

Figure 4.1, which shows the relationship between soluble dry matter in mucilage extract and immersion time, shows that the amount of soluble mucilage increased with the increase in immersion time. But, the soluble dry matter in mucilage extract was found to be constant after 30 minutes. It was obtained from the figure that the immersion time of 30 minutes is enough for the mucilage extraction.

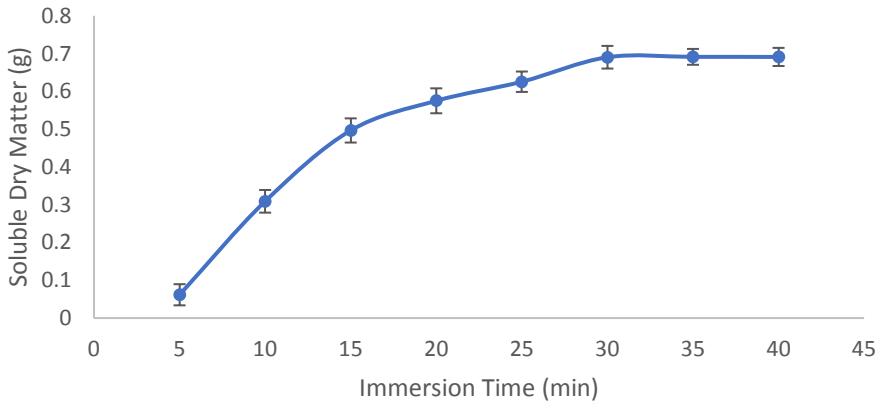

Figure 4.1 Soluble dry matter in suspension solution (g) changing with immersion time (min)

4.2 Sensory Analysis

In this study, sensory analysis was applied in two stages of product design process for investigating of formulation and drying time. According to a study, consumers' perceptions of taste, healthiness and naturalness importance was evaluated; taste was considered the most important, followed by healthiness, and then naturalness. For this reason in first stage, sensory analysis was evaluated in terms of flavor acceptability. The sensory quality evaluation results of the S1, S2 and S3 formulations were given in Table 4.1. The table shows that S1 formulation has the highest score with 6.93. It was also seen that, there is no significant differences between S2 and S3 bars in terms of their scores of flavor acceptability. S1 formulation included concentrated apple juice and so it has fruity/sour taste. The fruits in this kind of products, cause not only change in taste of the product but also in their texture. Ryland et al. has found that snack bars which were contained sour/fruity flavor, has stickiness to touch directly proportional with its hardness [101]. Since stickiness and hardness are not desirable in our product, the amount of apple concentrate has used as a low ratio of 24.52%.

Table 4.1 Sensory quality evaluation parameters of the three prototype snack bar (S1, S2 and S3)

	S1	S2	S3
Flavor Acceptability	6.93 ± 0.254^{a}	5.27 ± 0.98^{b}	5.00 ± 0.91^{b}

Means ± standard deviation (n = 30). Different letters in the same line means significant differences between samples ($p < .05$).

4.3 Titratable Acidity (TA)

Titratable acidity was calculated for S1 (Seeds and pistachio powder with apple juice concentrate), S2 (Seeds and pistachio powder with molasses) and S3 (Seeds and pistachio powder without apple juice or molasses) as malic acid, citric acid and citric acid, respectively. Sugar content was evaluated by means of DNS method.

Table 4.2 Titratable acidity and sugar content of the three prototype snack bar (S1, S2 and S3)

	S1	S2	S3
Titratable Acidity %	1.05 ± 0.32	0.91 ± 0.14	0.41 ± 0.38
Sugar Content %	15.05 ± 0.20	16.60 ± 0.31	4.83 ± 0.42

In Table 4.2, it was clear that the maximum percentage of titratable acidity was found in S1 formulation. Moreover, the maximum sugar content was found in S2 formulation. Therefore, as S1 has the highest score in sensory analysis in terms of flavor acceptability, it can be concluded that the sour taste, which comes from the apple juice concentrate gained attraction of panelists.

4.4 Texture Analysis

Texture analysis results of a foodstuff can vary because of so many differences such as its formulation, drying method and time. Parvinder Kaur et al. has found in their article that, in cookies, the results of the texture analysis changed with increase in amount of flaxseed [102]. The texture analysis results with respect to drying methods were given in Table 4.3. The fracturability was found to be similar for the three methods, which are oven, vacuum oven and microwave combined with vacuum oven drying. On the other hand, hardness values were found to be significantly different. From the table, it can be seen that the hardness value was not able to reach an adequate level for the sample dried with atmospheric oven. Moreover, the sample dried with microwave oven combined with vacuum oven method, was found to have excessive unfavorable hardness levels. It was concluded that, the ideal hardness level can be obtained with vacuum oven drying method.

Table 4.3 Texture parameters of snack bars with using oven, vacuum oven and microwave oven combined with vacuum oven.

Drying Methods	Fracturability (mm)	Hardness (N)
Oven	19.46 ± 0.9^{a}	10.07 ± 1.1^{a}
Vacuum oven	21.56 ± 0.62^{b}	24.36 ± 1.6^{b}
Microwave and vacuum oven	22.63 ± 0.65^{c}	31.19 ± 4.22^{c}

Different letters within the same column differ significantly from each other (n=3 ± s.d.; $p<0.05$).

