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## ABOUT THIS JOURNAL

The *International Journal of Gastronomy Research* (pISSN: 2822-6143; eISSN: 2980-1532) is a peer-reviewed academic journal that focuses on gastronomy research. The journal is an international journal, published twice a year (June and December), and its publication language is English only.

The *International Journal of Gastronomy Research* is an **open access** journal. There is **no fee** for submission and publication. The journal aims to contribute to the development of gastronomy science by ensuring dissemination of knowledge on gastronomy, culinary arts, and all its related fields based on scientific principles. The journal welcomes both research and review articles on gastronomy science.

The logo of the journal was designed by Gizem Güler from the Department of Graphic Design, Faculty of Fine Arts, Istanbul Arel University. We would like to thank Gizem Güler for her contributions to the journal.



## ABSTRACTING & INDEXING

International Scientific Indexing

Turkey Tourism Index

Ideal Online

Google Scholar

## TABLE of CONTENTS

*International Journal of Gastronomy Research*

# Neurogastronomy: Factors Affecting the Taste Perception of Food

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## Abstract

Neurogastronomy is a new formation that includes many researches to provide a connection between gastronomy and neurology. The existence of biological, emotional and cultural factors as flavor in the brain can be explained as neurogastronomy. The data received with the five senses are collected in the brain and perceived in its relevant parts. Research on what kind of perception is created with the formation of missing sensory data in the brain has been increasing day by day. In addition, by considering the different reflections of sensory data from reality, it is examined how they lead to perceptions in the brain. Plate design is very important in terms of visual presentation. What kind of an effect the presentation types of plate design have on customers and what kind of plate design they prefer is a matter of curiosity for researchers. Every stage of life continues in the light of technological developments. One of these technological developments is virtual reality. With the use of virtual reality in the field of neurogastronomy, it is possible to simulate the senses differently. This situation creates the possibility of causing different perceptions in the brain. In this study, neurogastronomy, the concepts of taste and flavor and the parameters affecting the perception of taste were addressed, the studies on the effect of plate presentation and atmosphere were examined, and information was conveyed by making a comprehensive literature review.

***Keywords:*** Flavor, Neurogastronomy, Sensory perception, Taste.

**Review Article** / *Received: 9 September 2022, Accepted: 15 October 2022, Published Online: 26 October 2022.*

## 1. Introduction

Neurogastronomy, a field, which is shaped around gastronomy and neurology, can be explained as that the brain triggers our perception with the creation of flavor using biological, emotional and cultural factors. It can be also defined as the examination of complex brain processes during eating (Robinson, 2015).

When dining in a restaurant, all external factors affect thoughts about food during eating experience. Playing of a music loved, the softness of yoghurt, the temperature and density of the food, the color of the meat and the smell of the food are among all these factors. So much so that, especially with the effect of smell, eating becomes an experience process during which all the senses are felt together with the revival and recall of past memories (Yilmaz & Tugcu, 2021).

Scientific research regarding the perception and experiencing of foods is mainly based on "neuroculinary" which includes the concepts of "neurochemsitry" and "neurogastronomy" (Shepherd, 2012). Although neurogastronomy mainly deals with the aspects of taste experience, it takes place in the field of molecular gastronomy. Molecular gastronomy is a much wider field of food preparation and presentation, which is also interested in the neurological connections of food perception and experience (Kuran, 2014). In recent years, in addition to ever increasing number of academic researchers, many marketing and design practitioners have revealed various factors that appear to increase the visual appeal or flavor of food images for the typical consumer (Spence et al., 2022).

Governing flavor is not an easy task. There are more than 400 smell receptors in the human nose. Each receptor may give response multiple different smell molecules, and each smell generator type may activate more than one receptor. Taste receptors are also quite complicated. First, researchers have found taste receptors in the lungs, intestines, and pancreas, which they suspect they encode information about metabolism. Second, researchers have recently asserted that humans have receptors for tastes

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different from the five basic tastes, with fat and calcium being leading candidates in this regard (Breslin, 2013).

At least some of the perceptual processes are biologically determined. Both taste and smell are based on the direct perception of chemicals in the environment by means of receptors on the tongue and nose. This process, which goes from the moment the knowledge of a chemical compound is possessed to the moment the representation emerges at the subjective level of the individual, takes place on a continuum between stimuli, senses, receptors, nerves and action (Tomc, 2011).

In the present study, neurogastronomy, the concept of taste and flavor, the parameters affecting the perception of taste, the perception of smell, visual factors, auditory elements, the factors affecting the flavor of the food on the plate as well as studies conducted on this topic were examined.

## 2. Conceptual Framework

Humans have a complex relationship with food. For some, food is sustenance, for some it is a source of subsistence, for some it is an emotional reward and it can be even a medicine. As the obesity epidemic shows, it can also be the exact opposite. Neurogastronomy encompasses a series of disciplines that address this relationship, including basic science, nutrition, psychology, agriculture, food science and health, and is a relatively new science, considering its history. The term was first designed and suggested in 2006 by Gordon M. Shepherd, a professor of neurobiology at Yale School of Medicine. Gordon Shepard used the term, neurogastronomy, in 2006, when he first realized how important smells are in producing certain tastes. That year, he published a paper about molecular biology of smell in Nature, in which the olfactory receptors and the biochemistry of food preparation and how all these are processed by the brain are included (Shepherd, 2006). The fundamental hypothesis of neurogastronomy is that food flavors are created in the brain as a product of information we receive from all of our senses. This explains that the thing that gives a steak its distinctive flavor and makes it different from the grilled chicken in taste is the smell. When a juicy steak is bitten, some of its molecules bind to taste receptors on the tongue and give basic sensations such as sweet, salty, sour, bitter or umami. On the other hand, more volatile smell molecules reach from the back of the mouth towards the nose. This retronasal olfactory signal combines with taste signals in the orbitofrontal cortex of the brain to give a more complex taste sensation (Fried, 2017).

Neurogastronomy is a new multidisciplinary field dedicated to understanding gastronomy in the context of the brain and behavior. It brings the science and cuisine together by exploring behaviors that affect how the human brain experience eating and drinking. This field has transformed into its own learning space by examining the molecular biology of olfactory receptors, the biochemistry of food preparation, olfactory imagery and the brain favor system (Pérez-Rodrigo & Aranceta-Bartrina, 2021). The field of neurogastronomy, in which the brain perceives taste, the relationship between the brain and behavioral models is important, and the senses are kept in the foreground, brings a new perspective to the perception of taste. This science focuses on how the brain can be reinvented to perceive food differently rather than exploring how food can be redesigned to change its taste. For example, it is a concept about making the brain think carrots are delicious, instead of genetically modifying carrots to improve their taste (Yilmaz & Tugcu, 2021).

Although quality controls of foods are mostly performed with objective evaluation methods, sensory analyses are also frequently used today. Sensory analysis is a method of evaluating foods in terms of appearance, taste, smell, touch and sound. The response of a person or persons given to a stimulus is measured in the sensory analyses. Consequently, stimulus-response reaction is essential in the evaluation in which intensity, quantity, quality, dimension and hedonic response (personal taste) are addressed. Perceived sensory properties, despite being associated with demographic structure of persons, show variation according to the geography lived, the family structure being raised and their personal education and development. The gastronomy concept is associated with the subject exactly at this point (Yilmaz et al., 2021).

## 3. Five Senses

Human beings need and use their five senses at the moment of decision making in every period of their life. Sometimes, contradictions may arise between senses. For example, from a distance, the drink in a glass may seem hot, but when approached, and touched by hand, it may be realized to be cold. Our most commonly used sense organ is sight and while using the sense of sight, other senses are used in the following steps either to confirm or contradict what is seen. When we go to a restaurant for dining and the moment we enter through the door, the first thing that attracts the attention of most of us is the style of the place. The first used sense is the sense of sight, which the next stages are decided according to the perception at this first moment. In other words, the decision regarding the taste of the food that will come out of the kitchen and how that food will be presented are made based on the appearance and comfort of the restaurant. The presentation of the plate, the amount of the portion, the color and shape of the presentation, the layout and quality of the table are other elements that the buyer attaches importance about (Yilmaz et al., 2021).

Olfaction is expressed as a "dual sense" consisting of orthonasal and retronasal smells. Orthonasal smell perception, which is received from external smells through the nostrils, is often associated with aroma by humans. By means of the perception of retronasal smell coming from inside of the mouth, small breaths are sent with exhalation from the back of the mouth and nasal passages, passing through the space connecting the nasal passage to the back of the throat. When it comes to the chewing and swallowing functions of the brain, it is possible to perceive and identify a wide diversity of foods with retronasal smell perception. In a study, apples and onions were cut into small cubes, participants' eyes were closed, their noses were gagged, and a food cube was placed in their mouth. Participants were then asked to suck on the cube. At this time, it was not understood what the product was, but when the nose was opened, it was immediately understood whether it was an apple or an onion in the mouth. In fact, sweet, salty, bitter, sour and umami tastes are perceived in the mouth, when the nose becomes involved, the smell of hundreds of millions of different olfactory stimuli are perceived. In other words, the perception is completed when nose and mouth function together (Herz, 2015).

No matter how important the olfaction is, it is not the only sense to create the perception of taste by combining with taste. In a workshop held to measure how much visual perception affects flavor, participants were given two glasses, one with white juice and the other with red juice, to measure how much visual perception affects flavor. Participants described the red juice to be more concentrated and selected attributives connected to forest fruits. They described the white juice as more delicate and resembling green apple or light-colored fruits. In reality, both juices were the same, but one contained red food colorant (Mitzman, 2014). It is seen that visual perception regularly affect the flavor perception of our brain. Thus, this prospect will also change the way we perceive food after we put it into our mouth. Although most people do not realize that the sense of hearing affects the flavor perception, potato chip manufacturers are aware of this and use it especially in their advertisements. It is stated that the sound of a food breaking crisply in the mouth evokes the feeling of freshness (Mitzman, 2014).

The smell of food is another important element and it shows us the finer details about everything. Such as whether it is good or bad, fresh or spoiled. Appealing to the buyer's sense of olfaction is more about ingredients' quality and being delicious than how the food looks on the plate. As smell and taste are interconnected, pleasant smells may increase appetite. Due to the fact that smells make the person think that the food is good, they enable a decision to be made about the food without tasting it (Holmes, 2017).

The sense of feel and touch is also very important in this regard. For example, it is revealed how important the sense of feel and touch is in situations such as touching a dirty chair caused by oil residue or being served cold soup or hot lemonade (Krishna, 2016).

Tasting is one of the most important factors in the presentation of the food. The taste of the food should undoubtedly be delicious. In fact, when the tasks are put in order, the stages are observing the food, smelling it and having an idea about its taste, checking whether it is cold or hot and finally tasting it. While trying to prove that the food is perfect from the beginning to the end of these stages, the actual taste of the food is felt in the final stage. At the end of the collective action of the five senses, the presentation of the food takes place (Wan et al., 2020).

Living organisms exhibit a substantial selectivity by utilizing their chemical and physical senses, instead of eating and reproducing with whatever is available (Le Bon et al., 2017). Taste is very important for the survival of people living in social groups. In a way, it is considered to be the most significant sense helping to distinguish between nutritious and poisonous food sources (Spence, 2017). Taste memory includes the recognition of a taste, and its characteristics related to hedonic value, degree of familiarity and nutritional or toxic properties associated with that taste and plays an important role in identifying nutritious foods and preventing toxins. Taste recognition is an often instinctive response that is part of an innate behavioral repertoire, however often involves brain processes that recall past experiences when it is mostly associated with the consequences of ingesting the food. In accordance with this, it can be expressed that a taste perception concludes with learning that allows the storage of information about the taste and its relationship with the environment and that can be used as a guide for future food consumption (Nunez-Jaramillo et al., 2009).

## 4. Taste, Flavor and the Presentation of Foods

Flavor and taste are often perceived as the same, but are actually two very different concepts. The perception of taste starts at the moment when we take the food into our mouth, then is directed to the brain where the final decision about the taste of the food is made. Thanks to receptors on our tongue, bitter, sweet, sour, salty and umami tastes are explored. There is a group of researchers stating that humans have five basic tastes, whereas another group indicates that it is possible to add oily, acidic and metallic tastes to these five basic tastes (Spence, 2017). Kokumi, which is called the sixth taste, functions as a flavor enhancer rather than a taste, increasing the perception of other basic tastes, especially sweet, umami and salty (Yilmaz & Altuntas, 2022).

While taste is two senses perceived in the mouth and nose, flavor is much more multidimensional. Flavor identification is an ability specific to the human being among species. In this dimension, perceptual senses such as appearance, smell, sound, temperature, taste and touch interact with each other. Flavor is the sum of all senses we perceive while eating the food (Breslin, 2013; Holmes 2017).

All senses, especially the sense of smell, are effective in the sense of taste, which is an important component of the sensory mechanism. The senses influence the person's food preferences as well as wishes, working together in a multisensory framework. A person's perception of food is about the mood in the brain, the effect of memory, and the inferences obtained from the one's learning and experiences (Shepard, 2006).

The duration that allows us to know whether the food is bitter, sweet or sour is at the macro level, but the process of perceiving flavor is a variable at the micro level (Baral, 2015). Flavor arises when we engage all our sense organs. Taste is a weaker perception than flavor. The perception of flavor is about concepts such as "memory, experience and neurobiology" (Konnikova, 2016). The orbitofrontal cortex is the part of the brain that processes flavor. Apart from the sense of taste; the senses of sight, sound, smell as well as temperature stimuli are elements that support and contribute the perception of taste (Kurgun, 2017).

Over the past 17 years, the laboratories of Dr. Nicholas Ryba of the US National Institute for Dental Craniofacial Research and Charles Zuker of the Hovart Hughes Medical Institute have identified receptor cells for sweet, sour, bitter, salty and umami tastes. The information from these cells is transmitted to the taste cortex of the brain. Recent studies have revealed that sweet and bitter tastes are represented in different regions of the taste cortex (Chen et al., 2011). While chewing a food, enzymes in the saliva break down the food. As the food breaks down, the tongue papillae touch the food particles. Each papilla contains taste buds possessing 50 to 100 chemical receptor cells that describe the five basic tastes: bitter, sweet, salty, sour and umami. An adult is assumed to have 2,000 to 4,000 taste buds. Taste buds are repaired and regenerated every week. The papilla also has many sensory cells that recognize and analyze the morsel in the mouth and transmit the information to the brain by activating nerve cells. According to studies, the perception of taste takes place in the brain, not in the tongue (Baral, 2015). At this point, understanding complex brain processes that help us comprehend what, how and why we eat falls in the field of neurogastronomy.

All foods have a taste, however, the likes and dislikes of two individuals eating the same food regarding its taste are actually created in the brain. How does this difference arise between two people who eat exactly the same food? The brain is affected many factors while creating this taste. Factors such as how the person feels at that moment, whether she/he is sick, whether she/he likes that food, whether the food is too hot or too cold, and the color of the plate affect the pleasure the person receives. All these are interesting domains of neurogastronomy. Neurogastronomy brings scientists and cuisine experts together to understand how we feel before or while eating. Thanks to this concept, the idea of developing alternatives for people who have taste disorders or dietary restrictions for various reasons becomes the source of scientific studies (Michel et al., 2014).

While eating and drinking, the person experiences numerous sensations including taste, smell, touch, temperature, sight, sound, and sometimes pain/irritation. This multifaceted sensory experience forms the basis of perceived taste. However, some sensations contributes more to taste perception than others (Kurgun, 2017).

