EFFECTS OF PROTEIN ADDITION AND SUBSTITUTION OF REFINED SUGAR ON THE QUALITY OF HAZELNUT BUTTER

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To My Family

ABSTRACT

Recently, people have preferred reducing their sugar intake and replacing it with high-nutritious sweeteners and consuming more protein. This study aims to promote hazelnut butter by replacing refined sugar with date syrup, enriching it with green pea protein and collagen, and analyzing their quality changes. Their sensory, color, emulsion stability, rheology, and stress sweep properties were investigated.

Sensory analysis showed that collagen had not affected the sensory properties. The overall acceptability of samples with green-pea protein was lower than those with collagen. Date syrup decreased the overall acceptability slightly, but the acceptability was satisfactory. Emulsion stability was high, ranging between 93% and 99%.

The viscosity of all samples decreased with increasing shear rate and showed pseudoplastic flow behavior, and the flow behavior (n) of the samples was similar. The Consistency index (K) and Apparent viscosity (μa) value of the samples containing date syrup were higher than those prepared with refined sugar. The incent and decent shear rate curves showed that they had thixotropic properties. In all samples, the storage modulus (G″) values were higher than the loss modulus (G′) values, which showed that the viscous behavior dominated the elastic behavior.

In conclusion, replacing table sugar with date syrup did not negatively affect the sensory properties of samples; therefore can be used as a sweetener in hazelnut butter. In overall Samples enriched with collagen showed better resulats than than the samples enriched with green pea protein. Rheological properties of samples were not changed compare to the samples without protein and replaced sugar with date syrup.

Keywords: date, hazelnut butter, protein, rheological properties

ÖZET

Son yıllarda insanlar şeker alımını azaltıp yerine besin değeri yüksek tatlandırıcılar almayı ve daha fazla protein tüketmeyi tercih ediyor. Bu çalışmada, fındık ezmesinde sofra şekerin tatlandırıcı olarak yüksek besin değeri nedeniyle hurma şurubu ile değiştirilmesi ve bezelye proteini ve kolajen ile zenginleştirilmesi ve kalite değişimlerinin analiz edilmesi amaçlanmaktadır. Bu çalışma, kolajen ile zenginleştirilmiş bir fındık ezmesi ürünü geliştiren ilk çalışmadır. Orneklerin duyusal, renk, emülsiyon stabilitesi, reolojisi ve gerilim salınma özellikleri incelenmiştir.

Duyusal analiz, fındık ezmesine kolajen ilavesinin duyusal özellikleri etkilemediğini göstermiştir. Yeşil bezelye proteini içeren numunelerin genel kabul edilebilirliği, kollajen içeren numunelerden daha düşüktü. Rafine şeker yerine hurma şurubu eklenmesi, genel kabul edilebilirliği biraz azalttı, ancak genel olarak kabul edilebilirlik tatmin ediciydi. Numunelerin emülsiyon stabilitesi, %93 ile %99 arasında çıkmıştır.

Örneklerin tamamının viskozitesinin akma hızı ile azalma ve psödoplastik akış davranış özelliği gösterdiği görülmüştür ve akış davranışının indeksi (n) benzer olduğunu göstermiştir. Hurma şurubu içeren örneklerin kıvam indeksi (K) ve görünür viskozite indeksi (μa) değerleri şeker ile hazırlanan örneklere göre daha yüksek bulunmuştur. Örneklerin gidiş ve dönüş kayma hızı eğrileri karşılaştırıldığında tiksotropik özellik gösterdiği görülmüştür. Tüm numunelerde depolama (elastik) modülü değerlerinin (G″), kayıp (viskoz) modülü (G′) değerlerinden yüksek olması viskoz davranışın elastik davranışa baskın geldiğini göstermiştir.

Sonuç olarak, sofra şekeri yerine hurma şurubu kullanılması örneklerin duyusal özelliklerini olumsuz etkilemediği için fındık ezmesinde tatlandırıcı olarak kullanılabilir. Örneklerin reolojik özellikleri, protein içermeyen ve şeker yerine hurma şurubu kullanılan örneklere göre değişmemiştir.

Anahtar kelimeler: fındık ezmesi, hurma, protein, reolojik özellikler

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LIST OF ABBREVIATION

DC..Samples prepared with date syrup, and Collagen

DG..Samples prepared with date syrup, and Greanpea protein

DH..Samples prepared with date syrup

DV...Daily Value

EAA...Essential Amino Acid

ES..Emulsion Stability

FAO...Food and Agriculture Organization

SC..Samples prepared with table sugar, and collagen

SH..Samples prepared with table sugar

SG..Samples prepared with table sugar, and green pea protein

1. CHAPTER

INTRODUCTION

The climate and soil in Türkiye are ideal for growing top-quality hazelnuts. The origin of hazelnuts is Anatolia, making the region both the genetic origin and the natural range of the most valuable wild species and the primary source of varieties grown on farms (Köksal et al., 2006). Approximately 65% of the world's hazelnuts come from Turkey, making it the primary producer. Furthermore, hazelnut exports account for 12% of Türkiye's total export revenue (Köksal et al., 2006). Nut butter is defined as having an ingredient ratio of 90% nuts by weight, while nut spreads are defined as having an ingredient ratio of 40% nuts by weight (Nielsen, 2010).

Generally, to create spreadable products, nuts are ground into a paste. Although there are numerous uses for nut spreads, the most common application is on sandwiches. Other uses include spreading it on crackers. The introduction of nut butter increased nut consumption and introduced consumers to nutrient-rich, non-animal breakfast meals (Ahmad Shakerardekani et al., 2013a). Figure 1.1 shows the steps of nut butter production. Hazelnut butter is a complex multiphase system in which different ingredients such as sugar, cacao powder, milk powder, nut, etc, are spread in a oil phase (Glicerina et al., 2013). Nut butter's nutritional value, texture, color, and flavor influence consumer interest to buy and eating them (A. Shakerardekani et al., 2013). According to the expanding global market for nut butter and the public's growing knowledge about the importance of eating healthy foods, these products should now have a high nutritional value and a low sugar content to attract consumers and improve public health (Šaponjac et al., 2016).

A nutritious diet is necessary for health and nutrition intake. Having healthy diet can help prevent various chronic noncommunicable diseases, such as heart disease, diabetes, and cancer (Alasalvar & Shahidi, 2008). Several studies indicate that high sugar is a risk factor for numerous health problems, like cardiovascular disease, obesity, diabetes, high blood pressure, high cholesterol, and chronic inflammation (Habiba & Mehaia, 2007).