Figure 4.2, Figure 4.3 and Figure 4.4 shows the change in hardness and fracturability with time for oven drying, vacuum oven drying and microwave oven combined with vacuum oven drying, respectively. It was obtained from the figures that, the fracturability was not changed with time depending on drying method. But, the hardnesses of samples obtained different drying methods were found to be different. In oven drying method, the hardness value found to be increased significantly after approximately 300 minutes. In vacuum drying, this increase found to be started at shorter time of approximately 120 minutes. In addition, in microwave oven combined with vacuum oven drying, the increase of hardness started almost at the beginning of the drying process.

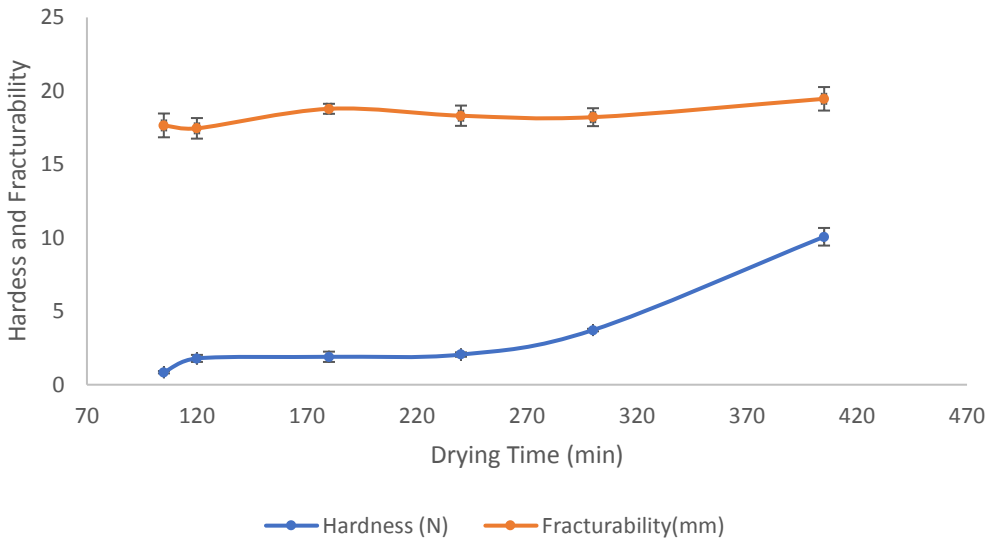

Figure 4.2 Hardness and fracturability change during drying time in oven

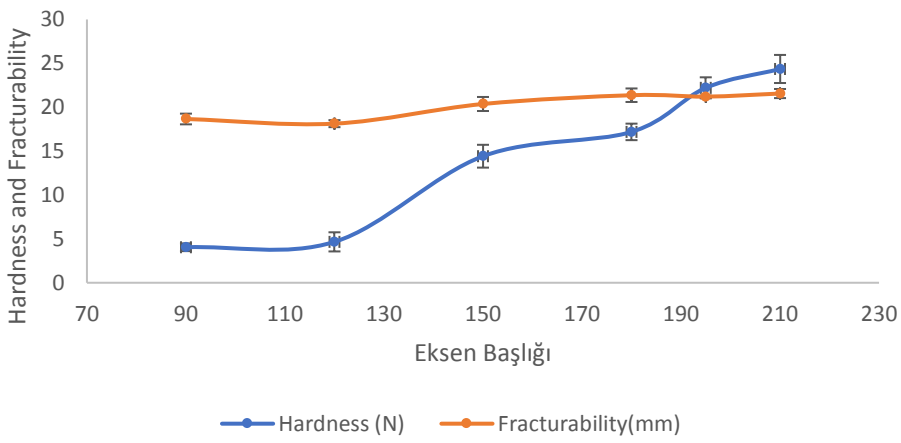

Figure 4.3 Hardness and fracturability change during drying time in vacuum oven

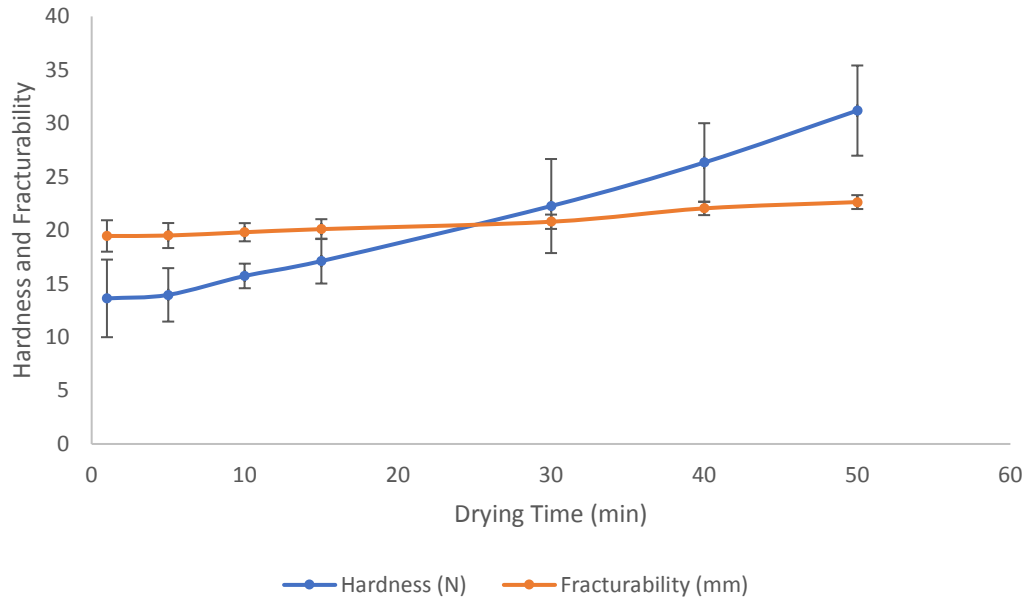

Figure 4.4 Hardness and fracturability change during drying time in microwave oven combined with vacuum oven