Customer expectations are formed at the moment when the food is ordered in a gastronomic facility. This is the first stage. The second stage takes place at the moment the food is served, during which the person decides the internal evaluation of the food or the restaurant in general with all her/his senses (Piqueras-Fiszman, 2012). The appearance and arrangement of the food on the plate are therefore decisive factors. Sight and followed by olfaction are the first senses enabling this decision to be made (Reisfelt, 2009). A good food presentation primarily appeals to the sense of sight (Zellner, 2011). Not only the visual presentation of the food, but also variables such as the color and shape of the plate can be effective in stimulating the desire to eat. For instance, changing the color of the plate to increase the visual contrast of the plate increases food and drink intake in a considerable extent (Kokaji & Nakatani, 2021). Carelessly prepared meals can lead to the development of the prejudice that the food is of poor quality, tasteless and non-hygienic, even before perceiving the taste of the food (Lee & Lim, 2020). Eating delicious food evokes positive emotions such as warmth, satisfaction, and relaxation (Petit et al., 2016). People are impressed by the beauty, and the same also goes for the arrangement of foods. Accordingly, guests who receive foods on the plate in an elegant style tend to claim that their food is more delicious compared to those who receive the same foods on the plate in an unattractive way (Zellner et al., 2014). The eyes are connected to the mouth via the brain, which is endorsed by the assumption that the food is more delicious and better for us, in case we like what we see (Michel et al., 2014).

In food presentation, different colors, ingredients, textures, shapes and arrangements of foods should be taken into consideration to create a pleasant combination on the plate (Styler, 2006). The perception of how food is prepared and to what extent quality ingredients are used, and good food presentation can create an indicator for food quality and appetite (Namkung & Jang, 2008). Food presentation is a way of reflecting the chef's skills to the food and also an indication of respect shown for the diners (Lee & Lim, 2020).

## 5. Effects of Food Presentation and Atmosphere on Consumption

The atmosphere of a restaurant can encourage people to eat faster, as well as lead them to overeating (Lawton, 2004). In a similar vein, an atmosphere can encourage a person to stay longer in the restaurant and order additional food (Wansink, 2004). For example, in a study, 1,400 diners have been examined in a restaurant in which instrumental music is played. It has been reported that, customers dined 11 minutes longer and spent more money on foods in the environment with music and that the money spent was much greater when slow music is played than when fast music is played (Milliman, 1986).

Fast-food restaurants are characterized by bright lights, reflective surfaces and stimulating yellow-red colors and are designed for customers to eat and leave quickly (Sobal & Wansink, 2007). In these restaurants, there usually exists reverberated music or loud sounds from customers. Some studies have shown that people dining in a fast-food restaurant eat faster and more per minute than those in a quieter restaurant (Van Ittersum & Wansink, 2012).

Lighting and noise psychologically affect food consumption and dining time directly or indirectly (Garg et al., 2007). People are less stimulated when the lights are low (Areni & Kim 1994; Lavin & Kanunsuz, 1998). Soft or warm lighting increases dining time (Scheibehenne et al., 2010). It has been found that severe or bright lighting reduces the length of stay in the restaurant, whereas soft or warm light usually causes people to stay longer (Summers & Hebert 2001).

The more disturbing the noise, the less time people stay in a restaurant (Hargreaves, 1996). This condition sometimes leads customers to eat faster. In contrast, slow music is associated with slow eating, but also with higher consumption of both foods and drinks (Caldwell & Hibbert, 2002).

The more customers like the music, the longer they stay in the dining environment (Wansink, 2004). When longer time is spent, more food such as dessert or another drink can be ordered. In general, loud music or noise has been stated to accelerate food intake in a restaurant (Stroebele & de Castro, 2004). On the other hand, soft music prolongs dining times, encourages additional consumption and leads more food to be ordered (Wansink & Ittersum, 2012). In a study examining the effect of vertical or horizontal serving of the plate on consumption perception, it has been found that even though the quantities served are the same, when the food is served vertically, that is, stacked on the plate, consumers perceive the portions as smaller compared to when the food is served horizontally, that is, evenly distributed. In addition, it has been noted that customers are more satisfied with the portion size when the food is served horizontally by spreading on the plate.

Traditionally, decisions about food plating in high-end restaurants are based on chefs' intuition and fundamental rules. The arrangement of the plate

Figure 1. Examples of asymmetric plating [Source: Zellner et al., 2014]

mostly depends on the ingredients constituting the flavor of the food and the style of the chef or restaurant. Trends regarding asymmetrical plating (Figure 1), which is one of the vertical food arrangements taking inspiration from architecture in Carême's time, preserve their place in modern food plating (Zellner et al., 2014).

In a study carried out in the London Science Museum, with the participation of 7,495 people, 65% of whom were female and 35% of whom were male, investigating the effect of plating on customers; the order of the food on the plate was demonstrated to participants in a way that there will be six different alignments, with different appearances. The results of the comparisons revealed that the plate with balanced presentation was highly preferred (Zellner et al., 2014).

It is well known that the appearance of the food, especially its color, may affect flavor perception and identification. Changing the appearance of foods can be achieved by using virtual reality (VR) technology, which has become increasingly accessible, sophisticated and widespread in recent years. VR offers researchers a new way to conduct sensory and psychological studies to explore the impact of visual information on consumer perception. In a study investigating whether making a coffee that appears milkier in a VR environment can change the perceived flavor and liking, 30 British consumers were given four samples of cold brewed black coffee at 4% and 8% sucrose concentration, served with a straw in a white mug. Participants put on VR headsets during the course of the study (Figure 2) and watched the same mug and straw on a virtual environment. The color of the beverage was manipulated in VR such that participants could see a dark brown or light brown liquid in the mug while sipping the coffee. Participants were asked to indicate sweetness, creaminess and liking for each sample. The results obtained indicated that the color of the beverage viewed on the VR display affected the perceived creaminess of the coffee; when participants were shown a lighter brown coffee by only changing the VR view of the beverage, they expressed to perceive the coffee to be more creamy. However, the color of beverage had no impact on perceived sweetness or liking (Wan et al., 2020).


Figure 2. Participant wearing a virtual reality headset [Source: Wan et al., 2020]

A study conducted to compare liking scores of chocolates with different shapes as round and squared has shown that participants rated the round chocolate as creamier/sweeter than the squared one. Shape-based food research indicates that when foods are round, preferences for these foods tend to increase, on the other hand, healthy foods are preferred when they are presented in a squared shape (Baptista et al., 2021).

In a study investigating the effect of visual presentation of food on consumer preferences, waffles prepared with the same ingredients were served in three different plates, luxuriously designed black stone plate, paper plate representing street food style and white classic plate (Figure 3). Various fruits, whipped cream, candies, white chocolate and tuile were used as waffle toppings. Biometric methods such as eye tracking and face reading were also employed in the study (Berčík, 2021). Based on the results, it can be said participants rated the visual presentation of a waffle placed in a luxurious black plate as the best. When the waffles were compared in terms of smell, the waffle served on a black plate smelled best to participants, followed by the one on a white plate. The waffle on the street plate, on the other hand, received the lowest smell score (Berčík, 2021).

The same study also noted that participants considered normal to pay a difference of about 1 Euro, when the same product is served in different plates. It was stated by participants that they would be willing to pay for a waffle an average of EUR 4.4 when served on the stone plate, EUR 3.54 on the classical white plate and EUR 3.04 on the street plate. This indicates a significant effect of the arrangement and presentation of foods on the perception of value (Berčík, 2021).

In a study exploring the effect of plate color on the desire to eat in Chinese restaurants, the consumer behavior of 581 participants has been examined. As a result of the study, gold, white and black colored plates were determined to be the colors of plates that most trigger the desire to eat. It was also reported that gold and white plates create a positive eating experience and that plate color has a significant effect on appetite (Chen et al., 2019). Red plates may cause increased appetite and thus, the presentation on red plates may increase the number of appetizer and dessert orders. Conversely, blue plates are not appetizing, as there are very few foods that are naturally blue.


Figure 3. Visual appearance of different plates on which the waffles were served [Source: Berčík, 2021]

## 6. Conclusion and Recommendations

Studies indicate that our brain perception has a structure that can be directed by transmitted data. The entrance of smell, sound, sight, taste and touch sensations to the brain in different forms results in the stimulation of different perceptions in humans. Notwithstanding that data coming from the five senses are interconnected with each other, shutting down a sense or reflecting the information coming to the sense different from the facts may cause a change in perceptions formed in the brain. In addition, the fact the brain tries to make decisions with teachings that are culturally from the past suggests that it essentially has habits and shapes the first decision making process regarding flavor with past data.

In terms of plating, people prefer balanced presentations rather than the unbalanced ones of the same components. Plate design is an important component in terms of modeling visual preferences. Also, the color and appearance of the food we eat determine our expectations for the taste of that food. The most important factors in the perception of food served to the consumer are variety, distribution on the plate and portion size, in addition to visual characteristics. Particularly in situations where it may be difficult to set the same scenario in the real world, utilizing virtual reality can be a practical approach. Moreover, the use of virtual and augmented reality will open new opportunities in the future to encourage healthy eating behaviors such as reducing fat intake.

One of the most effective aspects of neurogastronomy is the great influence of social and cultural factors on our flavor perception. By this means, chefs, scientists, artists, designers and musicians, by working together, may enable the doors to open towards developing multi-sensory experiences that engage all senses at various levels.

### Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

### Author's Contributions

P. Tokat (0000-0002-4455-2451): *Definition, Data Collection, Investigation Conceptualization, Writing, Methodology, Editing, Supervision, Investigation.*
İ. Yılmaz (0000-0001-5938-3112): *Definition, Data Collection, Investigation Conceptualization, Writing, Methodology, Editing, Supervision, Investigation.*

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# Diabetic Patients' Consumption of Diabetic and High Sugar Content Breakfast Products

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**Abstract**

Diabetes Mellitus is a metabolic disease that can cause serious damage to the human body if left untreated. High blood sugar level is among the symptoms of this disease, and nutrition therapy is very important in its treatment. On the other hand, breakfast is notable for being the first meal of the day and for containing high-sugar products in terms of nutritional content. Within the scope of the present research, a study was carried out using a semi-structured interview form in order to obtain information about the consumption trends of high sugar-containing and/or diabetic breakfast products in 19 diabetic patients and their situation of producing these products at home. In the study, it was observed that there were significant differences between the participants' tendencies to purchase, produce and consume these products regarding diabetic breakfast products. As a result, when homemade diabetic breakfast products were compared with industrial diabetic foods, it was seen that taste and consistency parameters became prominent. Rapid deterioration and maintaining these products' consistency, color and sweetness were among the difficulties encountered while preparing homemade diabetic breakfast products. It was determined that the participants used stevia, honey, molasses, dates, sweetener, carob, sugar alcohol and cinnamon as sugar substitutes, and pectin, dried nuts, dates and boiling process for thickening the product in making diabetic breakfast products at home. Websites and social media were the most common platforms where participants search for diabetic breakfast recipes. Besides, the participants also stated that diabetic product options were insufficient in out-of-home breakfast places.

***Keywords:*** Diabetes mellitus, Breakfast, High Sugar Containing Breakfast Product, Diabetic Breakfast Product.

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## 1. Introduction

Diabetes, which is medically known as Diabetes Mellitus (DM), is a metabolic disorder that develops as a result of insufficient secretion of insulin hormone, which is released from the pancreas and controls the use of blood glucose in the body, or defects due to action of insulin (Diabetes Mellitus Study and Training Group, 2014). Various types of diabetes are observed in people, and it is known that among these types, the most common ones are Type I (insulin-dependent) and Type II (non-insulin-dependent) diabetes (Yılmaz, 2010). In the course of the treatment of diabetes, sudden increase or decrease in blood glucose level needs to be avoided by following diabetic nutrition principles. In other words, sugary foods that can lead to sudden fluctuations in blood glucose level should not be preferred and consumed. Nevertheless, it has been determined in studies conducted that diabetic patients consume sugary products they should not eat in their daily diets, and that especially adult ones could consume high sugar content foods such as honey and jam (Alphan et al., 1994; Gizir, 2019; Üstel, 2013).

In the production of diabetic products, sweeteners are added into the product formulation in place of sugar, and the insufficient sweetness due to the absence of sugar is tried to be met with the sweetness that the sweetener brings to the product. Sweetening agents used in foods to replace sugar are divided into two subgroups, namely natural and artificial, and they are usually added into products not alone but in combination with other sweeteners. The use of sweeteners in food production makes the product both lower in calories in terms of energy value, and ensures that the product becomes consumable by diabetic patients (Çakmakçı & Çelik, 2004; Turkish Food Codex, No: 2006/45).

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Breakfast is one of the most important meals in the daily diet (Baysal, 1999). Products consumed during breakfast can show variation according to various factors (age, gender, physical activity, etc.) and it is stated that 15-25% of daily energy intake should be obtained in the breakfast meal (Sargın, 2019). There are numerous high-sugar content products (jam, marmalade, chocolate spread and halva) among foods to be served to consumers during the breakfast meal. It is known that diabetic patients could consume products such as chocolate spread, honey, jam and marmalade above the daily recommended level in the breakfast meal (Sami et al., 2020). This circumstance diversifies the process towards the development of breakfast products with low sugar content prepared with natural and artificial sweeteners for the consumption of diabetic patients (Carvalho et al., 2013; Demirağ & Şahin, 2012; Kaya et al., 2019). On the other hand, the tendency of diabetic individuals to stay away from products manufactured with artificial sweeteners with the consideration that they are harmful to health (Ural, 2018; Gizir, 2019) makes diabetic products prepared at home prominently. From this viewpoint, research to be conducted in the field of gastronomy regarding consumption tendencies of diabetic patients for breakfast products with high sugar content and the preparation of these products in the home setting are of importance in terms of disclosing issues that should be paid attention in the course of the preparation of breakfast product recipes suitable for the consumption of diabetic patients.

The present study aims to examine the opinions of individuals who need to consume a diet with low refined sugar content depending on DM towards the consumption of breakfast products with high refined sugar content and their diabetic forms in the breakfast meal, and to make suggestions in the field of gastronomy based on the findings.

## 2. Method

Diabetes is a disease that substantially affects the daily dietary habits of individuals. Individuals with this disease should consume products with low sugar content and have a lifestyle in accordance with the advice of health experts. For this lifestyle in question to be maintained, manufacturing low sugar content products that diabetic patients need, developing appropriate formulations and making them producible in the home setting carry an importance. Breakfast is the meal that allows consumers to be able to access many high-sugar content foods (jam, marmalade, chocolate spread, halva, etc.). In relation to that, it is important to conduct research towards examining the consumption tendencies of diabetic patients for breakfast high sugar content products and their status of preparing these products at home and their level of access to alternative formulations.

This is a descriptive qualitative study in which diabetic individuals were interviewed through a semi-structured interview form (Baltacı, 2019). The study design was approved by the İstanbul Gedik University Ethics Committee (June 14, 2021/E-71457743-050.01.04-2021.2.687). The individuals whose views were sought in the scope of the study were selected among type I and type II diabetic patients residing in the province of Istanbul. Nineteen individuals with DM (Type I and Type II) who consume low-sugar foods were reached through their dietitians using the snowball sampling method and interviewed through a semi-structured interview form. The phenomenological design was used in the research. The participants whose opinions were sought were coded as P1 (participant 1), P2, P3. The data obtained were subjected to content analysis. With this approach, it is possible to evaluate the experience of people on certain subjects (Carpenter et al., 2018). The outputs obtained as a result of the content analysis applied to the data are presented under the themes and sub-themes. Due to pandemic conditions, the data were collected via interviews by either phone or computer softwares that allow video calls. In the preparation of the semi-structured interview form, the literature search performed in the scope of the study was taken as a basis, and care was taken to develop original questions for the study's aim. The first section of the interview included questions towards obtaining demographic information, whereas the second section was prepared so that the participant can be examined in the context of gastronomy. The prepared questions were additionally reviewed by expert dietitians serving to diabetic patients.

The research questions were as follows:

1. Do you consume diabetic counterparts of high sugar content breakfast products such as jam, marmalade, etc. in the breakfast meal?

2. Do you purchase diabetic breakfast products from supermarkets or do you prefer to prepare these at home?

3. What kind of differences do you think there are in terms of sensory attributes between diabetic breakfast products you make at home and industrial products you purchase from supermarkets?

4. What are the aspects that you have difficulty in

making diabetic breakfast products at home?