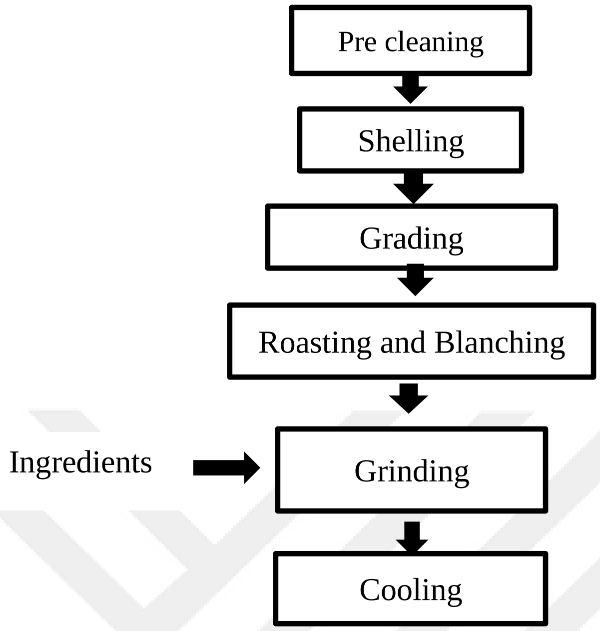

Figure 1.1: Nut butter production steps

Protein is essential for cell maintenance and regeneration. Children, teenagers, and pregnant women, in particular, need adequate amounts of protein to reach their full growth potential. There has been a dramatic increase in the variety of snack foods available at supermarkets that contain protein from both animal and plant sources (Masoro et al., 1989). Nowadays, Many people are concerned about their protein intake, especially those trying to live healthier lives. Manufacturers can take advantage of the protein trend by adding front-of-package protein claims. For making this development to produce any enriched food products, we need to investigate several aspects of the experiment (Beelen et al., 2017).

This study aims to investigate the sensory, rheological, color, and emulsifying properties of hazelnut butter in which refined sugar was replaced with date syrup and enriched with animal-based protein (collagen) or plant-based protein (green pea protein). There are numerous studies on substituting refined sugar with other types of sweeteners, but none on hazelnut butter enriched with protein

2. CHAPTER

CONCEPTUAL FRAMEWORK

2.1 Literature Review

2.1.1 Hazelnut

Nuts are dry fruits with a single seed, and as they ripen, the outer wall grows progressively stiff. Walnuts, brazil nuts, cashews, hazelnuts, pine nuts, pistachios, and almonds are the most popular tree nuts (Ahmad Shakerardekani et al., 2013b). According to FAO 2012, there are 2.1 kilograms of nuts consumed yearly per person worldwide. For example, the Europeans consumption is rate of 2.9 kilograms per person in a year (Bolling et al., 2011). The hazelnut tree is a member of the *Corylus* genus. It is indigenous to continental Europe, Asia, and America. In the last glacial age, approximately 18000 and 17000 b.c.e., hazel grew naturally, and became a component of the subsoil of deciduous woods (Grauke & Thompson, 1996). More than five thousand years ago, the Chinese began cultivating hazelnuts. (Hummer, 1995).

On the Hebridean island, major Mesolithic nut millings was discovered in 1995. The finds, according to carbon dating, are 9000 years old. In Staosnaig, hundreds of thousands of burnt hazelnut shells were found. Analysits indicates that the hazel trees were all felled at all toghether since the nuts were harvested at the same time last year (Mithen et al., 2001). The size and location of the activity are exceptional, implying that the island community traded processed hazelnuts with other islands (Mithen et al., 2001). On Rhum, there are hazelnut middens similar to Staosnaig at Kinloch and Papadil (Hummer, 1995). During the Roman Empire, hazelnuts were also used a lot. Carbonized hazelnuts have been found in places that were destroyed by Mount Vesuvius (Jashemski & Meyer, 2002, Jashemski & Meyer, 2002, Jashemski & Meyer, 2002).

According to several evidences in the past, hazelnuts were utilized as medicine and tonics. Greek doctors advocated toasting them since they were fairly healthy but hard to digest if consumed raw (Casas-Agustench et al., 2011). Additionally, they advised consuming a limited number of them because they thought that eating a huge amount of hazelnuts caused headaches and vertigo. One Greeked physician concluded that hazelnuts can treat cold and promote hair growth (Casas-Agustench et al., 2011; Lev & Amar, 2006). Fresh fruit and nuts were rarely eaten during the Middle Ages. They were regarded as poor food and frequently blamed for illnesses. Arnau de Vilanova, a Catalan-born alchemist, astrologer, and physician, writes in his book Regimen that hazelnuts "give some comfort to the liver due to their nature, but harm the stomach and the head (Cruz, 1997). There is no record of hazelnuts being used as basic ingredients, and they only were used as thickeners. While they were eaten alone and in combination with other nuts, they were not mentioned in any recorded culinary treatises (Hummer, 1995).

Nowadays, hazelnuts are known as one of the most nutrient-dense nuts, containing proteins, fibers, unsaturated fatty acids, sterols, and phytochemicals, as well as micronutrients including tocopherols, polyphenols, essential minerals like potassium, calcium, magnesium, selenium, and B-complex vitamins (Maestri et al., 2020). Due to their high potassium, magnesium, calcium, vitamins B and E, iron, and zinc content, hazelnuts can reduce cancer risk, strengthen bones, increase muscle mass, and protect the heart and digestive system (Atanasov et al., 2018). Hazelnuts contain 62% fat, 16% protein, and 11% carbohydrates. However, its composition varies significantly depending on soil, climate, and cultural interventions (Saricaoglu et al., 2018). They are frequently added to various food products like dairy, baked goods, coffee, and confections because of their high nutritional value and delicious flavor. It is estimated that 90% of hazelnuts are shelled for industrial use, while only 10% are sold in-shell (Ozdemir & Akinci, 2004; Pourfarzad & Mehrpour, 2017; Stévigny et al., 2007). Vegetarians can get many of the vitamins and minerals they need from nuts that would otherwise come from eating animal-based foods (Guiné & Correia, 2020; Gupta & Mishra, 2021; Wani et al., 2020, Sames, 2015). Hazelnuts can be consumed unroasted, blanched, or even raw. Among other applications, they can be used whole, chopped, or even made into a paste (Rosengarten Jr, 2004). Only

10% of the world's hazelnut production is used for direct consumption; about 70% is used in industrial applications, primarily chocolate. (Atanasov et al., 2018; Botta et al., 2019; Molnar, 2011; Sullivan et al., 2012). Additionally, hazelnuts have an economic impact on the community as well. Hazelnuts are an important economic and ecological resource in most countries (Gönenc et al., 2006; Holst, 2010). With a production area of 903.864 hectares, hazelnut ranks third after almond and walnut on the basis of global nut output. Türkiye has the most agriculture area, with approximately 703,000 hectares (Bello et al., 2016). Italy ranks second, followed by Azerbaijan, Georgia, Iran, the United States, Spain, Chile, and finally China (An et al., 2020; Diella et al., 2018).

There is a high concentration of hazelnut trees in the Black Sea region of Türkiye due to the extremely favorable environmental conditions that make the region ideal for the production of high-quality hazelnuts (Hummer, 2000). Turkey produces hazelnuts in 33 provinces. The provinces with the highest production are Ordu (32%), Giresun (17%), and Samsun (13%), followed by Sakarya (10%), Trabzon (9%), and Duzce (9%) (Congress, 2004; İslam, 2018; Köse & Gürcan, 2017). As previously stated, hazelnut is an economically significant nut because its parts are utilized in various industrial fields, particularly the food industry (Charron, 2020; Olsen, 2013). In addition to being suitable for fresh consumption as a snack, hazelnuts are used as an ingredient in 80% of the chocolate industry (Avanzato et al., 2007; Rinsky & Rinsky, 2008).

2.1.2 Hazelnut Butter

Nut butter is defined as having an ingredient ratio of 90% nuts by weight, while nut spreads are defined as having an ingredient ratio of 40% nuts by weight, which can be added in a variety of forms like whole nuts, a paste, or a slurry (Hart et al., 1971; Sibi, 2022).