In this study, the drying increased the hardness value of samples because of the decrease in moisture content. It is expected that the decrease in the amount of moisture decreased the hardness. Hii et al. has found similar results relying on the comparison of fresh and dehydrated cocoa beans. They have reported that, these results can be related to the fact that the higher moisture content result in more swollen and softer structures [103].

The property used to describe the texture of the samples was hardness, defined as the force at maximum compression and it was measured by saving the value of peak force for each sample three point bend test [104]. In Figure 4.5, Figure 4.6 and Figure 4.7, the results of peak force (PF), which is an indication of hardness were given for oven drying, vacuum oven drying and microwave oven combined with vacuum oven drying methods. The peak forces, which were obtained by using three point bend test with a three point bending rig, were found to be very different for three methods.

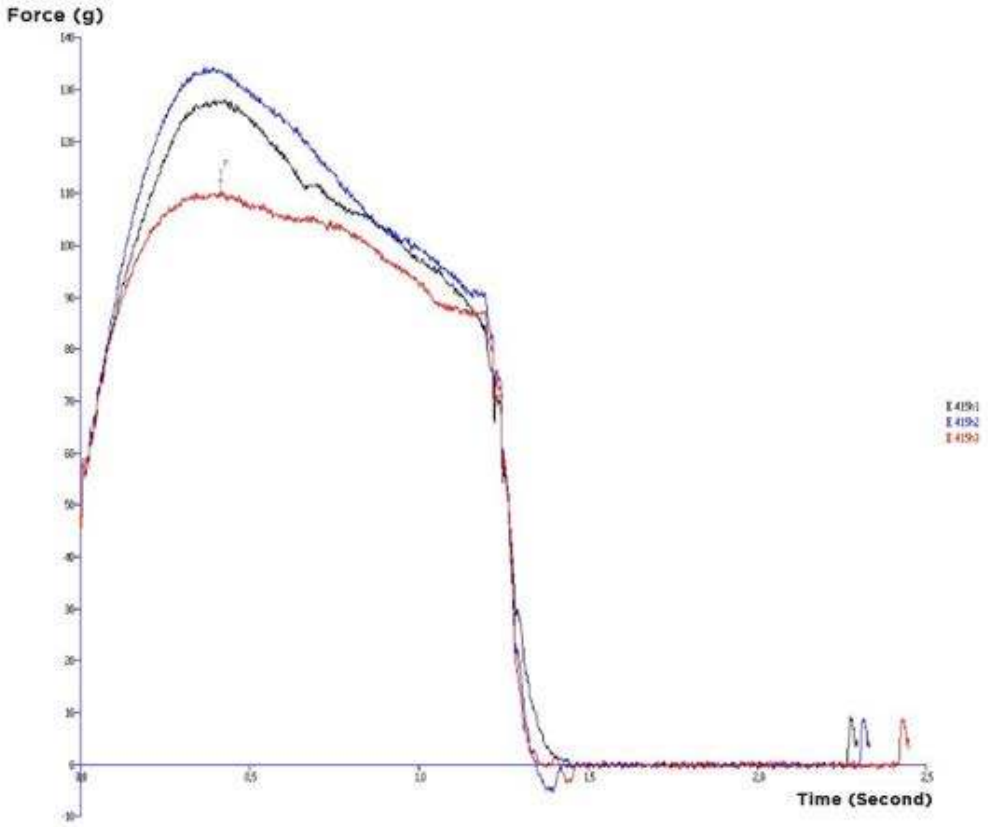

Figure 4.5 The peak force (PF)-time curve for oven drying

From the figure 4.5, it can be seen that the peak force curve for three snack bar sample which were dried at 75 ℃ for 415 min in the atmospheric oven. The samples dried by oven drying was found to have the lowest peak force value and it the crack was occurred at a time interval rather than sudden crack. This result has shown that this sample was not able to reach the adequate fracturability level.