5. Which ingredients do you use as sugar substitute in diabetic breakfast products you prepare at home?

6. Which ingredients do you use to increase the consistency of diabetic breakfast products you prepare at home?

7. What kind of resources do you collect information from when preparing diabetic breakfast products at home?

8. Do you think that diabetic alternatives of breakfast products are offered at an adequate level in out-of-home breakfast places?

The following issues were taken into consideration for the validity and reliability of the study (Kılınç, 2018). In order to ensure traceability and reproducibility, the data were classified under certain themes. The researchers were directly involved in the data collection process, and the views of the participants were directly quoted during the data analysis and evaluation process. The opinions of academicians working in the field of Gastronomy and Culinary Arts and expert dietitians were taken for the preparation of the interview questions and for the evaluation of the data obtained in the study. A literature review was carried out in order to deal with the subject in depth from a conceptual standpoint.

## 3. Results

Of the 19 participants with the age range of 18-62 years, five were male and fourteen were female. The study included participants from all levels of education, from primary school to graduate school. Eight participants had Type 1 Diabetes and eleven participants had Type 2 diabetes. The age of the participants when they were first diagnosed with DM was determined to be between 1 and 25 years.

In the study, three superordinate themes, namely *"diabetic breakfast product consumption", "preparing diabetic breakfast products at home", "access to diabetic products in out-of-home breakfast places"* and seven subordinate themes were identified.

### *3.1. Superordinate theme: Diabetic breakfast product consumption*

Some of the participants stated that they did not consume diabetic breakfast products, while some stated that they, although rare, could sometimes consume industrial or homemade diabetic breakfast products. It was determined that some participants preferred to purchase diabetic breakfast products, while some others preferred homemade ones. On the other hand, the participants compared industrially produced and homemade diabetic breakfast products from the sensory point of view touching very different aspects as can be seen in subordinate themes. In this context, the approaches developed by the participants for industrial and homemade diabetic breakfast products were discussed under the subordinate theme headings of "Diabetic breakfast consumption status", "preference for purchasing/production" and "views on sensory qualities".

#### *Diabetic breakfast consumption status*

When the diabetic breakfast product consumption status of the participants was examined, it was seen that three different consumption tendencies came into prominence. Some participants stated that they consumed the products in question moderately often, whereas some others indicated that they consumed them less often. Some other participants, on the other hand, stated that they did not consume diabetic products in their breakfast meal.

> *"Rarely. Sometimes, when I feel like it, I make them myself at home and consume them." (P4)*
>
> *"I only consume homemade jam 1-2 days a week." (P18)*
>
> *"I do not consume diabetic foods. I often consume their normal equivalents." (P15)*

#### *Preference for purchasing/production*

While some of the participants stated that they did not include diabetic breakfast products in their daily diets, the other participants who consume these products were divided into three subgroups: those who consume only homemade products, those who prefer only industrial products and those who consume both product groups.

> *"I both purchase them from the supermarket, and sometimes. I try to make them myself at home." (P3)*
>
> *"I do not purchase them from supermarkets; I make them at home. I put in less sugar than the regular recipe. My dietitian recommended that I do it that way." (P4)*

#### *Views on sensory qualities*

In the sensory comparison between industrial type diabetic breakfast products sold in supermarkets and those made in the home setting, the parameters of consistency and taste came into prominence, and both positive and negative views regarding the relevant sensory parameters were expressed by the participants. On the other side, although the participants were asked to make comments about sensory parameters, some discussed the subject with respect to product content and especially made negative references towards additives used in industrial type products.

> *"An artificial taste exists in those I purchase from supermarkets; but when I make it at home, I still use sugar, thus the one I make at home are much better." (P4)*

> *"The consistency and taste of those prepared at home are not always the same." (P3)*

> *"The consistency of the one I purchase from supermarkets is more like the one made by our mothers, however, the diabetic jam I make at home turns to be more aqueous. The industrial one is better." (P8)*

> *"Those in supermarkets include additives; I do not prefer them." (P5)*

> *"Additives, being sweetened with sugar analogues, additional fats, preservative substances are disturbing…" (P14)*

### 3.2. Superordinate theme: preparing diabetic breakfast products at home

The aspects the participants had difficulty in preparing diabetic products in the home setting are the inability to adjust sensory parameters of products such as consistency, color and taste as desired and the spoilage of the products they make in a shorter time compared to industrial products. In the preparation of diabetic breakfast products in the home setting, the participants made use of wide variety of products, mainly stevia, honey and molasses, as sugar substitute, and various plant products as thickening agents. In addition, it was observed that regarding access to diabetic breakfast product recipes, written resources, dietitian recommendations and personnel experiences were utilized as well as Internet-based resources. In this context, the production of diabetic breakfast product in the home setting were discussed under the superordinate theme heading of *"preparing diabetic breakfast products at home"* with the subordinate theme headings of *"problems encountered during production", "preference for sugar substitute", "consistency adjustment"* and *"access to recipe"*.

#### Problems encountered during production

The participants were understood to encounter four main problems in preparing diabetic breakfast products in the home setting. These were identified to be the inability to achieve suitable product consistency, not obtaining desired product color, inadequate sweetness level of the product and the spoilage of products in shorter time compared to industrial counterparts.

> *"Consistency and taste. Producing them similar to non-diabetic counterparts and the same at every time." (P3)*

> *"I cannot adjust its sweetness. I add less sugar." (P6)*

> *"Color and spoilage time." (P14)*

> *"I cannot know of any other ingredient to replace sugar. My dietitian also does not recommend sweeteners." (P4)*

#### Preference for sugar substitute

It was observed that some participants do not use any substitute to replace sugar and that some others mentioned the name of more than one substitute ingredient. The ingredients expressed to be used as sugar substitute were stevia, honey, molasses, dates, artificial sweeteners, sugar alcohols and cinnamon.

> *"… If I had made them, I would have preferred honey and molasses or dates." (P2)*

> *"I have tried couple of dessert recipes with stevia and carob flour…" (P18)*

> *"I do not use sweeteners. I put in less sugar than the regular recipe." (P4)*

> *"We add less sugar than the regular recipe." (P13)*

#### Consistency adjustment

The participants were determined to make references to the boiling process as well as ingredients, such as citric acid, water, pectin, cinnamon, nuts and dates, in adjusting the consistency of diabetic breakfast products.

#### Access to recipe

It was stated by the participants that they mostly utilized web pages as well as Internet-based platforms such as Instagram and YouTube to access recipes for obtaining diabetic breakfast products. On the other hand, printed books as well as dietitians also came to the forefront of accessing recipes.

### 3.3. Superordinate theme: access to diabetic products in out-of-home breakfast places

A large majority of the participants expressed that access to diabetic breakfast products was insufficient in out-of home settings where breakfast is served.

> *"For upscale places, yes; for average priced places, no; generalizing may not be appropriate. It changes depending on the price or locality and accommodation place." (P14)*

## 4. Discussion

It was determined in the study that some of the participants whose views were sought did not consume diabetic breakfast products, some others, on the other hand, consumed them moderately or rarely. The participants consuming these products were divided into three subgroups. According to this grouping, some participants preferred both homemade and industrial-type diabetic breakfast products, whereas some stated that they preferred either industrial or homemade products. In the statements of the participants who indicated to prefered homemade diabetic breakfast products, there was an emphasis on dietitian control and the fact that homemade products are healthier. It was understood that the participants who compared homemade and industrial type diabetic breakfast products in terms of sensory attributes underlined consistency and taste parameters. It was expressed that homemade diabetic breakfast products were poor in taste than industrial counterparts, whereas industrial diabetic breakfast products were sweeter but have artificial taste. Sugar used in the formulation of breakfast products such as jam and marmalade not only gives sweetness to the product, but also provides consistency and shapes product texture (MEGEP, 2011; Saldamlı, 2014). The fact that homemade diabetic breakfast products are of lower quality in terms of taste when compared to industrial counterparts results from the low sugar content present in the product recipe, as the participants also stated. On the other hand, the reason that industrial-type products have a sweeter but artificial taste is most likely artificial sweeteners used in the product formulation. This probably arises from that artificial sweeteners (eg, aspartame, saccharin) used in the production of diabetic products are substantially sweeter compared to sucrose (Çakmakçı & Çelik, 2004), thus rendering industrial-type diabetic products sweeter than homemade ones. On the flip side, the fact that artificial sweeteners give artificial sweetness characterized by metallic and bitter tastes to the product (Yılmaz, 2007) led to the participants to perceive artificial taste in industrial-type diabetic products. However, it was also observed that some participants made references to health concerns a lot while describing industrial-type products in terms of sensory attributes. Similar to the findings of Ural (2018) and Gizir (2019), it is possible to state that the tendency of the participants to stay away from products with artificial sweeteners with the view that they are harmful to health takes precedence over the sensory properties of the products in question. Taking the consistency parameter into consideration, it was concluded that the participants were not always able to achieve the same consistency in low sugar content diabetic breakfast products they made in the home setting, and that they consider the consistency of industrial products was better than that of homemade diabetic breakfast products. In the food industry, the insufficient consistency ensuing from the absence of sugar in manufacturing diabetic breakfast products can be compensated with the help of a wide variety of water-binding substances (Çakmakçı & Çelik, 2004), especially low methoxyl pectin (Üstün & Tosun, 1998), and the consistency desired by consumers can be procured. Apart from this, the insufficient consistency as a result of the deficiency of fruit-based acid, which has a role in shaping the desired consistency in jams, can also be eliminated by the addition of acid to the formulation (Cemeroğlu et al. 2003 as cited in Seymen, 2019). In this context, the addition of an acidity regulating agent to achieve the desired consistency in industrial-type products also makes these products more consistent compared to homemade ones. The most common problem that the participants experienced in preparing diabetic breakfast products in the home setting is the inability to adjust product color, consistency and sweetness. Additionally, another problem experienced with homemade diabetic breakfast products is that their shelf life is short and they spoil in a considerably short time. The poor taste of homemade diabetic breakfast products is probably due to the fact that the participants added sugar into the product recipe lower than that specified in the regular recipe and did not use suitable and enough amount of sweeteners to replace sugar. Also, the inability to achieve the desired consistency in homemade products arises from not eliminating low viscosity resulting from insufficient sugar with the use of alternative food additives and ingredients and not obtaining the acidity level needed in the home setting (MEGEP, 2011; Saldamlı, 2014; Cemeroğlu et al. 2003 as cited in Seymen, 2019; Çakmakcı & Çelik, 2004). The fact that the participants were not able to attain the desired product color in the home setting is probably due to that the participants did not have a product recipe with proper attributes. Probable reasons for the short product shelf life are the inadequacy of the heat treatment applied to the product as well as the product's water activity values not at the desired level. Water activity, which is the ratio of the water vapor pressure of the food to the vapor pressure of pure water at the same temperature, is an important parameter that gives information about whether microbial growth would occur in food. The water activity value should be kept below 0.6 in order to prevent microbial growth in a food product (Certel & Ertugay, 1996; Saldamlı, 2014). In this sense, sucrose used in the manufacture of high sugar content breakfast products increases the food microbial durability by lowering the water activity of the product. It may be considered that the desired decrease in water activity cannot be achieved due to using either no or very little sugar in homemade diabetic breakfast products. On the other side, the inability to perform acidity regulation process carried out in the industrial production in the home setting may have also led to the acidity induced microbial barrier not being achieved to the desired extent. Therefore, it is possible to state that product stabilization in industrial type diabetic breakfast products is ensured by the use of antimicrobial additives, the regulation of acidity and the application of adequate heat treatment.

It was determined that the participants mostly used stevia, honey, molasses, dates, artificial sweeteners and carob as a sugar substitute in the preparation of diabetic breakfast products in the home setting. In addition to those, it was also observed that cinnamon, sugar alcohols and fructose can also be utilized to replace sugar for the same purpose. The sugar substitutes that the participants mentioned are seen to be employed in the industry as well. Indeed, sugar alcohol, stevia, artificial sweeteners and honey, which the participants stated that they utilize, are also used in the industrial manufacture of low sugar content food products (Güneş et al., 2018; Dizlek & Giritlioğlu, 2018; Palamutoğlu et al., 2018; Kılınç, 2015; Güldane, 2014). A quantitative study carried out on 400 participants living in the province of Istanbul to investigate the sugar and sugary products consumption habits of individuals has concluded that participants made use of sweetening agents such as dates, honey and artificial sweeteners as sugar substitutes (Çiftci, 2019), similar to our findings.

The participants were observed to access the recipes for diabetic breakfast products with low sugar content mostly through web pages and social media. There are web pages with the aim of health communication where both healthy individuals and those with certain health problems follow in relation to health concerns and could get answers to their questions. On these web pages, patients can ask questions to health experts about their diseases and access informative content (Tosyalı & Sütçü, 2016). Social media is another channel in which access to food recipes is provided. The fact that social media users present food recipes they prepare enriched with photographs and video recordings in social media, experience sharing as well as the realization of communication between individuals make social media an important platform for users who are interested in special food recipes (Çaycı, 2019; Akdeniz & Temeloğlu, 2022).

Diabetic individuals have breakfast not only at home but also in food enterprises that offer services in the field of gastronomy. The participants whose views were sought in the scope of the study expressed that they had negative experiences in terms of accessing diabetic options of breakfast products in out-of home settings and that diabetic products were not at sufficient level among the breakfast product varieties offered to them. One participant on the other hand indicated being able to access enterprises with menus suitable for diabetes in out-of home settings, however complained about the expensiveness of the menus offered in these places. In parallel with our research findings, in another study in which the views of individuals with Type 1 Diabetes Mellitus on food and beverage enterprises were sought, it was reported that menus suitable for diabetic patients are more expensive than regular menus. Besides, in the same study, it was also determined that diabetic patients identify enterprises with appropriate menus through web pages or mobile applications and go there accordingly, and they do not go to places where they ascertain that the menu content is not appropriate (Gürkan & Ulema, 2020).

## 5. Conclusion

Breakfast, one of the most notable meal present in the daily diet, provides access to many products with high sugar content (jam, marmalade, chocolate spread, halva, etc.). In this context, it is of significance to conduct research in the field of gastronomy directed for the preparation of recipes of diabetic breakfast products with high stability and likability in terms of taste, consistency and color parameters and long shelf life for diabetic patients who have to consume a low sugar diet. In addition, it is also important for food and beverage enterprises that serve breakfast to include diabetic breakfast products in their menus and to annunciate these products to their customer base through their web pages or mobile applications. On the other hand, within the scope of gastronomic tourism, different countries and cities can be visited, and the products belonging to the geography in question can be tasted. In relation to that, in order to make gastronomic tourism convenient for diabetic patients, the fact that professionals trained in gastronomy and culinary arts develop diabetic forms of breakfast products belonging to their own cuisine matters. Based on the present study, the consumption of high sugar content products in diabetic individuals can be examined for other meals in addition to breakfast, and in the light of the results to be obtained, studies can be carried out to develop new recipes on a meal basis that can be consumed in the diabetes-specific diet to forestall the consumption of high sugar content products. Besides, new studies can be performed in the field of gastronomy and culinary arts towards increasing the number of culinary medicine chefs who would be able to develop special recipes for patients who have to follow a special diet due to health problems.

## Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

## Author's Contributions

E. Ercan (0000-0002-3487-4991): Conceptualization, Investigation, Methodology, Visualization, Writing-Original Draft Preparation, Editing, Resources.
B. Yalınkılıç (0000-0002-6195-7821): Data Curation, Investigation, Reviewing.

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# A Comprehensive Review on Simit, A Turkish Traditional Food

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## Abstract

Simit has an important place in the Turkish gastronomic culture. Simit, whose roots in Anatolia go back to the 14th century, strongly maintains its existence even in the smallest of places today. Contrary to many traditional foods that are on the verge of disappearance due to advancing technology and intertwined multicultural lives, simit is a noteworthy traditional product that gradually consolidates its existence both domestically and internationally. This study aims to comprehensively review and collate existing studies on simit, a topic that has received inadequate attention in the literature, and to provide a framework for future research. In this context, the definition, recipe and general specifications of simit were first explained, then. Thereafter, its historical significance was determined through the examination of historical documents pertaining to simit. The production process of simit was examined in-depth, and existing literature on various simit types was compiled. The study further explores the role of simit, which holds a prominent place in Turkish society's consumption habits, in nutrition and addresses its impact on community health based on existing data. However, owing to the limited availability of scientific documents on simit in the literature, some information was gathered from nonscientific open sources, which posed a significant limitation. The study concluded that there is a need for comprehensive scientific investigations that encompass an analytical examination of the production process of simit, its standardization, the implications of its consumption habits on nutrition and health, and an exploration of various simit types.