Hazelnut butter is one of the most popular nut butter in the world; usually, people prefer to consume them for breakfast, and children consume various types of snacks made with hazelnut butter. To make hazelnut butter, hazelnuts are roasted at

125 - 165 °C and ground in a ball mill to 100 to 450 m sizes (Ahmad Shakerardekani et al., 2013b).

Many foods can make with hazelnut butter, including bakery and dairy products, which are formulated using chocolate, paste, cream, confectionery, and desserts (Scazzina et al., 2016). In most cases, hazelnut butter is made with sugar and cacao. The formulations that are used can have a significant impact on the overall quality of nut butter. The high sugar content of these products can influence public health (Er Demirhan & Demirhan, 2022).

Hazelnut butter processing steps contain three main stages. The first step of hazelnut processing is roasting. Dry roasting can be performed either in batches or continuously. In the batch method, hazelnuts are roasted in revolving ovens at approximately 425°C in batches (Demir & Cronin, 2004). To improve their flavor and color, the preferred continuous method roasts hazelnuts on conveyor belts at temperatures between 160°C and 210°C for 20–40 minutes (Ahmad Shakerardekani et al., 2013b). This step as well improves the butter's safety. To ensure uniform heating, the nuts are typically vibrating or shaken as they are transported through the roaster. Frequently, a photometer is used to evaluate the fulfillment of cooking, the second main step is griding and the last step is cooling (Chang et al., 2016; Perren & Escher, 2013).

The development of nut butter could broaden people's exposure to nuts as food sources and provide them with a more nutritious, animal-free, and convenient option for their morning snacks, which would broaden the appeal of nuts as food sources (Horton & Yates, 1987). It may be possible to develop them to attract more people's preference and increase healthy food consumption by replacing sugar with alternative sweeteners, which would add more nutrients or enrich them with proteins (Enweremadu & Alamu, 2010). The characteristics of nut butter, such as texture, color, and flavor, significantly impact its marketability, sales, and consumption. For this reason, it is important to choose suitable ingredients for development. Furthermore, nut butter' rheological and textural characteristics are important to the industry. Roasting, milling, and the ingredients all have a significant effect on these features (A. Shakerardekani et al., 2013).

2.1.3 Protein-Enriched Foods

The rising demand for healthier and more convenient food options has led to a massive expansion of the market for protein-enriched foods. Energy and protein supplements and fortification could be used as safe, effective, and inexpensive ways to encourage people to eat more protein (van der Zanden et al., 2014). Adding protein to various food products has the potential to raise the product profile and make it more appealing to consumers to consume them (Stelten et al., 2015). Further, people who have trouble swallowing pills can take protein-enriched food products to overcome this problem (Mills et al., 2018). Globally, snack foods account for one-third of our daily calorie intake, representing a market size of $493.4 billion in 2020 (Luo & Koksel, 2023).

There is a strong recommendation that one should increase their protein consumption because it can improve muscle synthesis, contribute to fat loss, lower the risk of cardiovascular diseases, and help one feel full for a longer time (Morales et al., 2017). There has been an increase in discussions about how snack foods can be enhanced nutritionally by adding healthier ingredients, like protein isolates (Luo & Koksel, 2023). There are various studies on the protein fortification of food products. Some examples of fortified foods are protein-enriched bread with chickpea protein (Xing et al., 2021), protein-enriched soups (Donahue et al., 2014), and sauces enriched with plant-based protein isolated (Tsikritzi et al., 2015), protein and dairy-enriched with protein (Beelen et al., 2017; Lorefält et al., 2005), and high-calorie snacks or desserts enriched with plant-based protein (Tsikritzi et al., 2014), yogurt enriched with whey protein(Sodini et al., 2005; Stelten et al., 2015) and ice cream enriched with protein from brewing waste (Methven et al., 2010). Across all of the studies mentioned above, researchers concluded that consumers were more likely to accept and demand foods that contained protein (Scazzina et al., 2016).

2.1.4 Animal-Based Proteins

Proteins are one of the largest and most complex molecules in the human body, playing many important roles. All the tissues and organs made up of variety of cells and cells made up of proteins. A protein made with Twenty distinct types of amino acids. The amino acids sequence appoints proteins 3- dimentional structure and function (Ewy et al., 2022).

Due to their nutritional value and usefulness, animal-based proteins are of significant interest. In the food industry, simple forms of these proteins like milk and steak are widely used in dishes, and processed forms like yogurt and cheese are also popular. Animal-based proteins have a high quality due to their accentuial essential amino acids content, and their quantity is also high, these properties make them a nutritious source of food. (Smith et al., 2013). Essential amino acids, nonessential amino acids, and conditional amino acids are the three types of amino acids (Aristoy & Toldrá, 2009). Human body cant make some amino acids, due to that fact they named essential amino acids (EAA), they must be obtained from food. Assential Amino Acids are histidine, leucine, isoleucine, lysine, methionine, phenylalanine, threonine, valine and tryptophan (Wilson, 2003).

The following group is non-essential amino acids, which the human body can synthesize even if what they eat does not contain them, non-essential amino acids are alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, tyrosine, and serine (Lopez & Mohiuddin, 2020). The third group is conditional amino acid which is not required most of the time, except during rare circumstances such as disease or stress, they include arginine, cysteine ,serine, tyrosine, glycine, ornithine, proline, and glutamine (Elmadfa & Meyer, 2017).

The other good point of animal-based proteins is that their amino acids pattern is simillar to human body’s reqirement. In contrast, plant-based protein sources only provide them in trace amounts (Lonnie & Johnstone, 2020). Additionally, animal proteins are easily digestible by humans, thus enabling them to be absorbed into the body (Breslin, 2013). Hazelnuts provide only seven of the EAA’s, they are are low in lysine and methionine (Berrazaga et al., 2019; Pasiakos et al., 2015). Dairy, meat, seafood, and eggs are the most common animal proteins found in human meals. Insect protein is currently receiving increased attention (Roy et al., 2020).

Protein levels in milk vary from 3 to 7% depending on the animal species. Generally, goat, camel, and sheep milk have a protein content of between 3% and 7%, while bovine milk has a protein content of 3.2%. These differences are caused by genetics, farming systems, and seasonality (Barłowska et al., 2011).

Milk proteins from cows are mainly composed of caseins and whey proteins in a ratio of 80%:20% (Silva et al., 2018; Xiong et al., 2020). Dairy protein ingredients are ubiquitous in drinks, confectionery, bread products, meat and fish products, dietetic foods, newborn formulas, diets for the aged, slimming products, clinical and medical assistance (Harper, 2011, Mulvihill, 1992; Singh et al., 2008).

Meat is another source of animal-based proteins. Muscle meat's role as a food source is permanent, it has a relatively constant protein content across animals, averaging around 22% (Asghar et al., 1985). Comminuted and restructured foods manufactured from muscle, organs, or byproducts, among which are chopped meat, burgers, sausages, and nuggets, are popular, though they have a lower protein value than muscular meat (Day et al., 2022; Leoci, 2014). Animals are the only species that produce collagen. Structure and connective function are performed by collagen in the skin, bone, tendons, and vessels (Silvipriya et al., 2015). Gelatin is formed when collagen is hydrolyzed or denature by heat. Gelatin can use in different food products like jelly desserts and dairies (Gómez-Guillén et al., 2011, Day et al., 2022; Mariod & Fadul, 2013). Proteins can be found in a wide variety of forms and are extremely valuable in seafood. The protein content of edible fish muscle ranges from 16-21%. Fish is a significant source in several local association, accounting for approximately 16% of the world's total supply of animal proteins. (Muringai et al., 2021). Fishes are also a great source of vitamins and minerals. When compared to other protein-rich animal diets, fish has long been known as a food rich in protein with reduced energy and total fat, specifically saturated fat (Erbay & Yeşilsu, 2021; Mansfield, 2003; Sarkar et al., 2015).