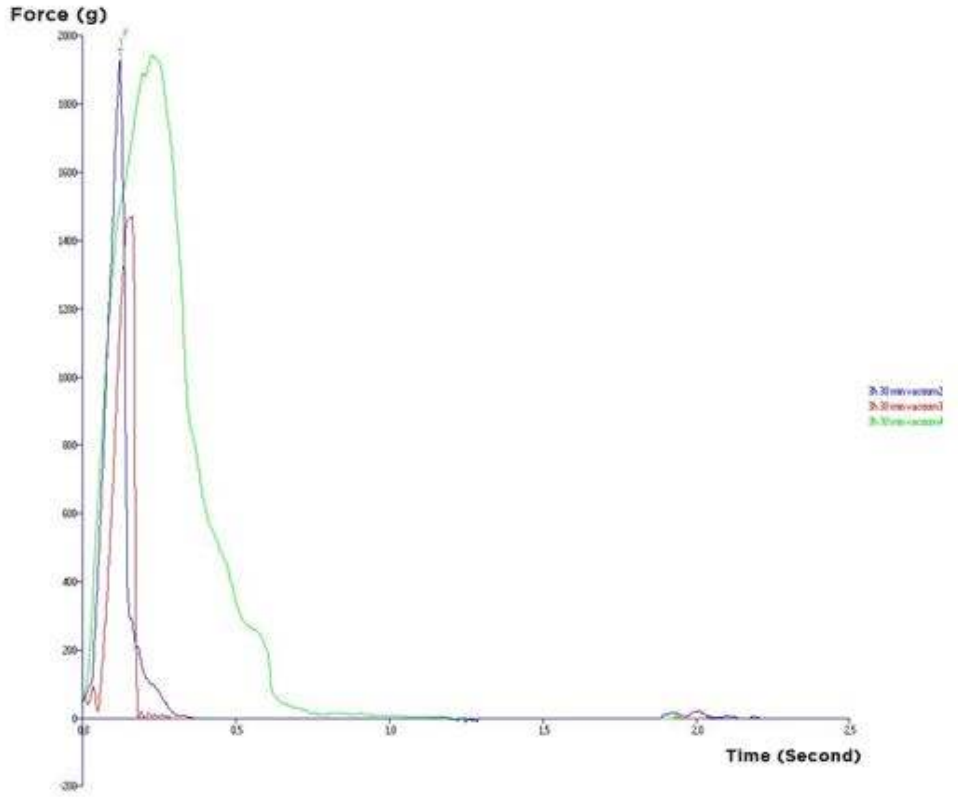

Figure 4.6 The peak force (PF)-time curve for vacuum oven drying

In the figure 4.6, it can be seen that the peak force-time curve for three snack bar sample which were dried at 75 C for 210 min in vacuum oven. With respect to the results of the analysis, the most ideal fracturability and hardness levels according to other drying methods obtained by vacuum oven drying method. The peak curve of this method was found to have a sudden crack together with an ideal peak force value.

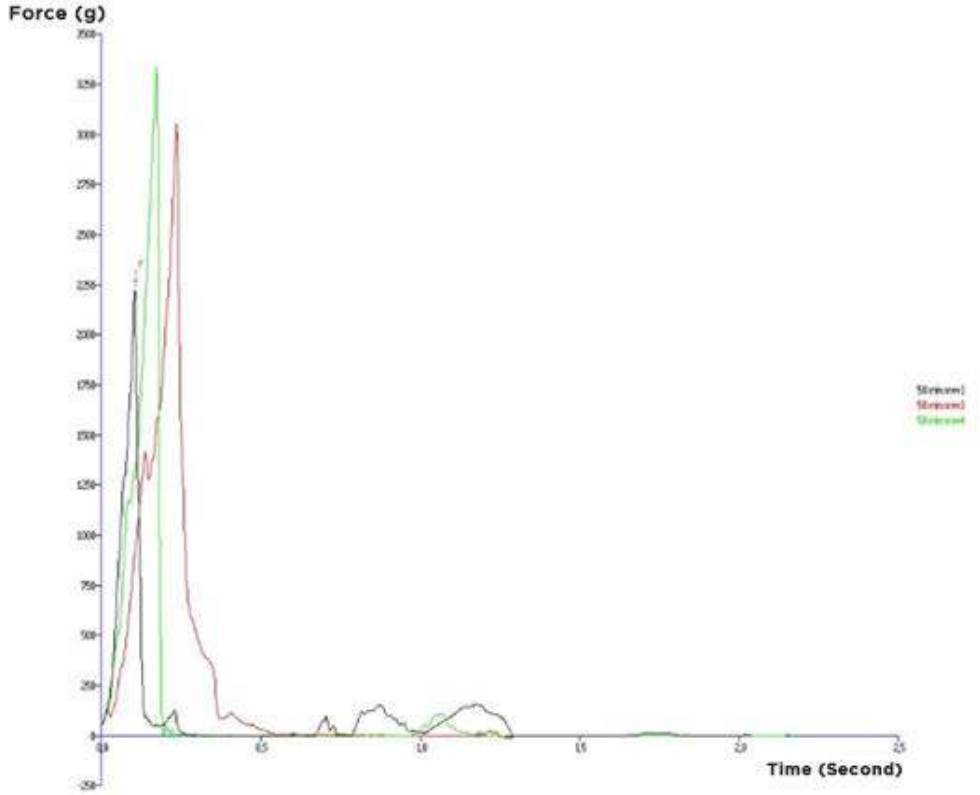

Figure 4.7 The peak force (PF)-time curve for microwave oven combined with vacuum oven drying

In the last drying method of this study, it can be seen that peak force-time curve for snack bar samples which were dried at 80% power for 1 min in the microwave oven and at 75°C for 50 min in vacuum oven. On the other hand, the sample dried with microwave oven combined with vacuum oven found to have very high levels of peak forces, despite the crack was occurred suddenly. It is not a desirable property for a snack bar because the product requires higher jaw force during eating, even if it has high fracturability. Also peak forces were different for 3 three same snack bar sample, this shows can be that they can't be dried as homogeny.