***Keywords:*** Simit, Turkish traditional food, Bagel, Gevrek.

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## 1. Introduction

Simit is a Turkish traditional food product characterized by its crispy texture, is made of wheat flour, potable water, salt, and baker's yeast. It has a characteristic ring shape and its surface is covered with sesame seeds (Figure 1).

Excluding sesame and molasses in simit's formulation, both simit dough and bread dough (consisting of flour, water, salt, and yeast) share similar characteristics. However, due to its thinner shape compared to bread, simit attains a crispy texture during the baking process. Another factor contributing that simit is more delicious than bread is sesame seeds on its surface. The sesame seeds on simit's surface, which are closely associated with its identity, significantly enhance its distinct flavor. Additionally, simit dough dipped into a molasses-water mixture acquires a richer aromatic flavor compared to bread. This effect is a result of non-enzymatic browning reactions that take place when simit is baked at high temperatures in the oven. Despite varying according to the type, simit with an average weight of 100 gr significantly differs from bread with its specific shape, size and weight. Apart from having unique sensory and physical properties, the cultural meaning of simit is considerably different from bread as well, which is evident in both its purpose of consumption and the social customs associated with it.

As per the Turkish Standard Institute (TSI) Simit Standard (TS 7097), simit should possess distinct sensory characteristics in terms of taste-smell, color-appearance and interior structure. The standard specifies that simit should have a maximum moisture content of 26% (m/m), a maximum salt content of 2% (m/m), a maximum insoluble ash content (in dry matter) in 10% HCl of 0.7 (m/m), and a maximum

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Figure 1. Traditional Turkish Simit
[Source: PNGWING, 2023]

acidity level (measured by the volume, in mL, of 1 M NaOH needed to neutralize the acidity of 100 g simit) of 6 mL. It also permits a maximum yeast and mold content of 3 logs in simit. Additionally, the standard dictates that simit should be of a size that can be comfortably held in hand, with a minimum width of 5 cm (TSI, 2006).

Simit was derived from the Arabic word samīd/semid, meaning "quality white flour" (Wehr 1976: 431; cited by Dikkaya, 2011). In traditional production, wheat flour is obtained by milling wheat grains.The resultant flour-bran mixture undergoes various sieving methods to eliminate the bran, yielding a whiter and higher-quality baking flour. Nonetheless, this sieving process is an additional step that increases the cost of the flour. In the 15th century narh (fixed price) records of the Ottoman Empire (Sahillioğlu, 1967, 40), flour is categorized into three groups based on the extent of bran removal: alâ, evsat and ednâ (first, second and third quality flour, respectively). Alâ (first quality) flour is used in simit production. Given the etymology of the word simit, and its context in the Ottoman Culture, it can be said that simit was "a special bread type made with white flour", however, it has evolved and acquired distinct characteristic over time.

Although the exact time and place of simit's first appearance are uncertain, Kaygusuz Abdal, a Turkish poet who lived in Anatolia (region currently within the borders of Turkey) in 14th century, mentioned simit in his poems (Table 1) (Ünsal, 2010). A kitchen notebook written in 1651 reveals that Istanbul Simit, made with

Table 1. Lines of Turkish Poet Kaygusuz Abdal who lived in 14th century, about simit ( Ünsal, 2010)

| *Original (Turkish)* | *English Translation* |
|---|---|
| "… | "… |
| Gaziler helvasından | With gazi halva, |
| Cihan dopdolu olsa | Wish the world is filled. |
| Zülbiye halkası ile | With together the zülbiye halka, |
| Simidi hem coğ olsa | Wish there is more simit. |
| …" | …" |

white flour, has been produced since the time of Beyazit II (lived between 1447 and 1512) (Şeker, 2018, 394-395; cited by Bayram, 2020, 18). The inclusion of simit in the narh records of the Ottoman Empire in 1525 indicates its popularity as a food during that period. Because, the narh records hold significance as they display ceiling prices of staple food products at the time. It is documented that simit was included in the narh records of Istanbul in 1593 (Ünsal, 2010, p.45) and Manisa in 1599 (Gökmen, 2013, 89-90). Additionally, a kitchen accounting notebook of the Ottoman Palace dating back to 1554-1555 mentions the existence of a simit oven (Emecen, 1996, 168). Based on the knowledge and information gathered from various sources, it can be stated that simit has been consumed by Turkish society since the 14th century and has been a popular food known by both the general population and the palace since at least that period.

It has been reported that simit was initially referred to as "simid-i halka" (simit in the shape of a ring), but later it became commonly known as "simit" only (Dikkaya, 2011, 74). A review of historical documents reveals that the size of simit has also evolved over time. In the early days, simit was large, resembling a wheel, and weighed approximately 432 g (135 dirhem). Subsequently, it began to be produced and sold in both large and small sizes (Dikkaya, 2011, 73-74). From the 17th century onwards, simit started being presented for sale in the size we recognize today in Istanbul (Dikkaya, 2011, 74). Ottoman records indicate that simit was produced in various forms, including İstanbul Simidi (Istanbul Simit), Saraylı Yağlı Simit (Palace-Style Buttery Simit), Saraylı and Katmer Simit (Palace-Style Layered Simit), Hurde Halka Simit (Small Ring Simit), Hurde Halka Simit Yağlı (Buttery Small Ring Simit), Yağlı Simit (Buttery Simit), and Simid-i Kandil Çörek (Kandil Simit or Kandil Simit Ban) (Gökmen, 2013, 74). In fact, today it is possible to encounter numerous types of simit across different cities.

In his travel book, Evliya Çelebi, who lived in the 17th century and was the most famous traveler of the Ottoman Empire, noted that simit was made in Balkan

Geography apart from Istanbul, this simit was called "gevrek (crispy)" (Dikkaya, 2011, 76). Simit still maintains its existence in Balkan countries today, and it is referred to by "gevrek" or words derived from gevrek. It is named as Gevrek in Bulgaria, Gjevrek in Macedonia, Devrek in Bosnia-Herzegovina, Djevrek in Serbia, and both physical appearance and production process of these simits are very similar to today's Istanbul simits. However, only in Greece, simit is called "Koulouri", distinctly from gevrek. All these said Balkan countries were within the borders of Ottoman Empire in Evliya Çelebi's time (17$^{th}$ century). The facts that the origin of simit in Turkish culture dates back to the 14th century and in most of the Balkan countries, simit is called with a name derived from the Turkish word "gevrek", which has meanings such as "fresh" or "crisp", may be due to that the simit culture in Balkan countries is of Turkish culture origin. The presence of dozens of simit types with unique appearances and tastes in different cities indicates that simit is a very suitable food to be produced in different formulations. Thus, it is not unreasonable that these products, which are called as "koulouri" in Greece, "sesame kaak" in Lebanon, "bokhegh" in Ermenia and "covrig" in Romania and are very similar to simit, are also of simit origin.

Sesame seeds are extensively used in the surface of the traditional Turkish simit. If it is just called "simit" without any addition to its name, "simit with sesame" is referred and it is understood as such by everyone. On the other hand, there are also some local cultures in Anatolia where sesame free simit is produced. These simits are popular in cities such as Rize, Giresun and Kastamonu. Although it is a common characteristic that simits produced in those cities are sesame-free, the simit type produced in each city has different production process and flavor, some even have geographical indications belonged to their own regions. Sesame-free simits in these regions are named as Kel Simit (Bald Simit), Kuru Simit (Dry Simit), Kabak Simit (Bare Simit) or Sade Simit (Plain Simit).

In addition to being different from other simit types by not including sesame seeds, sesame-free simits differ from others in terms of dough firmness, the way wick shaped dough is bound, shiny and sesame-free surface and rigid structure (Çelik-Yeşil and Akkuş, 2022). The absence of sesame seeds in sesame-free simits makes them less expensive compared to other simits (Başaran, 2017).

The aim of the present study is to evaluate general properties, history and cultural characteristics, types, production process and place in nutrition of simit, an important Turkish traditional food. In the preparation of this review study, all types of sources, scientific or nonscientific, were thoroughly scanned and sorted using a systematic method. This review article is an attempt to reveal an extensive and objective evaluation of simit based on literature search and personal experiences.

## 2. Simit Production

### *2.1. Ingredients*

The main ingredients used in the production of simit are simit dough made of flour, water, salt and yeast as well as molasses and sesame on its surface. The most essential component in the production of simit is its dough. Therefore, simit dough is a significant factor affecting the quality, taste and textural structure of simit, and its formulation may vary among simit types. The variety of wheat from which the flour used in simit dough is obtained, protein content and quality of flour and its ash content substantially affect simit dough. Low ash content in flour is crucial as it reflects the tradition of using white flour for simit production from past to present and enhances the functional properties of the dough. Bread wheat flour should be used to create desired simit dough. The drinking water included in simit formulation should be of medium hardness, and salt content should be limited to a maximum of 2% in the final product. Baker's yeast is usually used for leavening of simit dough, however in certain simit types, chickpea yeast (Manisa simit, Nevşehir simit), even carbonate (Osmaniye simit) can be utilized as exceptions.

Molasses, another key ingredient in simit production, is a Turkish traditional food product obtained from sugary fruits. In the production of molasses, fruits are broken down; their sugary juice is extracted and concentrated. The flavor and properties of molasses can vary based on the raw material they are produced from. In the production of each different simit, different molasses obtained from regional sources is used. Grape molasses is the most commonly used in simit production, but molasses from mulberry, apple, or pear are also used in different regions.

Sesame seeds on the surface of the simit significantly influence its flavor. The properties, quality and quantity of sesame seeds used are important in the formation of distinctive features of the simit type. Sesame seeds, which are usually high in fat, are typically used after being roasted. However, as mentioned earlier, sesame-free simit types are also available.

In addition to these ingredients mentioned, (as an exception) oil, butter or sugar can be incorporated to simit dough and black cumin, poppy seeds, sunflower seeds etc. can be sprinkled on its surface, apart from sesame seeds.

### *2.2. Production process*

Simit production process is presented in Figure 2.

#### *2.2.1. Preparation of simit dough*

The initial step in simit production involves the preparation of the simit dough. Specific quantities of flour, water, salt and yeast are mixed to form the dough. The proportions of these ingredients can vary depending on the type of simit, but simit dough is generally firmer than bread dough. The simit dough is formed after a process of kneading and fermentation. Unlike bread dough, less yeast is used in simit dough, and the fermentation process is shorter. An overuse of yeast in simit dough can lead to a product that is soft rather than crispy, which is not a desired characteristic for simits.

#### *2.2.2. Shaping*

The firm simit dough is first divided into lumps, and then rounded and given a cylindrical shape, known as "wick" (fitil), in a thickness that is usually close to that of a rolling pin. In the next step, the characteristic shape of simit is acquired by binding the edges of dough in the form of a ring. The ring shape can be achieved with a single wick or by spiraling a double wick together.

#### *2.2.3. Preparation of molasses solution*

Molasses solution is a mixture created by mixing molasses and water in specific proportions. Grape molasses are commonly used in the preparation of molasses solution, however, in certain regions, different molasses are also seen to be employed. The preparation of the molasses bath can be based on brix values or mixing proportions. In some regions, no water is added to molasses; instead, it is mixed with sesame seeds and applied to simit dough with a brush. Recently, there exists a secondary method for creating molasses solution. This method involves caramelizing sugar at high temperatures, followed by dilution. In addition to being more cost-effective, this technique is crucial for creating a crispier surface on the simit. Recently, this method has been employed as an alternative in many simit varieties.

#### *2.2.4. Molasses application*

The shaped dough is subjected to molasses application. This process involves immersing the simit dough in a molasses solution or covering it with the mixture. In some simit production methods, instead of molasses solution, pure molasses is directly used (by applying with a brush) or mixed with sesame seeds. The temperature during the molasses application process is a critical factor. Molasses application can be conducted in three

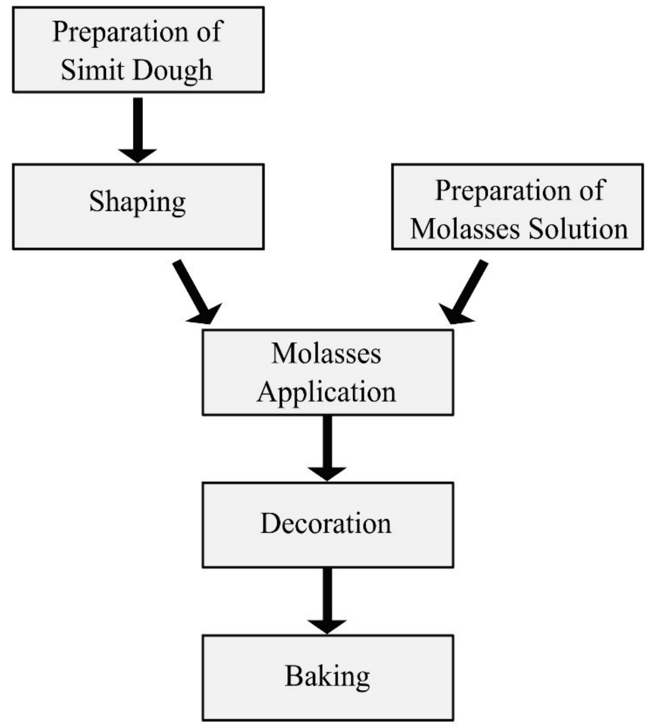


Figure 2. Simit Production Process

different ways: hot (or boiled), warm or cold. For example, simit dough is dipped into hot molasses solution in Izmir simit (hot molasses application), it is dipped into warm mixture in Ankara simit (warm molasses application) and cold mixture in Istanbul simit (cold molasses application). Hot molasses application also serves a pre-cooking process.

#### *2.2.5. Decoration*

When simit is mentioned, the first thing that comes to mind is sesame seeds on its surface. Unless specified otherwise, simits' surfaces should be covered with sesame seeds. After molasses application, the surface of simit becomes capable of holding sesame seeds. In the decoration step, according to the production process of simit, it is ensured that the surface of the dough is covered with sesame seeds. On the other hand, if different condiments (black cumin seed, poppy seed, etc.) are used in place of sesame seeds, they should be added in this step. In the production of Kel Simit (simit without sesame seeds), simit doughs are placed in simit tray without the addition of sesame seeds.

#### *2.2.6. Baking*

After placing simit dough in simit tray (simit tavası), the final step is baking. In the baking process, the type of oven, oven temperature and baking time vary based on the type of simit. In the case of hot molasses application, since simit dough is partially boiled, the oven baking time is reduced. Additionally, the type, thickness and size of simit also play a role in determining the appropriate baking method.

### *2.3. Fundamental differences in the production of different simit types*

Since simit is produced in different regions of Türkiye with the use of different ingredients and different production processes, simits come in very distinct flavor. The multiple distinctive characteristics of different simit types can be attributed to the following differences in the process and ingredients:

**Dough composition:** Flour, water, salt and yeast are generally used in simit dough as in bread dough. The properties of the flour preferred, the type of yeast and the amount of water added may substantially change simit dough properties. Moreover, the inclusion of butter or vegetable oils, sugar addition or no addition of salt considerably affect simit dough properties.

**Fermentation:** The most significant factors influencing the fermentation of simit dough are the fermentation method, type and quantity of yeast, processing time, temperature and dough properties. In the production, only small amount of yeast is used in some simit types (as in Samsun simit), whereas chickpea yeast (as in Manisa simit) and carbonate (as in Osmaniye Simit) can be used in others. Furthermore, the fermentation time is short in the production of some simit types (Samsun simit). The properties of simit may also change in a considerable extent based on the fermentation process.