The egg ranks as one of the world's major animal-based supply of protein. Egg proteins have a good nutritional content, are easily digestible, and include all of the essential amino acids (EAA) (Strixner & Kulozik, 2011). Most avian eggs contain 75% water and 12% protein. The albumen-rich egg white comprises around 50% of an egg's protein, the yolk includes 40%, and the rest of the proteins spread in the eggshell and eggshell membrane. Proteins account for over 90% of the dry matter in egg whites (Guha et al., 2019). Many food products, such as bakery goods, use egg white to form foam and maintain the foam's stability. The foaming properties of other protein sources usually compare with egg white foaming capability (Anton, 2013).

Another source of protein are insects, recently a growing number of people have been consuming insects as a rich supply of protein recently. Approximately 19–24% of insects contain protein, but this varies significantly based on the species or their maturity (Jonas-Levi & Martinez, 2017). Insects’s proteins are are in muscle tissue and the epidermis' cuticle layers. Insect-based proteins can use in foods that use whole insects that have been dried and ground into a powder from which they can be extracted (Lamsal et al., 2019; Rahman et al., 2023). Eating insects is usual in some regions like in Asia, Africa, and Latin America, most Western populations have never heard of it. Therefore, insects will be more likely to be used as processed protein ingredients (Kim et al., 2019). In addition to their nutritional benefits, proteins are crucial for the physicochemical composition and sensory quality of food. Proteins’ functional characteristics play a crucial part in food production (Geada et al., 2021). Functional properties of proteins include solubility, emulsifying activity index, oil-holding and water-holding capacities, emulsion stability, foaming capacity, foam stability, and gellıng properties (Tontul et al., 2018). Animal-based proteins are the most frequently used proteins for products that need to be stabilized by proteins due to their superior stabilizing qualities. These proteins can easily adsorb in both air-in-water and oil-in-water emulsions and are highly soluble in aqueous solutions. (L. M. C. Sagis & J. Yang, 2022). Animal-based proteins usually have solubilities above 85%, even though a much more comprehensive range of solubilities is found in plant proteins. Plant proteins are typically hydrophobic, as suits proteins designed to remain inactive and packed in the seed (Day et al., 2022; Wanasundara et al., 2016).

Emulsification is another important functional property of proteins. For being powerful emulsifier, proteins need to be able to adsorb to oil-water interfaces as well as stabilize them (Raikos, 2010). A protein needs to move from the aqueous phase to a formed interface, adsorb there, and frequently unfold, crosslink, or undergo other structural changes over time in order to generate a protein-stabilized emulsion. The best emulsifiers are readily soluble, adaptable and amphiphilic proteins like those found in milk and eggs (Hailing & Walstra, 1981; McClements, 2004). The molar concentration of small proteins for a given mass makes them more powerful emulsifiers in compare to large proteins (McClements & Gumus, 2016). For instance plant globulin proteins typically exist as high molecular weight, which limits their capacity to form emulsionsPlant globulins' natural structures can be changed by denaturation and restricted hydrolysis, which makes them strong emulsifiers (Tan et al., 2022; Walstra & De Roos, 1993). Overall, it has been demonstrated that technological functionalities like foaming, emulsification, and gelling provide food products with a acceptable texture and sensory attribute over plants (Dave et al., 2021; Day et al., 2022; Kim et al., 2020; Shaw et al., 2022).

Collagen

The most prevalent protein in the body is collagen, it is one of the most important proteins in our body. It is a fundamental part of the extracellular matrix that makes up the skin, hair, nails, joints, bones, and tendons (Subhan et al., 2021). There is a significant amount of consumer preference for the dermatitis efficacy of collagen due to the fact that collagen is an essential component of the structure of the hair, skin, and nails. Bone broth, fish, and meat are all excellent sources of collagen (Rustad et al., 2022; Silvipriya et al., 2015). It is found in nearly every extracellular tissue that serves a mechanical function and possesses excellent mechanical properties (Snedeker & Gautieri, 2014). Collagen in tendons and ligaments acts as a force transmitter from muscles to bones and stores elastic energy. Without these characteristics, it would be impossible to walk in a simple way (Linsenmayer, 1991). In addition, collagen makes up the majority of the organic matrix found in bones and tooth dentin, which gives these tissues their resistance to fracture (McGuire et al., 2014). It is even present in the muscles, which would be unable to function properly without collagen (Ramachandran & Kartha, 1954). Collagen serves more than just a mechanical purpose in our bodies. In the eye cornea, for instance, the ordered arrangement of collagen fibrils contributes not only to the cornea's mechanical stability but also to its transparency (Fratzl, 2008; Shoulders & Raines, 2009). The rate of collagen production in the body declines due to aging and a lack of essential nutrients (Hashim et al., 2015; Kobayashi et al., 2016). In recent days, collagen supplementation has become progressively popular in recent years as a potential anti-aging treatment. Consuming food products with added collagen is an excellent way to encourage people to consume collagen in order to improve their body health and for those who have difficulty swallowing pills (Al-Atif, 2022). Furthermore, since collagen has been shown to be biocompatible and can promote wound healing, it has been used in both medical and dentistry (Bunyaratavej & Wang, 2001). Collagen properties in the food industry are divided into two categories, gelling and surface properties. Gel formation, thickening, and water holding capacity are the features linked to their gelling behavior. Second, they have surface characteristics like emulsion, foam formation, stabilization, adhesion and cohesion (Lee et al., 2001).

Due to its superior biological unity and degradability, as well as its low antigenicity, it has found widespread use in the food, pharmaceutical, cosmetic, biomedical, and , tissue engineering (Hashim et al., 2015; Matmaroh et al., 2011). Self-aggregation and cross-linking allow it to form firm and stable fibers,these features cause it to be useful in drug delivery systems (Wang et al., 2008). In addition to its hemostatic activity, biodegradability, low allergenicity, and biocompatibility, collagen's extensive use in pharmacology is a result of collagen’s natural characteristics (Gorgieva & Kokol, 2011; Rezvani Ghomi et al., 2021).

The collagen polypeptide chain can be thermally denature or partially hydrolyzed to produce gelatin (Regenstein & Zhou, 2007). The molecular weight range of gelatin is broader than that of collagen because it is a denatured form of native collagen. Collagen outperformed gelatin in terms of its unique and superior characteristics, such as higher enthalpy, a more extensive fibril network, a lower isoelectric point, and high resistance to protease hydrolysis (Sarrigiannidis et al., 2021). Compared to the gelatin membrane, the collagen membrane had native triple helices and fibril structures that were more robust and firm (Mushtaq et al., 2022). While collagen has excellent mechanical strength and reversible extensibility, gelatin is remarkable due to its distinct rheological properties, like thermal stability, and viscoelastic properties. Some vertebrate species, primarily bovine and swine, have had their collagen extracted from their skin and bones (Liang et al., 2014).