4.5 Moisture Content

The most important expectation during a drying process of a foodstuff is not only short drying time but also not to affect product's taste, nutritional value and texture. It has been known that the temperature increase results in higher dehydration rate. Accordingly, drying time sharply decreases with increase in drying temperature [105]. In addition, it has been found that drying method has a powerful effect on drying time with respect to results in this study.

The drying curves of the snack bar samples were given in Figure 4.8, Figure 4.9 and Figure 4.10 for three different drying methods.

With respect to the Figure 4.8, the snack bar dried with oven could not reach the desired moisture content level, although it's drying time is very long. In order to prevent the snack bar from darkening, the drying was stopped when the moisture content became 6.58%.

Figure 4.9 shows that, drying curve of samples which were dried in vacuum oven. Hardness and fracturability values were optimum although drying time longer than microwave oven combined with vacuum oven. In addition, the most homogeneous drying is provided by the vacuum oven drying method.

Figure 4.10 have the drying curve of snack bar dried with microwave oven combined with vacuum oven drying method. Sudden moisture content drop (from 57.61% to 9.3%) was observed by means of the microwave drying for 1 minutes. Although the desired moisture content was obtained, its hardness has a high value and its drying was found to be non-homogenous. When this disadvantages were taken into consideration, the best drying method found as vacuum oven in terms of their drying curves.

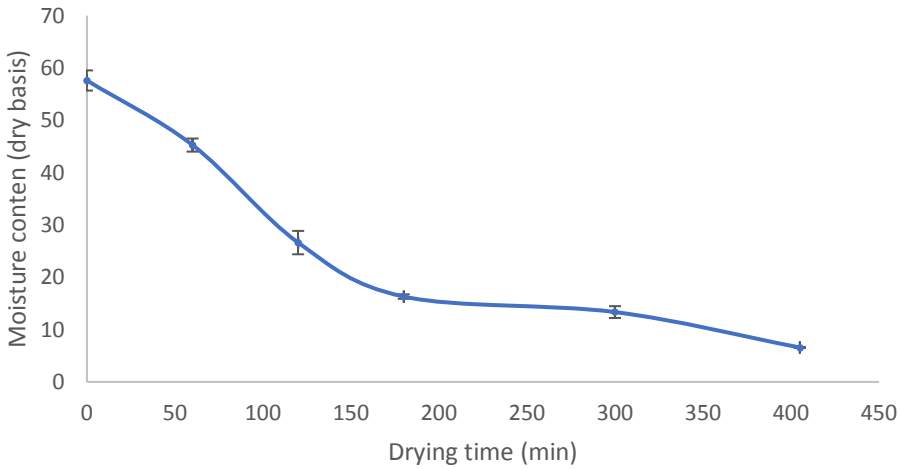

Figure 4.8 Drying curve for oven including change of moisture content (% dry basis) with drying time (min)

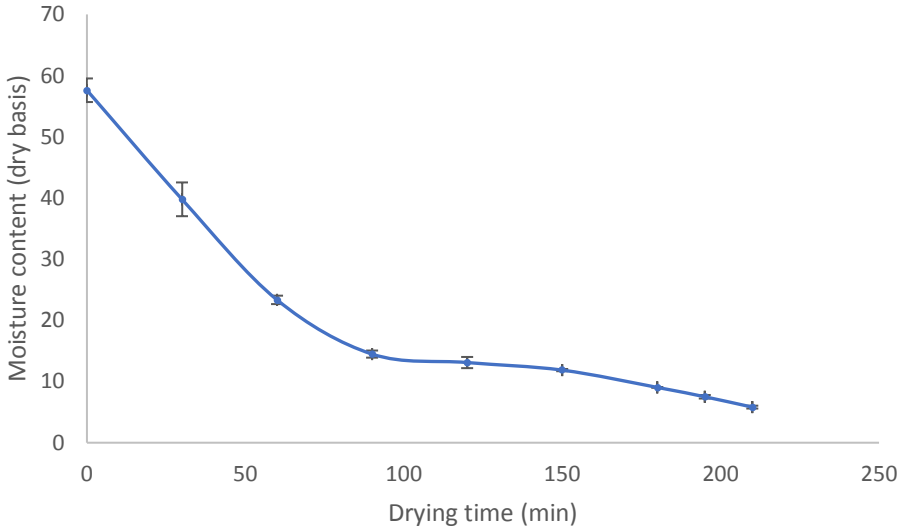

Figure 4.9 Drying curve for vacuum oven including change of moisture content (% dry basis) with drying time (min)