**Physical shape of simit:** Simits possess various physical forms such as thick/thin, flat/round, single wick/double wick, heavy/light and small/large. Although simit dough is similar to bread dough, its thin and crispy texture is one of its most important features that make simit distinctive.

**Preparation of molasses solution:** Molasses obtained from different fruits can be used in simit production. Besides, mixtures with varying proportions of molasses and water are utilized. Sometimes, various sugars in place of molasses can be utilized for this purpose as well.

**Molasses application (molasses solution dipping):** The temperature during the step where simit dough is dipped into the molasses solution significantly influences the final product. In certain production types such as Izmir and Samsun simits, the dough is dipped into boiling molasses solution. This step, which is denoted as a pre-cooking, imparts a distinctive characteristic to these types of simit, distinguishing them from others. In molasses application, in addition to process temperature, the source of molasses, brix of molasses solution and process time are other factors affecting the properties of simit.

**Condiment type**: Sesame seeds are used as condiment on the surface of simit in the production of simit. On the other hand, sesame-free simits, which are called Kel Simit, are produced in some regions, and the absence of sesame seeds significantly impacts their taste. In some specific simit types, black cumin seed and poppy seed are used instead of sesame seeds.

**Baking method:** Simits are typically baked in the oven. The properties of simit may vary based on the oven type, baking temperature and baking time. Furhermore, the use of hot molasses application as a pre-cooking treatment also significantly influences the baking process and becomes a factor effective on the flavor of simit.

## 3. Simit Types

As simit has a significant place in Turkish culture, its production and consumption are prevalent even in the smallest towns throughout Anatolia. In this extensive supply-demand network, simit makers produces unique simit types according to their own taste; there are, therefore, dozens of different simit types in the country. As a result of this diversity, clearly classifying all the types of simit produced in Turkey can be quite challenging. However, in Turkey, simits are typically differentiated based on several main criteria. These encompass the baking method used in its production, the place where it is sold, and the city where it is produced.

According to the baking method, simits are classified into three types: Taban Simit (Flat Simit), Tava Simit (Tray Simit) and Kazan Simit (Boiler Simit) (İlerigiden et al., 2020). In the production of Taban Simit, the product that is thrown by a baker's peel into the oven heated with wood, much like bread, is baked on the hot oven floor. This simit is baked directly on the floor of a stone oven. Simits baked in trays are called "Tava Simit". Simits are placed on trays that are known as tray, and baked in ovens with 4 or 6 shelves equipped with natural gas or electric steam blowing system. The production of Kazan Simit, on the other hand, is based on the method in which before baking, shaped simit doughs are dipped into boiling molasses solution and slightly precooked in a boiler.

According to the location of sale, simit can be categorized into two types: Street Simit (Sokak Simidi) and Patisserie Simit (Pastahane Simidi). Street Simit are recognized for their unique preparation in stone ovens, typically powered by wood fire, and their distinctive crispy texture. The dough of street simit typically consists of weak flour (1kg), water (0.5L), salt (30g), and yeast (10g), and they are commonly baked in a stone oven. In contrast, Patisserie Simit are baked in electric ovens. The dough for the patisserie simit is comprised of flour (1kg), olive oil (100 g), sugar (80 g), salt (30g), yeast (15 g), and water (350 g). Due to their dough composition, patisserie simit tend to be softer than their street counterparts.

In the most commonly used classification method, simits are named according to the city where they are produced. Since simits produced in different cities have different properties, which city's production method is used in the production, simits are called with the name of that city. The most important reason why the city where simit is produced is so effective in the name of the product can be explained by the fact that people in each region prefer their own simit and seek this taste. In addition, many cities have gone beyond calling their own simit with its characteristic name, they supported this situation by receiving geographical indication for their product. According to the Turkish Patent Institute (TPI)'s data, simits with geographical indication are Samsun Simit (2013), Ankara Simit (2017); Manisa Taban Simit (2018), Rize Simit (2019), Kastamonu Simit (2019), İzmit Simit (2019), Nevşehir Simit (2020), gevrek (İzmir simit) (2021) and Eskişehir Simit (2022). Istanbul simit, which is the most widely produced simit in Turkey, does not have a geographical indication. The best-known regional simits are Ankara simit, Izmir simit (Gevrek), Istanbul simit, Manisa simit, Kastamonu simit, Rize simit, Samsun simit, Devrek simit, Antakya simit and Osmaniye simididir. The best-known regional simits in Türkiye are Ankara simit, Izmir simit (Gevrek), Istanbul simit, Manisa simit, Kastamonu simit, Rize simit, Samsun simit, Devrek simit, Antakya simit and Osmaniye simit.

### 3.1. Ankara Simit

Ankara Simit is known to be a simit type that is thinner, smaller, richer in molasses and darker compared to other simit types produced in Türkiye. Molasses-water mixture used in the molasses application is prepared by mixing grape molasses with water, and its brix value is adjusted to 50-60 °B. The ring shaped simit dough is dipped into warm molasses-water mixture (45-50°C). Ankara simit has quite crispy properties due to the fact that there is no oil in its dough and it is cooked thoroughly at 250-270°C. The final weight of Ankara simit is about 60 g. In the production of Ankara simit, wheat flour + water (87%), baker's yeast (*Saccharomyces cerevisiae*) (1.7%), salt (NaCl) (maximum 1.50% in dry matter), grape molasses (0.60%) and roasted sesame seeds (9.20%) (Geographical Indication: December 05, 2017). In a study by Şenol (2004, p. 96), Ankara simit was reported to have the external diameter of 12.4 cm, the internal diameter of 7.6 cm, the thickness of 2.4 cm, the height of 2.1 cm and the baking loss of 12.3%; and L, a and b color values were determined as 62.0, 6.2 and 8.1, respectively. Ankara simit is darker in color compared to other simit types. This can be associated with both the dark color of molasses and the browning of reducing sugar in molasses during baking depending on the high molasses content of the surface of simit. On the other hand, in one of the districts of Ankara, Beypazarı, another simit type called as Beypazarı simit, which has its own specific properties, is produced. This simit resembles to Antakya simit rather than Ankara simit.

### 3.2. İzmir Simit (Gevrek)

İzmir Simit, Gevrek, is one of the simit types that received geographical indication registration. Simit, which is produced with different taste and methods in different places in Türkiye, is named as "Gevrek" in Izmir. "Gevrek" is a Turkish word and is expressed in the dictionary of Turkish Language Association as "(the thing that is) easily broken and crumbled" and "a type of pastry that is prepared to disintegrate easily in the mouth" (TDK, 2023). In many regions, simit sellers are asked whether "their simits are crispy (gevrek)" to make sure the freshness and crispness of simit, and simit is identified with its crispy property. After all, we are in the opinion that the word "gevrek" is in fact an adjective and turned into a name afterwards. Yildiz (2020) asserted that Izmir Gevrek is of Balkan origin considering the large number of Balkan immigrants living in Izmir and the fact that simits are called as "gevrek", "gjevrek" or "djevrek" in many Balkan countries; however, we disagree with this view, and in the light of historical facts, we believe that the naming in the Balkans is of Turkish origin.

In the preparation of Izmir simit dough, 100 kg wheat flour, 40-50 L drinking water, 600-700 g salt and 1-1.5 kg baker's yeast (*Saccharomyces cerevisiae*) are used. Molasses solution is prepared by mixing one liter molasses in 6.57 L drinking water. Ring shaped simits are dipped into boiling molasses solution and held for 0.5-1 minute, and then they are baked at 280-300°C for 12-15 min. The weight of the finished product is about 100 g (Geographical Indication: September 28, 2021)

### 3.3. İstanbul Simit

İstanbul Simit is a simit type without a definite standard and does not have a geographical indication registration.

The dough that is prepared by mixing flour, water, salt and yeast is rolled to thin and double twisted wicks and given a ring shape. In Istanbul simit, cold molasses application is used, then doughs are taken to the vat filled with sesame seeds, covered abundantly with sesame seeds on all sides and left to rest for a while. At the final step of the production, simits are baked in a stone oven at high temperature after correcting their shapes for the last time.

The features that distinguishes Istanbul simit from other simit types are the application of cold molasses, abundant sesame seeds on the surface, twisted double wick shape and the baking in hornbeam wood fired stone ovens. The aim in cold molasses application may be related to the desire to bake the product in the oven, rather than in the boiling step. Indeed, one of the factors providing the taste of Istanbul simit is the fact that it is baked in stone ovens.

### *3.4. Manisa Simit*

Manisa Simit (Manisa Taban Simidi), one of the simit types that have received geographical indication registration, is a simit type specific to Manisa. It is produced and consumed in Manisa, some districts of Izmir and surrounding cities. In these regions, this simit is also called as Taban Gevrek (Taban Gevreği). While it used to be widely consumed in Izmir, the neighboring city of Manisa, its popularity has decreased in the city center of Izmir in recent years (Yentürk, 2018).

Manisa Simit is thicker with narrower middle space than traditional Turkish simit. In addition, Manisa Simit has a flat structure flat structure. As per the geographical indication standard published by TPI, Manisa simit must have the width of 18-23.5 cm, the side height of 2-4 cm and the middle space of 5-7 cm. Although, TPI simit standard (2006) specifies the maximum moisture content of simit to be 26%, the moisture content of Manisa simit varies between 38% and 42%. Manisa simit can be likened to the "bagel", famous in the USA and Canada, with both its appearance and high moisture content.

Chickpea yeast is the most decisive factor in its production and provides the characteristic taste of Manisa Simit. Small chickpeas are usually used in the preparation of the yeast mixture, whose composition includes milled chickpea (50-60%), sufficient amount of water (30-40%) and salt (3-5%). Milled chickpeas and salt are added into boiling water; the mixture is cooled down to 35-45 °C, and chickpea yeast is obtained after six hours of fermentation at that temperature (Geographical Indication: May 07, 2018).

Unlike traditional simits, Manisa Simit is produced with the use of flour (40-60%), water (30-40%) and chickpea yeast (8-10%). Since salt is used in the preparation of chickpea yeast, no additional salt is needed in dough making. Due to chickpea yeast in its composition, it has a little sweeter taste and whiter internal structure than other simits. After the dough is given ring shape, it is boiled in boiling water for a short time (5-10 s). The boiled simit doughs are laid on the tray containing previously prepared sesame seeds with molasses and it is ensured that sesame with molasses adheres to one surface of simit. Molasses is important for both sticking of sesame seeds to simit and giving color to its shell. In the final step of the production, simit is baked at 180-200 °C for 10-15 min (Geographical Indication: May 07, 2018).

### *3.5. Kastamonu Simit*

Kastamonu Simit was registered as geographically indicated product by Kastamonu Municipality in 2019. The dough of this simit, which is prepared by mixing 100 kg wheat flour, 55-60 kg water, 1-1.5 kg salt and 1 kg baker's yeast is firmer than bread dough. After being kneaded, the dough is rested for 20-25 min, shaped, sweetened in boiling molasses-water mixture produced with the use of apple or grape molasses and baked in the oven. Since Kastamonu simit is sesame-free, it is also called as Kel Simit (Bald Simit), Sesame-Free Simit or Sade Simit (Plain Simit). One of the features that distinguishes Kastamonu Simit from other simit types is its sesame-free and shiny appearance (Çelik-Yeşil & Akkuş, 2022).

### *3.6. Rize Simit*

In the production of Rize simit, one of the simit types registered with geographical indication, the dough obtained by flour, water, salt and yeast is cut in pieces weighing about 65 g, rolled into a flat wick and given its unique shape. Afterwards, simit doughs are boiled in boiling water for 1-2 min and rested on benches called "pasa" for 5 min. They are then dipped into a container with cold molasses-water mixture to make them sweetened. After removal from the container, the doughs are laid on benches, rested for a while and baked. Rize simit is a traditional food product widely sold in bakery shops, grocery stores and peddlers. It has a firmer structure than other simits. Despite its similarities with other Kel Simits (Bald Simits), it is marketed in the name of "Rize Simit" in e-commerce sites in which traditional products specific to Rize are sold (Başaran, 2017; Apak, 2022; Geographical Indication: November 15, 2017).

### 3.7. Samsun Simit

"Samsun simit" is a type of simit that has been granted geographical indication by the TPI. For the preparation of its dough, 100 kg flour, 60 L water, 1.4 kg salt and 1 kg yeast are used. The dough is stiff and firm. Samsun simit is a simit type that contains less yeast and has short fermentation time. Following the kneading process, the dough should be rested for 15-20 min. Wicks (50-80 g) in the thickness of 2.5 cm are given simit shape. Molasses-water mixture made by grape, mulberry, apple and pear molasses is prepared for the hot molasses application. Simit doughs are immersed in the molasses-water mixture boiling at 100 °C and boiled for 1-2 min. Afterwards, they are removed from the boiler and placed to a perforated container (ilistir). Following the procedure to cover the doughs with sesame seeds, they are baked at 270°C about 6 minutes. The fact that Samsun simit contains much more sesame seeds than other simit types constitutes its characteristic feature. For 100 kg flour, approximately 6 kg molasses and 20 kg sesame seeds are used (Geographical Indication: September 09, 2013).

### 3.8. Devrek Simit

Devrek simit is made in Devrek District of Zonguldak and genuine to that region. Its dough includes sugar and sunflower oil in addition to flour, water, salt and yeast. After simit doughs are shaped, they are boiled in boiling mulberry molasses, placed on trays and covered with sesame seeds and baked in the oven at 200 °C. The most prominent feature of these simits is that they are lighter in color and thicker than regular simits. An oven built in 1911 played a very important role in making Devrek simit famous. However, the history of Devrek simit goes back much further (Devrek Newspaper, 2021).

### 3.9. Antakya Simit

Antakya simit stands out with its large size (about 20cm) compared to traditional simits. Its dough is prepared with flour (100 kg), yeast (1 kg) and sufficient amount of water, however, no salt is added. The firm dough obtained is divided into wicks weighing about 80 g that are given the shape of simit. Afterwards, they are dipped in molasses-water mixture, covered with sesame seeds and baked in the stone oven. Since it is a salt-free simit, it is sold with cumin-salt mixture in small pouches. Antakya simit is traditionally consumed by dunking cumin-salt mixture along with ayran (Hatay Province Culture and Tourism Directorate, 2023).

### 3.10. Osmaniye Simit

The dough of Osmaniye simit is prepared with flour, water, salt and carbonate. After resting for a while, the dough is shaped and covered with sesame seeds and sugar in a tray. Afterwards molasses-water mixture (in half shares) is applied with the help of a brush and baked in the oven until brown. The use of table sugar in the production of Osmaniye simit ensures that its surface turns red and its taste becomes sweeter. Regionally, Osmaniye simit is consumed with turnip juice. For people living in the region, simit and turnip juice are integral duo (Osmaniye Governorship, 2023). The use of sugar and carbonate in the preparation of Osmaniye simit is a distinct feature that differentiates it from traditional simit.

### 3.11. İzmit Simit

"Izmit Simit" is a type of simit that has been granted geographical indication by the TPI. The dough for this simit is prepared using 100 kg of flour, 44 L of water, 1.8 kg of salt, and 0.8 kg of baker's yeast yeast. The dough is then divided into 120-gram portions. From each portion, two 30 cm long wick, each weighing 60g, are created. These wick are first twisted around each other to form a spiral, then their ends are joined to create a ring. Molasses solution is prepared by mixing grape molasses (comprising 60-70% of the mixture) and water (30-40%). After the simit undergoes a cold molasses application, it is coated on all sides with sesame seeds. Following a resting period of 20 minutes, the simit dough is baked in a stone oven at 275°C for 7-8 minutes. The distinctive characteristics of the Izmit simit include its double spiral structure, cold molasses treatment, abundant sesame seeds, and a texture that is crispy on the outside while remaining soft on the inside (Geographical Indication, September 10, 2018).