2.1.5 Plant-Based Protein

Raising livestock has a significant negative influence on the environment since it contributes to problems such as soil erosion, water pollution, loss of forest land, expansion of deserts, production of greenhouse gases, and temperature rise (Silanikove & Koluman, 2015). Consuming meat and processed meat is another factor contributing to the increasing chronic diseases like cancer, diabetes, and cardiovascular diseases. Another concern about meat production is the use of antibiotics and hormones (Walker et al.2005). Besides, in order to meet the rising demand brought on by the increasing world population, and by economic and nutritional changes, it is imperative to increase protein production. Between 2000 and 2100, it is anticipated that both the global population and daily calorie intake will rise by 6 billion and 500 kcal per person, respectively, along with a rise in the amount of animal products in diets (Dawson et al., 2016). There will be a 30% increase in total global protein demand by the year 2100 or a 10% increase per person. Changes in diet are necessary to prevent severe strain on the planet's limited food sources (Henchion et al.2017; Tilman and Clark 2014). To meet rising protein demand while minimizing environmental impact, it is necessary to look into alternative protein sources like plants, insects, and mushrooms (Van Huis, 2015). Alternative protein sources can be used to create novel cuisines, or animal proteins can be substituted in conventional diets. Consequently, scientific research and the food industry are searching for a solution and replace more plant-based protein sources with animal-based protein (García-Segovia et al., 2020; L. M. Sagis & J. Yang, 2022; van Vliet et al., 2015). It is hypothesized that less water, land, and energy are required in the production of foods derived from plants in comparison to animal-based foods. This could reduce the economic and environmental costs of food production and help preserve the planet (Van Vliet et al., 2015) Grains, pulses, legumes, seeds, and nuts are the main sources of plant based proteins in human food. Algae, pseudocereals, and ancient grains make up a relatively small portion of the total global intake (Leterme, 2002; Tan et al., 2021).

Foods which made with grains typically contain 7–15% protein, which is lower than foods containing animal protein. Commercial production of protein supplements also uses grains, for instance, "vital wheat gluten," which is made with wheat as a byproduct of the making starch and is added to a variety of processed foods, has a protein content of up to 80% (Tan et al., 2021). As well as increasing protein content in flour-based products, gluten increases water-binding ability, e.g., in processed meats (Day et al., 2006).

Soy protein contributes less to the average human diet than wheat protein (Erdman Jr & Fordyce, 1989). However, Soy protein is the most often used plant protein component in prepared foods. Soy beans have a high protein content (35-40%) and an excellent amino acid balance, which are the primary reasons for replacing dairy and meat with soy beans (Qin et al., 2022). Commercial production of a wide range of soy protein derivatives includes flour, protein isolate, texturized and hydrolyzed proteins (Lusas & Rhee, 1995). The most refined version of soy protein is soy protein isolate, which contains more than 90% protein. They are chosen for their functional qualities, like water and oil binding capacity, emulsification, foaming, and gelation, therefore they can then be employed in a range of food products (Wang & Johnson, 2001; Wolf, 1970).

There is no doubt that peas are one of the most crucial grain legume crops in the world, and they are also one of the most popular vegetables used in human cuisine. The pea protein content is usually around 25% but varies greatly which is related to different factors like their genotype and growing situation (Day et al., 2022).

Beans, chickpeas, and lentils are also commonly consumed legumes. Similar to peas, the protein amount of these legumes ranges between 20-36%. Lupins contain a protein level similar to soybeans, at around 40%. Even though these legumes encompass relatively high volume of protein, their quality is inferior to that of animal proteins (Kussmann et al., 2010). Protein content can range from 85-95% in flours, and protein isolates derived from legume seeds. As a result, these items could be incorporated into baking, soups, nutritous snack bars, pasta, and meal replacements, formulas for baby food, and processed meats. Ingredients derived from peas can be utilized as an enhancer in emulsified meat products due to their oil-holding, water-holding, and emulsification properties (Fernández-Quintela et al., 1997).

Pseudocereals such as quinoa, amaranth, chia, and others are becoming increasingly popular in human diets as they are gluten-free grains with an excellent amino acid balance. In general, pseudocereals have a more or less higher protein content comparing cereal grains, the protein content of them can vary between varois genotypes and their growing situation (Malik & Singh, 2022).

One of the key sources of plant-based protein is nuts. The amount of protein in nuts can be different greatly. The highest protein-containing nuts are peanuts, cashews, walnuts, almonds, and pistachios, with a protein amount of 20% or more. Brazil nuts, hazelnuts, and pine nuts follow with an 11–15% protein. The least amount of protein is found in pecan and macadamia nuts, at less than 10%. Most people eat nuts as snacks or in soups, cakes, pastries, cookies, bars, and pesto (Sharma et al., 2012; Yang, 2009).

In the Far East, especially in Japan, seaweeds have long been used as sea vegetables. Some are hydrocolloid sources as well. Recently, seaweeds have drawn much interest in Western nations due to research into their potential as healthy, sustainable plant foods. Seaweeds are divided to three groups brown, green, and red. Because water accounts for 80-90% of the weight of natural seaweeds, their protein content is rather modest (1-5% wet weight and 6-30% dry weight), and it varies substantially by species, season, and location (Gupta & Pandey, 2007).

The use of microalgae as food is more common in Asian countries. However, microalgae have not yet achieved major prominence as food proteins despite their high protein contents (on average 1.2-14% wet weight with 80% water and 6-70% dry weight) (Geada et al., 2021; Stone & Nickerson, 2012). Algal material's dark green hue and slightly fishy odor make it difficult to incorporate into typical food products. Microalgae production costs are too high to compete with traditional protein sources. The majority of the market is made up of Chlorella, Spirulina, and Dunaliella microalgae, which are available in pill, liquid, and powder form (Becker, 2007).

Protein functionality is means that how they act as a colloidal biopolymer in a food system, either with or without other food ingredients. This behavior is determined by the intrinsic and/or extrinsic physicochemical properties of the proteins, rather than by their biological roles, functions, or nutritional bioactivities (Foegeding & Davis, 2011; Plundrich et al., 2015). Proteins have a variety of functional properties, including solubility, gelation, emulsification, foam formation, binding to water and fat, viscosity, and film formation. The molecular characteristics of the proteins in their natural, intermediate, or denatured states are what determine all of these functionalities (Foegeding & Davis, 2011).

The structural changes, particularly as they relate to the pH, temperature, and ionic strength of the solution in the local environment, have an effect on the way proteins function, which in turn affects the quality of the food that proteins produce, as well as the nutritional value of those foods and the body's capacity to absorb those nutrients (Tharanathan & Mahadevamma, 2003). According to several studies, plant-based proteins have lower benefits in food applications than animal-based proteins (Tharanathan & Mahadevamma, 2003).

The molecular size of plant proteins is one of the reasons for this. The molar concentration of small proteins for a given mass makes them more effective emulsifiers than large proteins or aggregates (McClements & Gumus, 2016). Plant globulin proteins typically exist as high molecular weight trimers or hexamers, which limits their capacity to form emulsions. Denaturation and limited hydrolysis, however, can alter the native structures of plant globulins, turning them into powerful emulsifiers (Tan et al., 2022; Walstra & De Roos, 1993).

2.1.4.1 Green Pea Proteins

Green peas, also known as "garden peas," are tiny, spherical seeds produced by the *Pisum sativum* plant. They have been a staple of the human diet for centuries and are consumed globally. They belong to the legume family, which includes plants that produce pods containing seeds (Edelenbos et al., 2001).