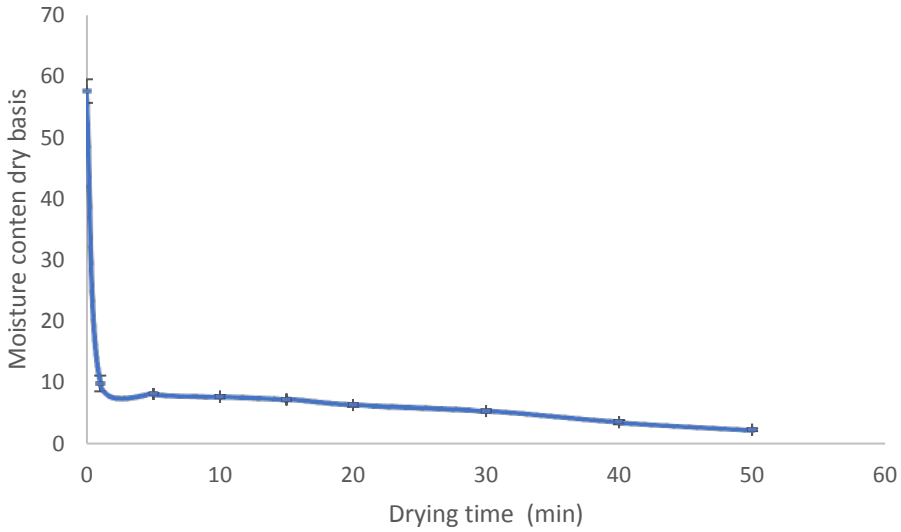

Figure 4.10 Drying curve for microwave oven combined with vacuum oven including change of moisture content (% dry basis) with drying time (min)

4.6 Color Change

The color analysis of snack bar for three different drying methods were performed after drying of samples to nearly 5% moisture content. Table 4.4 shows the color parameters of the samples. As it can be seen from the table, there was no any considerable color difference compared with the raw bar. In terms of L* value, microwave oven combined with vacuum oven method has the highest value of 41.05. A comparison of the color attributes of potato chips fried under vacuum and

atmospheric conditions was worked by Garayo and Moreira. [104]. Their results showed that the potato chips fried under vacuum pressure had significantly higher L* value than the potato chips fried under the atmospheric condition

Table 4.4 Color analysis of snack bar for oven, vacuum oven and microwave oven combined with vacuum oven

Samples	L^*	a^*	b^*	ΔE^*
Raw bar (Initial)	35.16±1,58	7.48±1.51	16.96±1.38	0
Oven (Dry Bar)	34.70±1.11	6.69±1.57	14.20±1.61	1.63±1.35
Vacuum oven (Dry Bar)	36.80±2.55	6.55±1.59	17.46±1.59	1.95±1.28
Microwave and vacuum oven (Dry Bar)	41.05±1.85	7.68±0.08	20.68±1.2	6.98±0.86

The change in L*, a*, b* values with respect to drying time were given in Figure 4.11, Figure 4.12 and Figure 4.13 for three different drying methods. In Figure 4.12, the snack bar dried with oven had an increasing value of L* until 180 minutes. This increase can be interpreted as raw snack bar has darker color because of its high moisture content than dried one. A darkening was observed after 180 minutes of drying. It can be concluded that the reason of this darkening is caramelization.

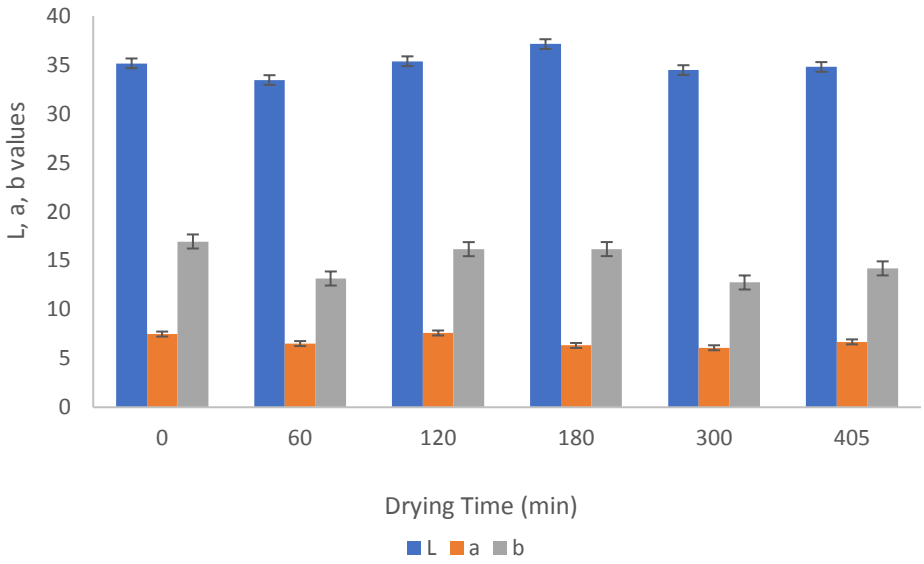

Figure 4.11 L*, a*, b* values-drying time for oven

As it was illustrated in Figure 4.12, there was an increase in L* value before the drying time of 195 minutes and decrease after this time. It was found that the L* value in vacuum drying was higher than it was in oven drying.