### 3.12. Eskisehir Simit

Eskisehir Simit is a type of bagel that has been granted geographical indication by the TPI. The dough for this simit is prepared using 100 kg of flour, 40-50 L of water, 1.5 kg of salt, and 1.5-2 kg of baker's yeast yeast. The dough is kneaded for 15-30 minutes, then allowed to ferment for an additional 15-30 minutes before being divided into 110-120-gram portions. From each portion, two wick, each 30 cm long, are created. These wick are twisted around each other to form a spiral, with their ends then being joined to create a ring. A molasses solution is prepared by mixing fig molasses (1.8L) with water (30L). Eskisehir bagel is known for its abundant sesame seeds, with local craftsmen believing that the fig molasses helps to better adhere the seeds to the bagel. The bagel dough is boiled in the molasses water at a temperature of 80-100°C for 15-60 seconds, resulting in the so-called 'hot molasses' process. Afterward, 10-15 grams of sesame seeds are added to each bagel. The bagel is then baked in a stone oven, heated with oak wood, at 260-270°C for 10-15 minutes. The baked Eskisehir simit weighs approximately 100 g. The defining characteristics of the Eskisehir simit include its double-twisted structure, the abundance of sesame seeds on its exterior, and its texture, which is crispy on the outside and sufficiently firm on the inside (Temizkan et al., 2021; Geographical Indication, 2022, 4 April).

### *3.13. Other simit types*

In different regions and cities, there may be minor and major differences in the ingredients used in simit and/or its production process. These differences have allowed the production of numerous simits with varying flavors, and the development of new simit types is still ongoing. For example, softer and more aromatic Tereyağlı Simit (Buttery Simit) can be obtained by adding butter into simit dough. As simit is widely consumed with cheese, Kaşarlı Simit (Simit with Kashar Cheese) has been developed. Moreover, different food ingredients are added into simit to create new types and its shape can also be altered to facilitate its production.

Simits with unique flavors are widely produced by sprinkling various alternative condiments such as black cumin seeds, poppy seeds and sunflower kernels on the surface of the product, other than sesame seeds. However, in the case where any condiment other than sesame seeds is used in simit, the ingredient used should be specified in its name. For example, simits covered with black cumin are named as “simit with black cumin”, and those with poppy seeds are called “simit with poppy seed”. If there are no sesame seeds or any other covering materials on simits’ surface, these simits are called “Sesame-Free Simit” or “Kel Simit (Bald Simit)”. The fact that simits with no covering material are defined as “sesame-free” is indeed a significant indicator of the importance of sesame seeds for simit.

Even though the word “simit” is present in the name of “Nevşehir simit”, which received geographical indication registration in December 07, 2020, it carries very different properties from traditional simits in terms of both appearance and taste. Nevşehir simit is produced in a shape close to rectangular with rounded edges, unlike the shape of simits produced in other regions of Türkiye. Furthermore, chickpea yeast is employed in dough fermentation. This chickpea yeast is prepared with a method similar to the production of chickpea yeast used in Manisa simit, without the addition of salt. Simit dough is made with wheat flour, water and chickpea yeast. The shaping of the product is performed on a marble bench. A mixture known as “simit yüz suyu (simit surface water)” is utilized instead of molasses-water mixture. This mixture is prepared by blending 20-30 g flour, sufficient amount of water and one egg or a table spoon of grape molasses, boiling for 10 min and diluting with water. “Simit yüz suyu” is applied to the surface of simit dough before they are baked in the wood-fired oven at 180-200 °C for about 10 min. The shelf life of Nevşehir simit varies 7-10 days. The taste of Nevşehir simit, which is known as “bensimet” and “besimet” in the region, is more akin to bread than to simit (Geographical Indication: 2020, December 07; Ahiler Kalkınma Ajansı, 2020: 55)

Another traditional simit type is “Kandil Simit” that is made specific to kandil nights, which are religious rituals in Türkiye, and sold in the shape of small rings in boxes. Although its name and shape (the size of kandil simit is much smaller than regular ones) resemble simit, kandil simit is in fact a type of pastry. As a tradition emanating from the Ottoman period, kandil simit is brought as a present to houses or family elders visited on kandil nights. Kandil simits are produced and consumed in two types: those topped with sesame seeds and those with black cumin seeds. Their shelf life is longer due to the fact that they are crunchier and drier.

## 4. Simit and Nutrition

Simit has a special place in Turkish gastronomic culture. It can be enjoyed individually or paired with a variety of foods such as cheese, jam, honey, and chocolate spread during breakfast, teatime, or while travelling. Having an important place especially at breakfast in Turkish cuisine, simit can also be consumed at other meals, or as an intermediate snack. Traditionally regarded as a street food, simit has recently gained popularity in coffee shops.

The consumption of simit quite prevalent in Turkish society. According to the report published by the Ministry of Health of Türkiye (2019, 101), among the countyr’s residents, 5.1% consume simit everyday, 46.4% at least once a week, 64.7% at least once a month, whereas the proportion of the population who never consume simit is 20% (Table 2).

Table 2. Bread and simit consumption habits of people in Türkiye (The Ministry of Health, 2019; p. 101)

| *Consumption frequency* | *Simit (%)* | *Bread (%)* |
|---|---|---|
| 6-7 times per week | 5.1 | 72.1 |
| 4-5 times per week | 3.7 | 3.9 |
| 2-3 times per week | 16.8 | 5.7 |
| Once a week | 21.0 | 3.5 |
| 1-3 times per month | 20.4 | 2.5 |
| Less than once in a month | 15.3 | 2.6 |
| Never | 20.0 | 9.5 |

The nutritional composition of simit, a food rich in carbohydrates is presented in Table 3. Although simit mainly contains carbohydrates like bread, sesame seeds on its surface change its nutritional composition and energy content, because sesame seeds includes high quantity of fat (55%), protein and cellulose (Kalita et al., 2014). As such, the inclusion of sesame seeds significantly contributes to the increase in the fat, energy, and dietary fiber content of simit.

Table 3 also illustrates the nutritional composition of bagel, a staple food widely consumed in the USA and Canada, alongside that of the simit. However, it is crucial to note that there are numerous simit and bagel types. One of the most discerning factors in comparing simit and bagel is that the moisture content of simit is substantially lower than that of bagel. Moreover, simit, which has a high sesame content, is also quite high in energy, fat and dietary fiber contents compared to bagel. The protein and ash contents in both products have been reported to be roughly similar. A medium size simit, which we often consume in our daily life, weighs about 100 g and contains approximately 342 kcal of energy. In this regard, simit can be regarded as an energy-dense food.

While simit can be enjoyed at any mealtime, it is predominantly favored at breakfast. For Turkish people, simit-tea, simit-ayran and simit-cheese-tea combinations are relished and serve as alternate breakfast options. Although simit is often chosen as a standalone breakfast substitute in Turkish dietary culture, it is clear that this consumption is insufficient for a balanced and adequate diet. Furthermore, it should be noted that substituting breakfast foods with only simit, a carbohydrate-laden food, results in a protein-deficient breakfast option. However, when paired with the right breakfast food choices, consuming simit as the central component of breakfast could contribute to a balanced diet.

Studies investigating nutritional habits of students indicate that simit is widely used as a breakfast substitute. Simit provides a practical and cost-effective alternative for students to have breakfast or any other meal. In studies conducted on this subject, it was found that simit is prevalently consumed by both primary education students (Şimşek et al., 2009) and university students (Sıtkı et al., 2006) with one out of every 3-5 students opting for simit instead of a traditional breakfast. Ünlüsoy (2017) reported that half of university students consume simit as an alternative to breakfast at least 1-2 times per week. Individuals who spend significant portions of their day away from home are observed to have a higher tendency to consume simit.

Table 3. Nutritional Composition of Simit and Bagel

| *Nutritional element* | *Nutritional composition** | |
|---|---|---|
| | *Simit (%)* | *Bagel (%)* |
| Moisture (%) | 19.6 | 33.8 |
| Total lipid (fat) (%) | 8.8 | 1.2 |
| Protein (%) | 10.1 | 10.6 |
| Carbohydrate (%) | 59.4 | 52.4 |
| *Dietary Fiber (%)* | 3.7 | 1.6 |
| Ash (%) | 2.1 | 2.0 |
| Energy (kcal) | 342** | 264 |

* Nutritional compositions of simit and bagel were respectively reported by (Ergun, 2014: 39) and USDA (2023) for bagel. **Energy content of simit was calculated based on its nutritional composition by BeBiS software.

On the other hand, it iss critical to remember that solely consuming simit would not suffice to meet the needs of an adequate and balanced diet, particularly for students in the developmental age.

One key factor that contributes to simit's appealing taste is its browned surface. Considering its production process, the reducing sugar content on simit's surface is substantially increased due to the application of a molasses-water mixture before baking. The sugars derived from the molasses on simit's surface result in product browning under high oven temperature conditions. The characteristic color and aroma that develop on simit's surface during this browning process are largely attributed to the non-enzymatic Maillard reaction. After the Maillard reaction, there may be losses in certain components such as amino acids and fatty acids, whereas some compounds including hydroxymethylfurfural and acrylamide (Başlar et al., 2022). Consequently, it is crucial to thoroughly evaluate the health implications of simit production.

## 5. Conclusion

Renowned and widely consumed in Turkish culture, simit has been a staple food product in Anatolian geography for centuries. Despite being enjoyed by a significant portion of the population, there is a limited body of scientific research concerning simit in the literature. However, simit is not a mere commercial food, it is also a cultural symbol. Although there have been attempts to standardize simit production through geographical indications over the past decade, it was determined that the current documentation is still insufficient. Furthermore, simit, boasting substantial commercial potential and entrenched as a societal habit over centuries, warrants thorough exploration in both the social and natural sciences. Concurrently, it is thought that conducting comprehensive research on both the production process of simit, which is consumed so widely by the society, and its effect on nutrition habits would also bear significance for public health.

**Declaration of Competing Interest**

The authors declare that they have no financial or non-financial competing interests.

**Author's Contributions**

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# The Some Physicochemical, Microbiological and Sensory Properties of Butters Treated by Different Plant Hydrosol

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**Abstract**

This study evaluated the physicochemical and microbiological properties of butter subjected to different hydrosols treatment were evaluated. For this purpose, butters were washed with 3 different types of hydrosols (rosemary, black cumin, thyme), vacuum packed and stored at 4°C for 30 days. At 0th, 10th, 20th and 30th days, microbiological, peroxide, free fatty acidity, sensory analysis and color measurements were carried out. Peroxide values were undetectable for the butter samples, but the free fatty acidity values were reached 1.76-2.14 KOH / gram butter at the end of the 30th day. Sensory analysis revealed that control samples were more appreciated by the panelists. The total mesophilic aerobic bacteria (TMAB) number of hydrosol washed samples were < 2 log cfu/g and for the control sample it was found to be 3.15 log cfu/g at the end of the 30th day when microbiological analysis was investigated. At the end of storage, the highest yeast-mold number was found in the control sample (6.26 log cfu/g), and the lowest one was in the black cumin hydrosol washed sample. In conclusion, it was observed that hydrosol washed samples were not preferred from a sensorial point of view whereas color parameters did not change and microorganism levels were decreased.

***Keywords:*** Butter, Hydrosol, Antimicrobial, Antioxidant.

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## 1. Introduction

Butter is an animal foodstuff obtained by churning the milk of animals such as sheep and cows. The raw material of butter is milk fat. Butter is composed of 84% fat, 0.8% protein, 0.5% carbohydrate, 0.2% ash and 15-16% water. It is particularly rich in vitamins A and D. It serves as an indispensable and challenging-to-replace raw material for the food industry and the food and beverage sector (MEGEP, 2013). It is an ingredient that enhances all kinds of dishes from roast meat to special sauces and gives a distinct flavor to the dishes. Butter is an indispensable food product that we spread on bread at breakfast, add to bakery products, and that imparts a distinct aroma to our meals.

Efforts to transform milk fat into a more durable product and offer it for consumption as butter date back to ancient times. Although there are records of butter in 3000 BC in Western sources, it was also found in the records of the Urartu, who lived in Eastern Anatolia in 8000 BC. Butter production started to be established towards the middle of the 19th century relying on the principle of creaming milk in containers. The first churns were made using wooden materials. However, instead of these materials, new methods and technologies started to be used in production as a result of the rapid progress of technological development, superseding traditional ways of production and enabling faster and standardized production has been possible. The production of quality and standard butter in enterprises producing milk and dairy products is crucial to protect consumer health and to produce products in accordance with legal regulations and standards (Oğuz, 1976).

A major problem in our country is that butter is not a sufficiently durable food product. Most of the time, butter cannot be stored for more than a few weeks and many sensory defects occur during storage. Attempts are made to increase its durability by converting it into clarified butter by salting or melting. This practice makes it difficult to use butter as a breakfast product. Oxidation of the fat in butter is one of the main causes of food spoilage and can cause significant economic losses for the food industry. This is because oxidation causes the formation of various off-flavors in edible fats

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and oils and other fat-containing foods, called rancid flavors, which render foods unacceptable or reduce their shelf life. Furthermore, oxidative reactions are reported to reduce the nutritional value of foods and some oxidation products have toxic effects (Öztürk, 2002).

Hydrosols are also referred to as essential oil or organic hydrosol. Essential oils are volatile, strongly odorous and oily mixtures obtained from plants or plant juices by water or water vapor distillation, which are liquid at room temperature, but sometimes freeze. Hydrosols and essential oils are distillate extracts obtained from organic plants by supercritical fluid extraction or pressing. Hydrosols have many medicinal benefits because they contain the water-soluble constituents, vitamins and minerals of the distilled plant. Hydrosols may also contain small amounts of aromatic oils of the treated plant (Çalıkoğlu et al., 2006; Sagdic et al., 2013).

The most important advantages of hydrosols for the food industry are that they can be obtained easily and with low cost methods and they do not cause health problems in humans (Tornuk et al., 2011). Various edible plants and spices are added to perishable foods such as meat and fish in order to prolong the preservation period as well as to add flavor to foods. In addition, their use in the treatment of diseases has a history dating back to ancient times (Sağdıç et al., 2003). It is known that many plants growing in the vegetation of the Mediterranean region are rich in aroma and essential oils. The heterogeneous distribution of the region in terms of soil and climate naturally allows for aromatic plant diversity (Sağdıç et al., 2005). Many plants rich in essential oils such as thyme, sage, mint, rosemary are widely grown in our country. The activities of these plants against microorganisms that cause food spoilage or pathogenic microorganisms have been investigated in laboratory environments (Sağdıç et al., 2005). Hydrosols of thyme (Thymbra spicata L.), sage (Salvia pilifera Montbret Aucherex Bentham), tea (Stachys pumilia Banks&Sol.), coral mole (Origanum majorana L.) and mint (Micromeria fruticosa L. fruticosa L.) showed inhibitory effects against pathogens such as Escherichia coli O157:H7, Staphylococcus aureus, Yersinia enterocolitica and Listeria monocytogenes (Sagdic et al., 2013; Tornuk et al., 2011; Sağdıç et al., 2002; Özkan et al., 2003; Sağdıç, 2005).

In this study, the effect of hydrosol obtained from 3 different materials, which are used in foods for flavoring and consumed as tea in our country, on the microbial, oxidative, and sensory properties of butter was investigated. This was to examine the potential for using hydrosol, both separately and in combination (as a mixture), in butter production.

## 2. Material and Methods

### *2.1. Material*

In this study, butter was produced by churning technique in the Food Pilot Application Center of Safiye Çıkrıkçıoğlu Vocational School. These butters were washed with rosemary, black cumin, thyme and mixed hydrosols prepared in advance at the last washing stage for 5 minutes and a control group was formed. The butters were vacuum packed under aseptic conditions, 250 grams each, delivered to the laboratory under appropriate conditions and kept at 4°C until the analysis was performed. Butter samples were analyzed on days 0, 10, 20 and 30.

### *2.2. Method*

Peroxide, free acidity, microbiological, color and sensory analysis of butter samples were carried out.