Green peas cause a modest increase in blood sugar after consumption or have a low glycemic index (GI), and are high in fiber and protein, which can control blood sugar levels. This is because fiber prevents the rapid assimilation of carbohydrates, leading instead to a more gradual and steady increase in blood sugar. Moreover, some research suggests that eating protein-rich foods can aid people with type 2 diabetes in maintaining stable blood sugar levels (Rungruangmaitree & Jiraungkoorskul, 2017).

Pea protein has garnered a lot of attention because of its lack of allergenicity, high nutritional value, wide availability, and low cost. Similar to other plant proteins, the use of pea protein as a food ingredient faces functional and flavor/color limitations (A. C. Y. Lam et al., 2018; Owusu-Ansah & McCurdy, 1991). However, as with other plant proteins, there are limitations in functionality and flavor/color difficulties when using pea protein as a food component. Green peas are high in protein and carbohydrates, low in fat, and high in vitamins and minerals. they have a high lysine content but are poor in methionine and tryptophan (Boukid et al., 2022). As a result, pea protein is frequently ingested alongside cereal grains because they offer an important amino acid profile that is complementary to cereal proteins, which are typically low in lysine while high in sulfur amino acids (methionine, cysteine). Legume proteins predominantly consist of salt-soluble globulin proteins; the second significant group of proteins is water-soluble albumin proteins (Dhaliwal et al., 2021; Hoover et al., 2010; A. Lam et al., 2018).

2.1.6 Refiened Sugar Alternatives

In the modern social environment, dietary choices are frequently determined by convenience, flavor, and enjoyment. A market trend towards sweet snacks and desserts that are low in calories, low in fat, or low in sugar has emerged in response to expanding sales of sweet foods and snacks and an increasing prevalence of overweight or obesity (Stokols et al., 2006). There is a growing concern that table sugars have been linked to an increased risk of obesity, type 2 diabetes, and heart disease, as well as cell damage and insulin resistance (Shah et al., 2010). In a 15-year research, those who took 17% to 21% of their calories as added sugar had a 38% higher chance of suffering from cardiovascular disease versus those who ingested 8% of added sugar (Bogart et al., 2013). excessive added sugar consumption may cause chronic inflammation and blood pressure, each of which major pathological routes for coronary disease (Bogart et al., 2013).

Date syrup is one of the alternatives to refined sugar. Date syrup contains sugars, minerals, vitamins, and antioxidants, making it an essential food. Dates have been shown to have a low glycemic index. Anti-cancer and antimutagenic properties (Al-Farsi & Lee, 2012; Shahein et al., 2022; Vayalil, 2002) The preparation of date syrup involves boiling of chopped dates, puréeing the cooked dates, and squeezing out their liquid, leaving behind a thick paste that can be used for other purposes. After straining, the date liquid is quite thin but flavorful (Vayalil, 2002).

3. CHAPTER

METHODOLOGY

3.1 Material

In this study, the hazelnut butter supplied by Findik Ocagi (Trabzon, Turkey) contained 100% hazelnuts. The alkalized cacao powder and sugar were supplied by Pakmaya (Kocaeli, Turkey). The green pea protein powder purchased from Soft (Istanbul, Turkey) contained 85% protein, 4% fiber, 4.5% carbohydrates, and 8.5 % fat. Date syrup was purchased from Ancora Life (Ankara, Turkey) and contained 70% sugar and 2% protein. The collagen powder was provided by Guru Sağlıklı Gıda (Istanbul, Turkey). All other materials were purchased from a local market (Istanbul, Turkey).

3.2 Methods

3.2.1 Recipe Development

For selecting the best recipe for hazelnut butter, several recipes, as shown in Table 3.1, were prepared, and their taste, cost, appearance, odor, and spreadability were evaluated.

3.2.1.1 First Trial of Formulation

The first trial formulations have shown in Table 3.2. In the first trial, different sweeteners, two different cacao powders, green pea protein, and coconut oil in different combinations were examined.

Table 3.1: Ingredients used in the pre-trial-recipes

Hazelnut butter	Sweeteners	Cacao powder	Oil	Emulsifier
Smooth	Sugar	Organic	Hazelnut oil	Green-pea protein
Rough	Date puree	Alkalized	Coconut oil	Soy protein
	Date syrup		Rapeseed oil	Aquafaba
	Apple syrup		Sunflower oil	
	Coconut sugar		Cacao butter	
	Grape extract			
	Carob powder			
	Date flour			

3.2.1.2 Preparation of The Samples

According to the results of the first trial, date syrup was selected as a replacement for refined sugar, and one plant-based protein (green pea protein powder) and one animal-based protein (collagen) were used to enrich the hazelnut butter with protein. To compare the quality of the new hazelnut butter product, the same recipe is used with refined sugar.

Table 3.2: First trial of formulation

Sample number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Hazelnut butter (gr)	37	37	38	38	38	114	114	112	64	54	152	50	140	140
Sugar(gr)	8	1	0	0	0	12	15	9	17	15	30	0	26	8
Alkalized cacao (gr)	4	1	1	1	1	2.1	2.4	2.4	0	0	0	0	1	0.6
Organic cacao(gr)	0	0	0	0	0	0	0	0	0	0	8	2	4	4
Apple syrup(gr)	0	0	0	7	20	15	15	0	0	0	14	20	14	6
Grape extract(gr)	0	4	0	0	0	0	0	12	0	0	0	0	0	6
Coconut oil (gr)	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Honey (gr)	0	0	6	0	0	0	0	0	0	0	0	0	0	0
Carob powder (gr)	0	0	0	0	0	0	0	0	14	14	0	5	0	0

Table 3.3: Second trial of formulation

Sample number	7-2	7-3	7-4	7-5	7-6	7-7	7-8	7-8-2	7-9	7-10	7-11	7-14	7-15	7-16	7-17
Smooth h.b (gr)	114	0	114	0	114	0	114	114	0	114	0	114	114	114	114
Rough h.b (gr)	0	114	0	114	0	114	0	0	114	0	114	0	0	0	0
Alkalized cacao(gr)	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Organic cacao(gr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apple syrup(gr)	15	15	15	15	15	15	0	0	0	0	0	0	0	0	0
Grape extract(gr)	0	0	0	0	12	12	12	27	12	0	0	0	0	0	0
Date extract (gr)	0	0	12	12	0	0	0	0	0	12	12	30	0	9	0
Coconut sugar(gr)	15	15	0	0	0	0	15	31	15	15	15	0	30	0	0
Date flour (gr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36

Table 3.4: Prepared samples' recipes

Sample	Hazelnut butter (gr)	Alkalized cacao (gr)	Sugar (gr)	Date syrup (gr)	Collagen (gr)	Green pea protein (gr)
SH	114	2.4	17	0	0	0
SG	114	2.4	17	0	0	13
SC	114	2.4	17	0	13	0
DH	114	2.4	0	9	0	0
DG	114	2.4	0	9	0	12
DC	114	2.4	0	9	12	0

DH, prepared with date syrup. DC, with date syrup and collagen. DG with date syrup and green pea protein. SH, with refined sugar. SC, with sugar and collagen. SG, with sugar and green pea protein.

3.2.2 Sensory Analysis

The samples were evaluated by 15 panelists, whose ages ranged from 19 to 35. On a 9-point hedonic scale, the panelists were asked to rate six samples in each session, the samples labeled with three-digit random numbers (each approximately 5gr) in two sessions hedonic scale ranging from 'dislike extremely' (1) to 'like extremely' (9). The assessment form is given in Figure A.1.