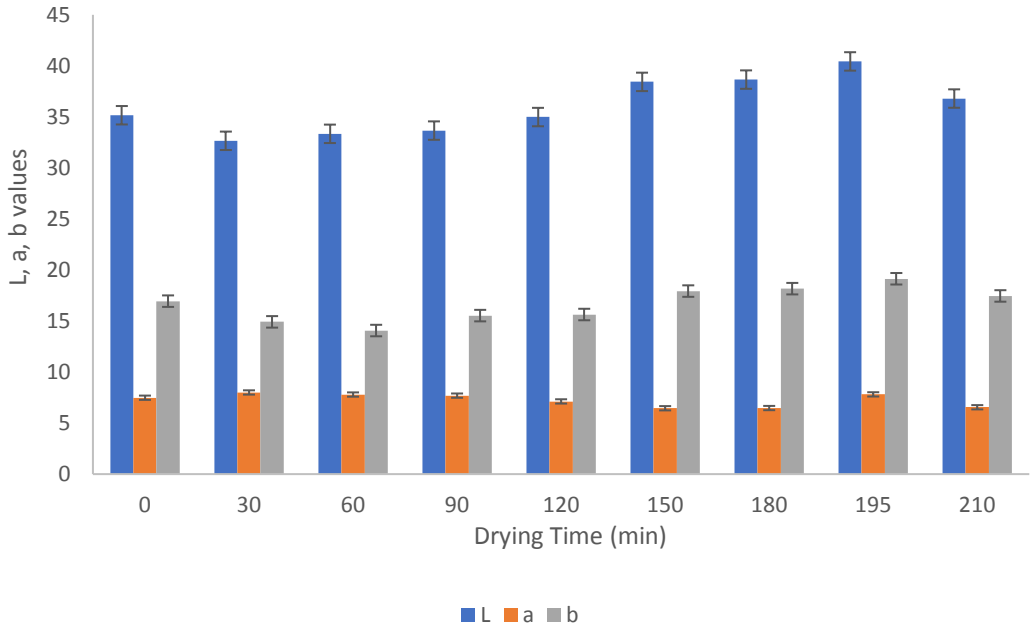

Figure 4.12 L*, a*, b* values-drying time for vacuum oven

In Figure 4.13, the changes in L*, a* and b* values of the snack bar firstly dried in microwave oven for 1 minute, later on dried for 50 minutes in vacuum oven were given. A higher L indicates a lighter color. The light-colored product looks more attractive and fresh. The L* value (41.05) was found to be best among the other drying methods.

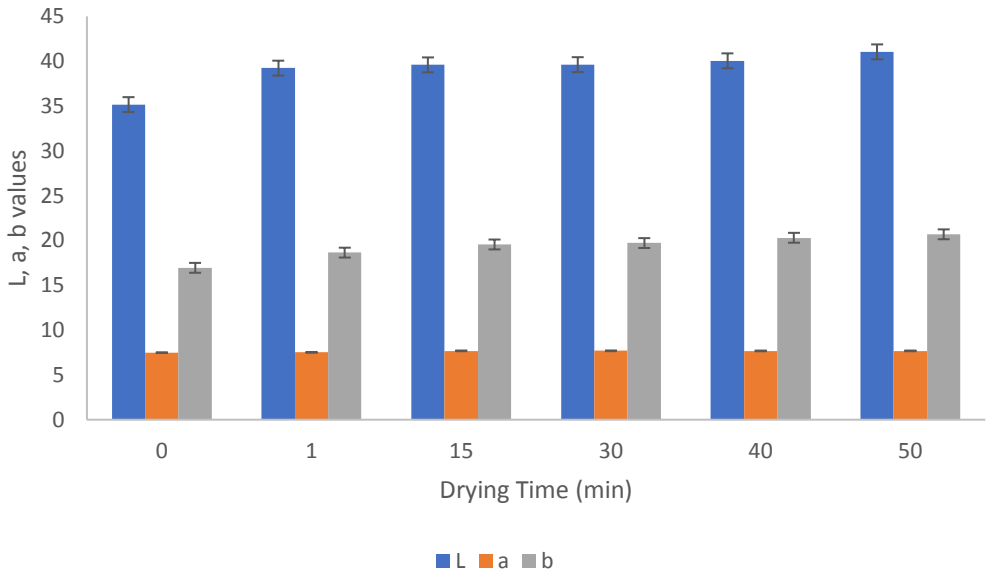

Figure 4.13 L*, a*, b* values-drying time for microwave oven combined with vacuum oven

4.7 Sensory Analysis for Final Product

The sensory quality evaluation results of the final product, which was dried with vacuum oven for different times, were given in Table 4.5. This analysis was carried out with the aim of determining the optimum drying time in vacuum oven. Consequently, the sample dried for 210 minutes handled the highest scores in fracturability (6.67), hardness (6.93), chewiness (6.67) and overall acceptability (6.90).

Table 4.5 Sensory quality evaluation parameters of the snack bar in vacuum oven for different times (180, 195 and 210 min).