#### *2.2.1. Peroxide Analysis*

Peroxide determination involved dissolving the prepared samples in 10 ml of chloroform solution, adding 15 ml acetic acid solution and 1 ml saturated potassium iodide solution, shaking for 1 minute, and then dark-incubating for 5 minutes. Following the addition of 75 ml of distilled water and 1 ml of starch solution, the sample was titrated with sodium thiosulfate. The presence of peroxide was determined by observing for a color change during titration (Karaman et al., 2012). The peroxide value (PV) was then calculated according to the equation: $PV= [(V1-V0)\ N]/M$. Here, where V1 is the amount of sodium thiosulfate used for titration (mL), V0 is the amount of sodium thiosulfate used for the blank (mL), N is the normality of sodium thiosulfate and M is the weight of sample (g). PV was expressed as milliequivalents (meq) of active oxygen per kg of butter.

#### *2.2.2. Free Fatty Acid Analysis*

Three parallel samples of 2 grams of butter samples were placed in Erlenmeyer flasks and dissolved in 10 ml of ethanol: diethylether solution. The solution was then titrated with Potassium Hydroxide Solution (KOH 0.5 N) in the presence of phenolphthalein (Simsek, 2011). The free fatty acid number was then calculated according to the equation: $FFA, \% = (V/m) \times 5.6$ mg KOH/gram butter. Here, where FFA is the acid number, V is the consumption volume, m is sample weight (g).

### *2.2.3. Microbiological Analysis*

The sterile packaged samples brought to the laboratory were homogenized by weighing 10 g into sterile ringer solution prepared in advance for microbiological analysis under sterile conditions. Then, serial dilutions were prepared and cultured on specific media. Results were expressed as log cfu/g.

Plate Count Agar (PCA) was used to count TMAB in butter samples. The previously prepared PCA medium was inoculated by spreading method and incubated at 30°C for 2-3 days. Colonies were counted at the end of incubation (Sagdic et al., 2012).

Dichloran Rose Bengal Chloramphenicol (DRBC) agar was used for total yeast-mold count in butter samples. Appropriate dilutions were inoculated onto DRBC agar medium by spreading method and petri dishes were incubated at 25°C for 3-5 days. At the end of incubation, colonies were counted (Sagdic et al., 2010).

De Man, Rogosa and Sharpe (MRS) agar was used for Lactic Acid Bacteria (LAB) enumeration in butter samples. Appropriate dilutions were spread on MRS agar medium and petri dishes were incubated at 30°C under anaerobic conditions for 24-48 hours. At the end of incubation, colonies with cream to white color were counted (Sagdic et al., 2012).

### *2.2.4. Color Analysis*

L*, a* and b* values were analyzed using Konica Minolta (Japan) color spectrophotometer in our laboratory. Color analysis was performed for each sample in 5 parallels.

### *2.2.5. Sensory Analysis*

In order to determine the sensory characteristics of the butter samples, 5 people were selected in accordance with the panelist rules. The samples were asked to be evaluated in terms of flavor, odor and general taste. The panelists were prevented from influencing each other and the butter samples were tasted at certain intervals. The panelists were asked to rate their responses on a scale from 1 to 9 (9: very good, 1: very bad). The standard deviation and mean of the data were taken and evaluated (Yetim & Kesmen, 2012).

## 3. Results and Discussion

### *3.1. Oxidative Properties of Butter*

The peroxide value, a key parameter, informs about the degree of oxidation of oils. Peroxides contribute to the formation of a bitter taste and an unpleasant odor in fat-rich foods, serving as a significant criterion for the food industry. Peroxides were undetected in the peroxide number analysis of butters treated with hydrosols on days 0, 10, 20, and 30 (Table 1). This result bears significance, suggesting that the use of hydrosol does not augment the peroxide value.

Free fatty acidity, an essential quality index for oil, serves routinely as a shelf-life monitoring parameter. It ranks among the most important analyses in quality control since an increase in free fatty acidity or its abundance signifies reduced stability against oxidation. This is an important indicator that the oil will begin to turn bitter. Free fatty acidity values of butter samples are depicted in Table 1. As per the table, it was ascertained that the free fatty acidity values of the butter samples on day 0 spanned between 1.37-2.24 KOH/gram butter. The free fatty acidity values of the butter samples washed with thyme and black cumin hydrosols were lower than those of the other samples, with these values determined as 1.37 and 1.94 KOH/gram butter, respectively. The free fatty acidity values of the butter samples exhibited no significant fluctuation on the 10th and 20th day of storage. On the 30th day of analysis, the free fatty acidity values of the butter samples ranged between 1.76-2.14 KOH/gram butter. The free fatty acidity values of the butter samples washed with rosemary and black cumin hydrosols were lower than those of the other samples, with these values recorded as 1.76-1.91 KOH/gram butter, respectively.

The butter sample treated with rosemary hydrosol revealed a decrease in the free fatty acidity value on the 30th day compared to other day analysis (Table 1). In the butter sample treated with thyme hydrosol, the free fatty acidity value on day 0 was lower than the other day analysis.

Table 1. Peroxide and FFA values of butters produced by using different plant hydrosols

| Sample | $0^{th}$ | $10^{th}$ | $20^{th}$ | $30^{th}$ |
|---|---|---|---|---|
| | *Free Fatty Acidity (KOH/gram butter)* | | | |
| Control | 2.24±0.00 | 2.42±0.07 | 2.37±0.14 | 2.03±0.42 |
| Rosemary | 2.24±0.00 | 2.13±0.15 | 2.16±0.06 | 1.76±0.33 |
| Black cumin | 1.94±0.00 | 2.18±0.26 | 2.22±0.02 | 1.91±0.01 |
| Thyme | 1.37±0.00 | 2.21±0.03 | 2.28±0.57 | 2.01±0.13 |
| Mixed | 2.22±0.00 | 2.03±0.14 | 2.22±0.27 | 2.14±0.16 |
| | *Peroxide (meq g $O_2$/kg butter)* | | | |
| Control | ND | ND | ND | ND |
| Rosemary | ND | ND | ND | ND |
| Black cumin | ND | ND | ND | ND |
| Thyme | ND | ND | ND | ND |
| Mixed | ND | ND | ND | ND |

### *3.2. Microbiological Properties of Butter*

Table 2 contains Total Mesophilic Aerobic Bacteria (TMAB), yeast-mold, and Lactic Acid Bacteria (LAB) counts in butter samples. While the 0, 10, 20 day analysis values remained unchanged in the control group butter sample, these values dwindled to 3.15 log cfu/g in the 30th day analysis. In the butter samples washed with other plant hydrosols, the 0, 10, 20 day analysis values remained unchanged, whereas these values receded to <2 log cfu/g on the 30th day analysis.

The yeast-mold counts of the butter samples washed with herb hydrosols on day 0 were the lowest compared to other days, recorded as <2 log cfu/g (Table 2). Butter samples washed with black cumin hydrosol demonstrated lower yeast-mold counts, recorded as <2, 3.34, and 3.95 log cfu/g on days 0, 10, and 30, respectively (Table 2).

The LAB count analysis on day 10 in the butter samples washed with thyme hydrosol was lower than in butter samples washed with other hydrosols, with this value registered as 2.95 log cfu/g (Table 2).

Table 2. Microorganism counts of butters produced by using different plant hydrosols (log cfu/g)

| Sample | Storage (Days) | | | |
|---|---|---|---|---|
| | $0^{th}$ | $10^{th}$ | $20^{th}$ | $30^{th}$ |
| | | TMAB | | |
| Control | 5.99±0.03 | 6.19±0.06 | 5.39±0.10 | 3.15±0.21 |
| Rosemary | 5.95±0.01 | 6.10±0.02 | 5.39±0.06 | <2 |
| Black cumin | 5.33±0.01 | 6.19±0.02 | 5.66±0.05 | <2 |
| Thyme | 5.57±0.02 | 6.13±0.02 | 5.72±0.05 | <2 |
| Mix | 5.86±0.02 | 6.15±0.04 | 5.80±0.04 | <2 |
| | | Yeast and Mold | | |
| Control | 2.24±0.34 | 4.89±0.04 | 5.31±0.11 | 6.26±0.02 |
| Rosemary | 2.24±0.34 | 4.62±0.04 | 4.96±0.08 | 6.24±0.00 |
| Black cumin | <2 | 3.34±0.06 | 5.13±0.03 | 3.95±0.07 |
| Thyme | <2 | 4.83±0.03 | 5.70±0.04 | 6.19±0.02 |
| Mix | 2.30±0.43 | 4.48±0.01 | 5.62±0.01 | 5.84±0.06 |
| | | LAB | | |
| Control | 4.83±0.04 | 4.15±0.27 | 4.97±0.05 | 3.87±0.12 |
| Rosemary | 4.73±0.13 | 3.94±0.14 | 5.04±0.06 | 3.39±0.12 |
| Black cumin | 4.38±0.05 | 3.63±0.11 | 4.64±0.29 | 3.15±0.21 |
| Thyme | 4.24±0.05 | 2.95±0.07 | 5.04±0.05 | 3.54±0.09 |
| Mix | 4.75±0.12 | 4.04±0.06 | 4.82±0.02 | 3.45±0.21 |

### *3.3. Sensory Properties of Butter*

During the sensory analysis on the 0th, 10 th, 20 th, and 30 th day, the control group butter earned the highest score concerning flavor, odor, and overall liking. Butter washed with rosemary and mixed hydrosols scored the lowest within these values. Related values are displayed in Table 3.

Table 3. Sensory properties of butters produced by using different plant hydrosols

| Sensory Properties | Control | Thyme | Black cumin | Rosemary | Mix |
|---|---|---|---|---|---|
| | | | $0^{th}$ day | | |
| Flavor | 8.40 ±0.55 | 6.20 ±2.49 | 6.10 ±2.25 | 5.46 ±1.93 | 6.10 ±2.66 |
| Odor | 8.60 ±0.55 | 6.00 ±2.12 | 6.60 ±1.52 | 5.80 ±2.86 | 6.40 ±2.51 |
| Overall acceptability | 8.56 ±0.52 | 7.16 ±2.35 | 6.72 ±2.33 | 6.30 ±2.31 | 6.74 ±2.75 |
| | | | $10^{th}$ day | | |
| Flavor | 8.60 ±0.55 | 7.40 ±1.52 | 7.20 ±2.68 | 6.00 ±1.22 | 6.70 ±1.64 |
| Odor | 9.00 ±0.20 | 7.40 ±2.51 | 7.60 ±1.52 | 6.40 ±2.07 | 7.30 ±0.97 |
| Overall acceptability | 8.70 ±0.45 | 7.57 ±2.03 | 7.60 ±2.19 | 6.32 ±1.23 | 7.02 ±1.47 |
| | | | $20^{th}$ day | | |
| Flavor | 8.80 ±0.45 | 7.70 ±0.45 | 7.60 ±1.34 | 6.60 ±1.52 | 7.10 ±0.74 |
| Odor | 8.80 ±0.45 | 7.90 ±0.74 | 7.20 ±0.84 | 6.60 ±1.52 | 6.70 ±1.20 |
| Overall acceptability | 8.80 ±0.45 | 8.00 ±0.79 | 7.80 ±0.84 | 7.10 ±1.82 | 7.30 ±0.84 |
| | | | $30^{th}$ day | | |
| Flavor | 8.20 ±1.10 | 6.00 ±1.73 | 7.20 ±0.84 | 5.00 ±2.45 | 5.00 ±1.87 |
| Odor | 8.20 ±1.10 | 6.20 ±1.92 | 5.40 ±2.19 | 7.40 ±1.14 | 5.75 ±0.96 |
| Overall acceptability | 8.60 ±0.55 | 7.00 ±0.71 | 7.40 ±0.55 | 7.40 ±0.55 | 6.40 ±1.14 |

Color analysis of butter also formed part of this study. Color, flavor, and texture constitute three crucial characteristics for a food's acceptability. However, the initial judgment about food quality is usually predicated on the product's color. In this context, manufacturers must pay careful heed to the color properties of the product and color shifts during processing. Thus, color measurements serve as an index in analyzing quality alterations due to factors like food processing, storage, etc., in ascertaining the compliance of food quality to standards, and in the quality control of raw and processed foods (Karaman et al., 2012). The outcomes of the 0th, 10th, 20th, and 30th day color analysis of the control group butter and butter washed with plant hydrosols are provided in Table 4 as L, a, b values. The a* values ranged between

Table 4. Color properties of butters produced by using different plant hydrosols

| | L* | a* | b* |
|---|---|---|---|
| | | 0th day | |
| Control | 90.37±0.22 | 1.33±0.04 | 15.88±0.12 |
| Rosemary | 90.01±0.01 | 1.17±0.01 | 14.81±0.01 |
| Black cumin | 90.21±0.01 | 1.21±0.01 | 15.29±0.02 |
| Thyme | 89.39±0.06 | 1.10±0.01 | 14.98±0.01 |
| Mix | 89.43±0.05 | 1.21±0.01 | 15.03±0.02 |
| | | 10th day | |
| Control | 88.56±0.18 | 1.00±0.02 | 15.31±0.05 |
| Rosemary | 89.26±0.02 | 0.93±0.01 | 15.42±0.02 |
| Black cumin | 89.42±0.04 | 0.90±0.04 | 15.26±0.05 |
| Thyme | 89.31±0.02 | 1.02±0.01 | 15.88±0.03 |
| Mix | 89.64±0.00 | 1.10±0.01 | 15.74±0.01 |
| | | 20th day | |
| Control | 89.74±0.05 | 1.41±0.01 | 16.04±0.05 |
| Rosemary | 89.78±0.01 | 1.29±0.01 | 15.79±0.01 |
| Black cumin | 89.70±0.02 | 1.32±0.01 | 16.01±0.02 |
| Thyme | 90.02±0.06 | 1.17±0.01 | 15.37±0.03 |
| Mix | 89.82±0.04 | 0.99±0.01 | 14.39±0.03 |
| | | 30th day | |
| Control | 89.33±0.25 | 1.17±0.02 | 15.59±0.07 |
| Rosemary | 89.04±0.03 | 1.13±0.02 | 15.13±0.03 |
| Black cumin | 89.05±0.03 | 1.37±0.02 | 15.64±0.07 |
| Thyme | 87.92±0.14 | 1.23±0.05 | 15.32±0.07 |
| Mix | 89.04±0.08 | 1.21±0.04 | 15.47±0.08 |

0.90 and 1.10 in the 10th day analysis. A marked decrease was observed in the a* values of the butter samples washed with rosemary and black cumin hydrosols compared to other day analyses during the 10th day analysis. These values stood at 0.93±0.01 for rosemary and 0.90±0.04 for black cumin.

In the 20th day analysis, a significant dip was recorded in the a* and b* values of the butter sample washed with mixed hydrosol compared to other day analyses. The a* and b* values were recorded as 0.99±0.01 and 14.39±0.03, respectively. The L* values of butter washed with thyme hydrosol ranged between 90.02±0.06 and 87.92±0.14. The 30th day analysis documented a significant reduction in the L* value of the butter sample washed with thyme hydrosol compared to other day analyses. This value stood at 87.92±0.14.

## Conclusion

The extension of the shelf life of butter is of high significance, and positive changes have been observed in both the microbiological and oxidative properties of all butters produced with hydrosols. Furthermore, it was established that the usage of hydrosols did not lead to significant alterations in the butter samples. Although the sensory quality of the butter samples using hydrosols remained within acceptable levels, it has notably declined compared to the control samples. The change in sensory properties could become more negative depending on the specific material from which the hydrosol was derived. This implies that despite the significant benefits of hydrosols on the shelf life of butter, they exhibited a negative impact on the sensory properties of the butter. Based on these substantial findings, it is suggested that further research be conducted on the usage of hydrosols derived from different materials that could potentially complement the sensory properties of butter.

## Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

## Author's Contributions

O. Özdoğan, L.M. Renkli, A.C. Taflı: *Definition, Data Collection, Investigation Conceptualization, Methodology, Editing.*
İ. Öztürk (0000-0003-1434-4763): *Definition, Investigation Conceptualization, Writing, Editing, Methodology, Supervision.*

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# From Fresh to Dried: Evaluating Drying Kinetics of Sultana and Besni Grapes

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**Abstract**

This research investigates the thin-layer drying kinetics of Sultana and Besni grapes using the forced-air drying method. The study evaluates the applicability of three drying models (Lewis, Page, and Henderson & Pabis) to the experimental data and concurrently determines the effective moisture diffusivity and activation energy of dried grapes at varying temperatures. The grapes were dried at different temperatures (55, 65, and 75 °C) in an air-forced drying oven until a moisture ratio of 0.14 ± 0.01 kg water/kg dry matter was achieved. When evaluating the coefficient of determination (R2), chi-square (χ2), and root-mean-square error (RMSE) values for the dehydrated grapes, the results reveal that all three models provided a reasonable fit for the experimental data, with the Page model proving to be the best fit. Effective moisture diffusivity values increased significantly with rising temperatures, and higher temperatures accelerate the drying process. The conclusions drawn from the study underscore the importance of understanding grape-specific drying kinetics for improving energy efficiency and optimizing drying procedures. The Page model has been highlighted as particularly useful for future studies and industrial applications. This study provides valuable insights into both the academic community and the food industry, suggesting potential pathways for energy conservation and enhanced drying processes in dehydrated foods.

***Keywords:*** Drying Kinetics, Sultana Grapes, Besni Grapes, Forced-air Drying.

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## 1. Introduction

The grape is a fruit widely consumed worldwide. Grapes can be enjoyed fresh or be transformed into various grape-based food products through numerous food processing methods. One such method is the drying process. This process extends the shelf life of grapes by reducing their water content. Simultaneously, it enhances their aroma and nutritional values, transforming them into a popular product - raisins.

Turkey occupies a significant place in agricultural production and boasts substantial potential in grape cultivation. Grapes constitute a commercially valuable agricultural product, cultivated extensively in different regions of Turkey. Raisins, derived from dried grapes, are among Turkey's most exported agricultural commodities. Besni and Sultana grapes are among the most widely grown and commercially valuable varieties used in raisin production in Turkey. Besni grapes, grown primarily in southeastern Turkey and particularly in Adıyaman, are comparatively larger and seeded, with a sweet-sour aroma profile. In contrast, Sultana grapes are seedless, sweet grapes grown in Turkey's Aegean Region, especially in the cities of Manisa, Aydın, and İzmir.

Sun drying and hot air drying methods are commonly utilized for drying grapes. While grapes were traditionally sun-dried, hot air drying methods have gained prevalence with the rise of industrial production. The rapid, standardized production capabilities offered by the hot air drying method make it industrially appealing. Forced air drying, a method that uses hot air to remove moisture from grapes, involves passing controlled airflow around the grapes (Karasu et al., 2016; Yalinkilic et al, 2023). This method results in high hot air circulation, potentially leading to the oxidation of vitamins and color compounds. However, unlike slower drying methods such as sun drying, it quickly inhibits yeast and mold formation and slows down the development of mycotoxins.

This study aimed to create thin-layer drying models for Sultana and Besni grape varieties, two popular white grapes in Turkey, using the forced-air drying method.

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Thus, grapes were dried at different temperatures, and their compatibility with three popular models was analyzed. This study also determined the effective moisture diffusivity and activation energy of dried grapes at varying temperatures.

## 2. Materials and Methods

### *2.1. Materials*

Dehydration experiments were conducted utilizing, whole grape (Vitis vinifera L.): Sultana (syn. Thompson seedless) and Besni. The Sultana grapes were cultivated in Manisa, Turkey, while the Besni grapes were grown in Adıyaman, Turkey. Prior to the dehydration process, all samples underwent a traditional pretreatment, entailing a two-minute immersion in a Potas solution. This solution comprised a 5% potassium carbonate and 0.5% olive oil aqueous mixture, at temperature of 25°C.

The initial moisture content of the grapes was determined by employing the oven drying method as described by the Association of Official Analytical Collaboration (AOAC, 2000). In this process, grape samples were subjected to drying at a temperature of 105 ºC until a stable weight was reached, indicating the evaporation of all free water content.

### *2.3. Drying experiments*

The samples (approximately 60g) were dehydrated with air-forced drying oven (Memmert UF 110, Germany) set at 55, 65 and 75 ºC. Dehydration continued until the moisture ratio (MR) hit an approximate target of 0.14 ± 0.01 kg water/kg dry matter (d.b.), correlating to about 12% of moisture content. The sample weights were periodically measured throughout the dehydration process for obtaining drying curves. The weighing procedures were performed within a 15-30 second post sample removal from the drying system. In addition, the energy consumption during the dehydration was tracked using an energy meter (PeakTech 9035, Germany). For validation, all experiments were replicated.

### *2.3. Mathematical Modelling*

The experimental grape drying data were modeled using three prevalent thin-layer drying models: Lewis (Bruce, 1985), Page (Madamba et al., 1996), and Henderson & Pabis (1961). These models represent the moisture ratio (MR) at any given drying time (t) (Başlar et al., 2014). Moisture transfer throughout thin-layer drying of food materials is generally characterized by diffusion. The effective moisture diffusivity is determined by plotting ln (MR) versus time (min) using the experimental drying data. The activation energy can be calculated using a modified form of the Arrhenius equation. The moisture ratio (MR), the effective moisture diffusivity (Deff), and activation energy (Ea) were calculated using equations provided in the study by Başlar et al. (2014).

### *2.4. Statistical Analysis*

Drying kinetics data from the samples were analyzed using a non-linear regression procedure in SPSS 15.0 software program (SPSS Inc., Chicago, IL, USA). The fitness of the experimental data to the models was evaluated by the coefficient of determination (R2) provided by the program, in addition to the chi-square (χ2) and root-mean-square error (RMSE) values, calculated using the equations in the study by Togrul and Arslan (2004).

## 3. Results and Discussion

### *3.1. Drying kinetics of grapes*

The initial moisture content (d.b.) was established at 3.979 kg water/kg dry matter for Sultana grapes and 3.258 kg water/kg dry matter for Besni grapes. Dehydration was executed until the moisture content reached 0.14 ± 0.01 kg water/kg dry matter (d.b.),

approximating about 12% moisture content. While the drying times of the Sultana grapes at 55, 65, and 75 °C were 2100, 1080, and 660 minutes respectively, the drying times of Besni grapes at the same temperatures were 1875, 960, and 645 minutes respectively. For both grape types, an increased temperature significantly truncated the drying time. As an example, drying at 55°C extended the drying time approximately three times compared to drying at 75°C (Table 1). It was seen that the drying time of the grapes was close to that of the study by Doymaz and Altıner (2012).

According to Table 1, when an evaluation is made in terms of the energy consumption of the drying system at different temperatures, the temperature increase provided energy savings, but it was twice as much as in the drying time.

Table 1. Drying time, energy consumption, and effective moisture diffusivity of grapes

| Grape | T (°C) | t (min) | E (kW.h) |
|---|---|---|---|
| Sultana | 55 | 2100 | 5.689 |
| | 65 | 1080 | 3.756 |
| | 75 | 660 | 2.925 |
| Besni | 55 | 1875 | 5.080 |
| | 65 | 960 | 3.339 |
| | 75 | 645 | 2.859 |

*T*: Drying Temperature(°C), *t*: Drying time (min). *E*: Energy consumption measured in the oven during drying (kW.h)

The plots of moisture ratio versus time at 55, 65, and 75°C for Sultana and Besni grapes are shown in Figure 1. The drying curves are typical of those for similar fruits and vegetables. The moisture content of grapes decreased exponentially depending on the elapsed drying time.

### *3.2. Fitting of thin-layer drying models*

Mathematical modeling serves as a beneficial and practical approach for creating new designs and optimizing the drying process. In this study, the drying kinetics of Sultana and Besni grapes at various temperatures were examined, fitting the experimental data to three commonly used drying models: Lewis (Bruce, 1985), Page (Madamba et al., 1996), and Henderson & Pabis (1961). The parameters estimated from fitting these models to the grape drying data are presented in Table 2.

The most effective model for thin-layer drying kinetics was assessed based on the coefficient of determination (R2), chi-square (χ2), and root-mean-square error (RMSE) values for the dehydrated grapes. Upon evaluating the models using these parameters, all of them were generally found to fit well. However, the Page model provided a better fit for both grape varieties. This finding is consistent with the studies conducted by Doymaz and Pala (2002), where the Page model was identified as the most suitable model for drying seedless grapes, and by Doymaz (2006), where the Page model was found to be the best fit for drying black grapes. Furthermore, a study by Doymaz and Altıner (2012) on the drying kinetics of seedless grapes also found a good fit with the Page model, though they ultimately concluded that the Parabolic model was the optimal fit for their seedless grapes.

The primary aim of developing drying models is to facilitate mathematical analysis of the drying process over time and temperature, particularly in industrial applications. Consequently, it is crucial that these models strike a balance between accuracy and simplicity of use. This study concludes that the Page model meets this criterion, displaying a commendable level of both accuracy and ease of application.

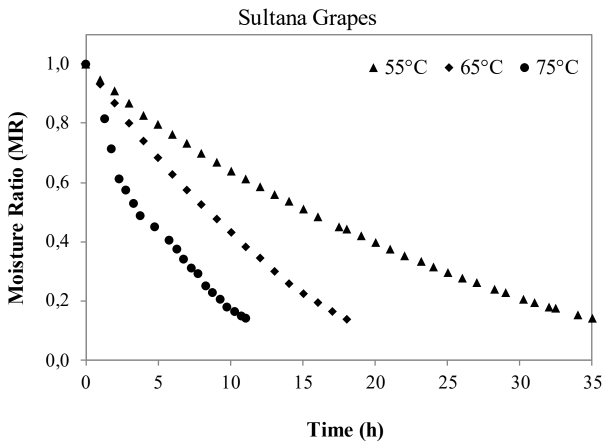
### *3.3. Effective moisture diffusivity*

The effective moisture diffusivity (Deff) values for Sultana and Besni grapes, provided in Table 3, range from 1.265×10-9 to 4.915×10-9 m2/s. The Deff value substantially increases with rising temperature. This pattern could indicate that an increase in vapor pressure, which is induced by the temperature rise, accelerates the drying process. Drying at 75°C yields the highest value of effective moisture diffusivity, whereas the lowest value is obtained at 55°C for both grape varieties. Notably, the Deff values increase by almost a factor of 3.6 for Sultana grapes and Besni grapes when the temperature is increased from 55°C to 75°C, highlighting the significant impact of temperature on the drying efficiency.

Table 2. Estimated model parameters and statistical parameters obtained from fitting of the drying models for grapes

| Model | Parameters | Sultana Grape | | | Besni Grape | | |
|---|---|---|---|---|---|---|---|
| | | 55 °C | 65 °C | 75 °C | 55 °C | 65 °C | 75 °C |
| Lewis | $k$ (×$10^{-4}$) | 8.079 | 14.942 | 28.895 | 8.337 | 16.278 | 30.745 |
| | $R^2$ | 0.994 | 0.984 | 0.985 | 0.972 | 0.978 | 0.986 |
| | RMSE | 0.01970 | 0.03291 | 0.02827 | 0.04444 | 0.03991 | 0.02798 |
| | $\chi^2$ | 0.00040 | 0.00114 | 0.00084 | 0.00204 | 0.00169 | 0.00083 |
| Page | $k$ (×$10^{-4}$) | 4.377 | 3.839 | 5.014 | 0.892 | 2.667 | 49.057 |
| | $N$ | 1.087 | 1.212 | 0.906 | 1.320 | 1.287 | 0.920 |
| | $R^2$ | 0.996 | 0.997 | 0.990 | 0.997 | 0.999 | 0.989 |
| | RMSE | 0.01490 | 0.01472 | 0.02365 | 0.01364 | 0.00999 | 0.02462 |
| | $\chi^2$ | 0.00024 | 0.00024 | 0.00062 | 0.00020 | 0.00011 | 0.00068 |
| Henderson & Pabis | $k$ (×$10^{-4}$) | 8.202 | 15.714 | 27.753 | 9.041 | 14.469 | 29.900 |
| | $a$ | 1.012 | 1.041 | 0.966 | 1.066 | 1.058 | 0.976 |
| | $R^2$ | 0.994 | 0.988 | 0.987 | 0.981 | 0.985 | 0.987 |
| | RMSE | 0.01912 | 0.02871 | 0.02586 | 0.03670 | 0.03267 | 0.02692 |
| | $\chi^2$ | 0.00039 | 0.00092 | 0.00074 | 0.00144 | 0.00121 | 0.00081 |

$k$: constant of drying velocity ($min^{-1}$). $a$ and $n$: dimensionless drying constant. RMSE: Root-mean-square error. $\chi^2$: chi-square, $R^2$: Coefficient of determination



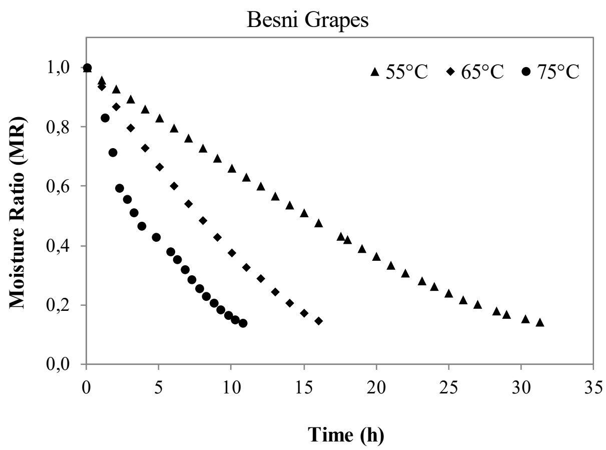




Figure 1. Drying curves of dried Sultana and Besni grapes

The Deff values procured in this study fall within the generally desirable range for drying food materials (Zogzas et al., 1996). This further validates the experiment and provides strong grounds for its application in practical settings.

The activation energy of Sultana and Besni grapes, as determined by the Arrhenius equation, was found to be 60,804 J/mol (R2=0.999) and 57,797 J/mol (R2=0.998) respectively. These results suggest that Besni grapes are relatively less sensitive to changes in drying temperature. Therefore, increasing the temperature for Besni grapes has a less significant impact on the drying rate compared to Sultana grapes. A comparison of the activation energy found in this study with the literature reveals that the obtained results are slightly higher than those reported in other studies. This could be attributed to the specific properties of the studied grape varieties, the drying method used, or both.

Table 3. Effective moisture diffusivity of the grapes

| Grape | T (°C) | $D_{eff}$ (m²/s) | $R^2$ |
|---|---|---|---|
| Sultana | 55 | $1.265\times10^{-9}$ | 0.724 |
| | 65 | $2.420\times10^{-9}$ | 0.687 |
| | 75 | $4.612\times10^{-9}$ | 0.825 |
| Besni | 55 | $1.351\times10^{-9}$ | 0.674 |
| | 65 | $2.632\times10^{-9}$ | 0.667 |
| | 75 | $4.915\times10^{-9}$ | 0.835 |

T: Drying Temperature (°C). $D_{eff}$ : Effective moisture diffusivity (m$^2$/s). $R^2$: Coefficient of determination.

## 4. Conclusions

This study sought to explore the drying kinetics of Sultana and Besni grapes, providing crucial insights into the impact of drying temperature on these processes. Our observations revealed a significant decrease in drying time with the increase in temperature for both grape varieties. Upon fitting the experimental data to three established drying models (Lewis, Page, and Henderson & Pabis), it was found that all models generally provided a good fit for our data. But the best compatible model was the Page model. This compatibility highlights the Page model's practicality for future studies and industrial applications. Our investigation into the effective moisture diffusivity (Deff) of Sultana and Besni grapes also yielded noteworthy results. There was a substantial increase in Deff values with rising temperatures, suggesting an acceleration in the drying process due to heightened vapor pressure. In conclusion, this study underscores the importance of understanding grape-specific drying kinetics for improving energy efficiency and optimizing drying procedures. Researcher thinks that these findings will prove valuable to both the academic community and the food industry, stimulating further exploration and innovation in this field.

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### Declaration of Competing Interest

The authors declare that they have no financial or non-financial competing interests.

## Author's Contributions

M. Başlar (0000-0002-8369-0769): *Definition, Data Collection,* Investigation, Conceptualization, Methodology, Writing, Editing.

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