3.2.3 Color Measurement

L* (brıghtness), a* (redness (+) / greenness (-)), and b* (yellowness (+) / blueness (-)) values were measured using a colorımeter (CR-400, Konıca Mınolta, Japan) for color analysis. The Chroma (Ch) value and hue angle (h°) was according to Equation 1 and 2.

$$Ch = \sqrt{a^{*2} + b^{*2}} \qquad (1)$$

$$h = arctan\,(b/a) \qquad (2)$$

3.2.4 Emulsion Stability

To evaluate the emulsion stability (ES) of hazelnut butter, 10 g of the sample (F0) was placed in 14 mL centrifuge tubes and centrifuged at 3000 rpm for 10 minutes (EBA 20, Hettich, Germany) The supernatant (F1) was subsequently weighed. The emulsion stability (%, w/w) of the samples was calculated using Equation (3).

$$ES = \frac{F_0 - F_1}{F_0} \times 100 \qquad (3)$$

3.2.5 Rheological Analysis

To investigate the rheological behavior of the hazelnut butter samples, shear stress (τ) and viscosity (μ) values were measured at 25°C, in the range of 0-300 s^{-1} shear rate ($\dot{\gamma}$), using a rheometer (Haake RS1, Thermo Scientific, Germany) and a 35 mm diameter parallel titanium plate sensor (PP35 Ti, Thermo Scientific, Germany). First, the shear rate (γ) was increased from 0 to 300 s^{-1} (ascent, 5 minutes). Then, without waiting, it was decreased from 300 to 0 s^{-1} (descent, 5 min). The thixotropy value was obtained using the rheometer software to calculate the area between the flow curves (ascent and descent). The power law model was used to calculate the consistency index (K) and flow behavior index (n) (Equation 4). At a shear rate of 50 s^{-1}, the apparent viscosity (a) value was calculated.

$$\tau = K\,\gamma^{n} \qquad (4)$$

Second, the elastic modulus (G') and viscous modulus (G'') were measured using stress sweep, increasing shear stress from 0 Pa to 1000 Pa at 1 Hz and 25 °C. The intersection of the G' and G'' curves and the yield stress were also obtained from the software of the rheometer.

3.2.6 Statistical Analysis

All factors used in the study were repeated three times. As an experimental plan, the panelist and session effects were accepted as blocks in the evaluation of the sensory analysis data. The data were evaluated using a statistical program IBM SPSS Statistics 27 using analysis of variance (ANOVA) and Tukey's multiple comparison tests ($P < 0.05$).

4. CHAPTER

RESULTS AND DISCUSSION

4.1 Recipe Development

In the first trial, different sweeteners, two different cacao powders, green pea protein, and coconut oil in different combinations were examined. It was observed the carob powder taste and texture were unacceptable. Coconut oil addition had not good result since the oil content of hazelnut butter was high enough; therefore, the addition of any kind of oil was rejected. Organic cacao powder addition had not had satisfying results because of its texture and unsatisfactory cacao odor and color. After a frequent combination of ingredients, sample no 7 had better results. Therefore, the second trial was based on sample number seven formulations. In the second trial recipe, number 7.16 had better results.

The following examination was tested on sample number 7.16 with a different combination of date syrup, sugar, green pea protein, and collagen in a mixture of alkalized cacao and hazelnut butter.

4.2 Sensory Analysis

Table 4.1 shows the sensory evaluation. According to the data, we can conclude that the substitution of refined sugar with date decreased the hazelnut butter samples' odor, color, flavor, texture, spreadability, and overall acceptance scores ($P < 0.05$). In contrast, the addition of collagen had no negative effect on the sensory properties of the samples when compared to those without protein addition ($P > 0.05$). Although, the scores for taste, texture, and general acceptability of samples containing green pea protein were significantly lower than those of samples containing collagen or no protein ($P < 0.05$). The odor of samples containing green pea proteins was also rated lower than the samples containing collagen ($P < 0.05$).

The odor of the SC samples had higher scores than the D and DG samples ($P<0.05$). The odor of DG was also less liked by the panelists compared to that of D

(P<0.05). Even though the odor scores of the SC samples were the highest, it was not different than that of the S, DC, and SG samples (P > 0.05).

Separability is a sensory property that is highly regarded for its impact on the overall flavor and texture impression of many foods, particularly nut butter. The spreadability of samples that containing date syrup and green pea protein (DG) is lower than others, and the samples which contain sugar without added (SH) protein showed higher spreadability. Figure 4.1 shows the pictures of the final samples.

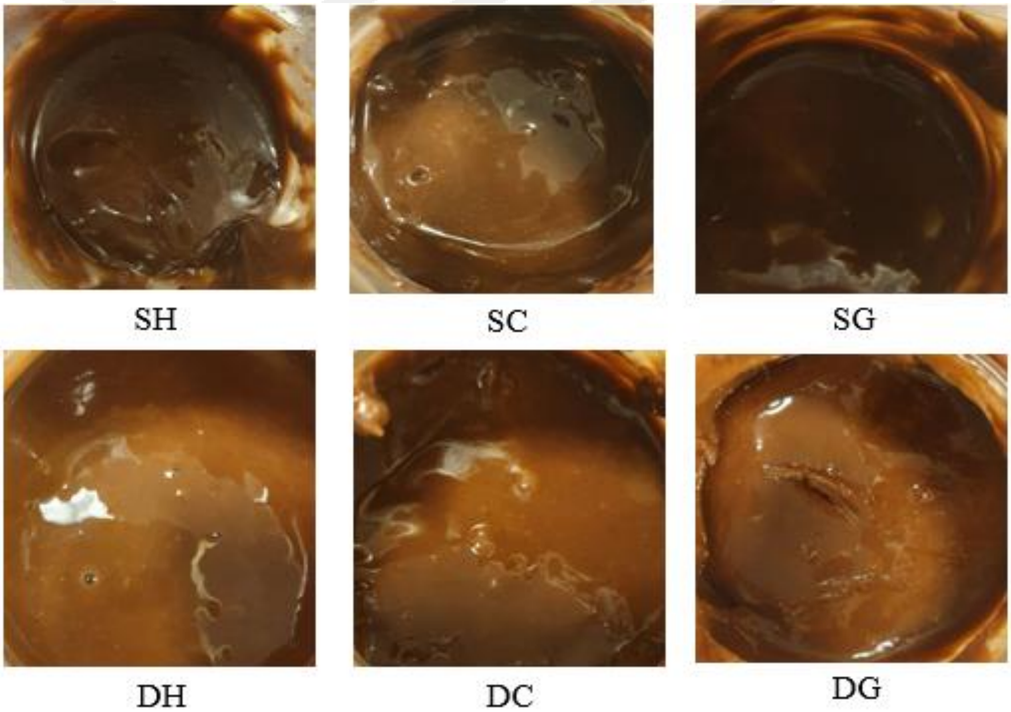

Figure 4.1: Pictures of prepared Samples

DH, prepared with date syrup. DC, with date syrup and collagen. DG with date syrup and green pea protein. SH, with refined sugar. SC, with sugar and collagen. SG, with sugar and green pea protein.