Drying time	Fracturabilility	Hardness	Chewiness	Overall Acceptability
180 min drying	$2,47 \pm 0,819^{a}$	$3,07 \pm 0,640^{a}$	$2,23 \pm 0,774^{a}$	$2,50 \pm 0,572^{a}$
195 min drying	$2,57 \pm 0,626^{a}$	$3,40 \pm 0,675^{a}$	$2,60 \pm 0,968^{a}$	$2,80 \pm 0,551^{a}$
210 min drying	$6,67 \pm 0,479^{b}$	$6,93 \pm 0,254^{b}$	$6,67 \pm 0,479^{b}$	$6,90 \pm 0,305^{b}$

Means ±standard deviation (n = 30). Different letters in the same line mean significant differences between samples ($p < .05$).

4.8 Nutritional Profile of Final Product

In this study, a healthy and non-additive product has been made instead of a diet product. Therefore, to reduce the product's calorie value, fat and carbohydrate

reduction process has not been applied. Seeds were used as a whole and, this also makes it possible to benefit from the health benefits of unsaturated fatty acids. In particular, pistachio and flaxseed contain highly unsaturated fatty acids [39, 106]. Unsaturated fatty acids not only prevent elevation in cholesterol, but also can help to stabilize it in the blood. Furthermore, thanks to using of seeds as a whole, all of the beneficial nutrient content has been maintained. Although the energy value of the product (237.92 kcal for 40g serving size) has been higher than other diet bars (194 cal for 47g serving size), it has been predicted to be more saturator [101] .

The product is found to have higher amount of protein (16.89% of its weight) when it is compared with the similar snacks. For instance, in the study of Ryland et al., the amount of protein was 3.2g in the snack with total weight of 47g (6.8% of its weight) [101]. In another study which includes a snack developed by Yan, the protein content was 11.6% of the total weight [107]. As a result, the product can be considered as a snack capable of meet the protein needs of athletes with its high protein content.

It was found that the snack in this study had high total phenolic value with the help of high amount of pistachio membrane content. Total phenolic content was calculated as 24.36mg GA for 1g sample. According to an article, in fresh pistachios TP values was found as 16.2 mg/GAE [108]. Additionally, with the rich protein content, low sugar content and the use of natural fruit sugar, the product can be recommended for the nutrition of athletes, pregnant and children. Furthermore, high fiber and pulp content of pistachio, quinoa and flaxseed are very useful for the digestive system [109].

Drying method is another factor that affects the nutritional profile as much as the content of the product. In this study, the used vacuum oven method for drying provided our product to save its nutritional value. During a drying process of a food product, the selected drying method, its time and temperature affects some other values such as the vitamin c and phenolic content. In order to preserve vitamin C, reis et al. have found vacuum drying method more efficient than other drying methods. They have achieved 60% retention on apples and strawberries with microwave-vacuum drying [110]. In addition, the increase in drying temperature cause a decrease in phenolic content. Mrad et al. have found in their study that the increase of drying temperature from 30 to 70 °C leaded to higher degradation in phenolic content [105].

In the literature, snacks are defined as another eating concept, other than breakfast, lunch and dinner. The greater eating frequency provides beneficial effects on cardiovascular health. Moreover, there is a connection among the weight management, eating frequency and lower risk of obesity [111]. However, the quality of the snacks to be consumed between the main meals is very important. It is known that the variety inside a meal need to be increased. Moreover, intake of the foods such as nuts, vegetables and fruits in children is consistently below recommendations, and the increase in consumption of these foods provide benefits on health of children [112]. Since the snack product in this study is both completely natural and rich in nutritional content, it can be appropriate to consume between meals or main meals.

Table 4.6 Nutritional profile of final product

Specifications	For 100g	Serving Size 40g
Energy (kcal)	594.8 ± 7.59	237.92 ± 3.03
Sugar (g)	15.05 ± 0.079	6.02 ± 0.03
Protein (g)	16.89 ± 0.50	6.76 ±0.20
Fat (g)	33.17 ± 0.41	13.27 ± 0.16
Ash(g)	2.38 ± 0.16	0.95 ± 0.06
Total Phenolic Content mg GA	2436 ± 19.29	974 ± 7.72

Ingredients: pistachio powder (100 g), chia (20 g), flaxseed (12 g), quinoa (8 g), water (80 g) and concentrated apple juice (52 g)

CHAPTER 5

CONCLUSION

The results of this study show that it is importance of drying time and drying method in terms of increasing attractive of product. The most accepted formulation have been dried by using microwave oven combined with vacuum oven, atmospheric oven and vacuum oven to obtain the best drying method and time to get a product which has desired hardness and color properties. The hardness, fracturability and color of the product which has been dried by using vacuum oven were better than those dried by using microwave combined with vacuum oven and atmospheric oven method. Furthermore, a formable dough structure was obtained without the use of additional sugar (glucose syrup, fructose syrup, artificial sweetener, tea sugar, etc.) by advantage of the binding property of the gel-like extract which is suspension of flaxseed and chia seed. As a result, designed a healthy snack bar which can fulfil daily energy needs, gluten free, preservative-free, additive-sugar-free (glucose syrup, fructose syrup, artificial sugar etc.) and high nutritious

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