Dubost investigation on sensory analysis of peanut butter which enriched with soy protein showed that the consumer acceptability of samples was satisfactory, and the aroma and taste of that enriched sampleswas highly accepted when compared to commercial peanut butter. The sensory results of this study is simillar to current study (Dubost et al., 2003). According to Romanchik and Cerpovicz's investigation on sensory analysis of peanut butter crackers fortified with soy flour instead of wheat flour, the sensory results of color, smell, and texture showed that the samples fortified with 75% soy protein was highly acccpted. The resutls of this study is simillar to current study (Romanchik-Cerpovicz et al., 2011).

Table 4.1: Sensory evaluation

Sample	Color	Odor	Taste	Texture	Spreadability	Overall likeness
DH	6.50±0.86 [a]	6.13± 1.38 [bc]	5.93±1.70 [a]	5.86±1.73 [ab]	5.90±1.98 [ab]	6.23±1.22 [a]
DC	6.53±1.07 [a]	6.76± 1.1 [ab]	6.40±1.52 [a]	6.10±1.80 [ab]	6.16±1.51 [a]	6.43±1.19 [a]
DG	6.33±1.26 [a]	5.80±1.44 [c]	4.80±1.99 [b]	5.00±2.27 [b]	5.00±2.36 [b]	5.0±1.89 [b]
SH	6.90±1.06 [a]	6.90±1.12 [ab]	6.23±2.44 [a]	6.50±2.20 [a]	6.96±1.27 [a]	6.80±1.62 [a]
SC	7.00±1.05 [a]	7.06±1.04 [a]	6.50±1.83 [a]	6.70±2.21 [a]	6.53±1.33 [a]	6.60±1.40 [a]
SG	6.76±1.22 [a]	6.33±1.44 [abc]	5.86±1.75 [ab]	5.96±2.05 [ab]	6.86±1.04 [a]	6.40±1.47 [a]

Samples labeled with different superscript letters are significantly different ($P < 0.05$)
DH, prepared with date syrup. DC, with date syrup and collagen. DG with date syrup and green pea protein. SH, with refined sugar. SC, with sugar and collagen. SG, with sugar and green pea protein.

According to Tolve et al investigation on sensory analysis of hazelnut butter in which refined sugar was replaced with inulin and maltitol and fortified with vitamin D, the overall acceptance of the final product was greater than 6 and they concluded that the results were satisfying. The sensory results of this investigation is similar to sensory results of current study (Tolve et al., 2021). Shah investigated the chocolate in which sugar was replaced with Stevia, the sensory analysis showed that panelists preferred samples with sugar over samples prepared with Stevia. When the results of the current study about panelists' preferences for sugar and date syrup were compared, the sensory results revealed that samples containing sugar scored slightly higher than samples prepared with date syrup (Shah et al., 2010).

4.3 Color Measurements

The L*, a*, b*, Ch, and h values of the hazelnut butter samples are given in Table 4.2. The L*, b*, and Ch values of the samples prepared with refined sugar were higher than the samples prepared with date syrup ($P < 0.05$). The hue angle (h) values of the samples which contain sugar is slightly higher than the samples contain date syrup. ($P > 0.05$).

The interaction of sugar and protein did not affect the L* and a* values ($P < 0.05$). b, Ch, and h values were affected by sugar ($P < 0.05$) and not affected by protein addition ($P > 0.05$).

Table 4.2: Color values of the samples

Sample	L*	a*	b*	Ch	h°
DH	34.69±0.42 ^{a}	9.06±0.22 ^{a}	17.97±0.3 ^{bc}	20.13±0.36 ^{b}	1.1±0.005 ^{b}
DC	34.19±0.59 ^{a}	9.14±0.16 ^{a}	17.82±0.28 ^{bc}	20.03±0.31 ^{b}	1.09±0.005 ^{b}
DG	36.50±0.69 ^{a}	9.02±0.25 ^{a}	18.49±0.79 ^{abc}	20.58±0.82 ^{ab}	1.11±0.005 ^{ab}
SH	35.63±4.8 ^{a}	9.27±0.13 ^{a}	19.21±0.46 ^{ab}	21.34±0.4 ^{ab}	1.12±0.005 ^{ab}
SC	39.90±0.54 ^{a}	8.93±0.07 ^{a}	19.66±0.55 ^{a}	21.59±0.5 ^{a}	1.14±0.005 ^{ab}
SG	39.35±2.18 ^{a}	8.23±0.99 ^{a}	19.39±0.3 ^{a}	21.08±0.49 ^{ab}	1.17±0.005 ^{a}

Samples labeled with different superscript letters are significantly different ($P < 0.05$)
DH, prepared with date syrup. DC, with date syrup and collagen. DG with date syrup and green pea protein. SH, with refined sugar. SC, with sugar and collagen. SG, with sugar and green pea protein.

According to Leahu's research on walnut butter, which replaced sugar with maple syrup the color measurement results were similar to those of this study in terms of L* and b* values (Leahu et al., 2022).

The L* and a* values of chocolate spread in which sugar was replaced with grape pomace were similar to the current study (Acan et al., 2021).

In another study, in which Abhishek B, sugar was replaced with Stevia to analyze chocolate without sugar in color measurement the results were similar to the current study, the L* values were between 48 to 59 and a* values were between 9 to

14 and b* values were between 8 to 16 (Shah et al., 2010). The similarity indicates that the addition of date syrup and protein did not affect the color of the hazelnut butter, so it was satisfactory.

4.4 Emulsion Stability

The emulsion stability of samples is shown in Table 4.3, In general, the emulsion stability of samples was high and ranged between approximately 93% and 99%. The emulsion stability of the samples containing date syrup (DH, DC, DG) was higher than the others (SH, SC, SG) ($P < 0.05$). DG had the highest emulsion stability with 98.84%.

Long-term storage causes phase separation, which both the producer and the consumer find undesirable. In contrast, as oil builds up as a layer on the product's surface during storage, the product at the bottom of the package solidifies and becomes harder to use.To prevent this stabilization issue in hazelnut paste, the correct ratio of hazelnut, sugar, and stabilizer must be used, and conditions (temperature, time, homogenization, etc.) that do not disrupt stabilization must be determined. Even though there are many studies on oilseed pastes with functional properties, no studies were found that determined the compositions of hazelnut pastes enriched with different sweeteners or stabilizers during storage and the stabilization conditions for such pastes.

Table 4.3: Emulsion Stability of samples (%, w/w)

Sample	Emulsion stability (%, w/w)
DH	98.02 ± 0.54^{ab}
DC	96.98 ± 0.32^{b}
DG	98.84 ± 0.33^{a}
SH	94.08 ± 0.32^{c}
SC	93.68 ± 0.2^{c}
SG	94.54 ± 0.59^{c}

$^{a-b}$ Values labeled with different letters are different ($P < 0.05$).
DH, prepared with date syrup. DC, with date syrup and collagen. DG with date syrup and green pea protein. SH, with refined sugar. SC, with sugar and collagen. SG, with sugar and green pea protein.

According to Pourfarzad and Shokouhi's evaluation of hazelnut butter emulsion stability, the ES of samples was high and similar to the current study. High emulsion stability is an important factor in nut butter since they eliminate the separation of oil during storage and affects people's preference to purchase (Pourfarzad & Shokouhi Kisomi, 2020).

4.5 Rheological Properties

The consistency index (K), flow behavior index (n) and apparent viscosity (μa), and thixotropy values of the samples calculated according to the power law model are given in Table 4.4. It was observed that the viscosity of all samples decreased with increasing shear rate and showed pseudoplastic flow behavior, which is shown in figure 4.2.

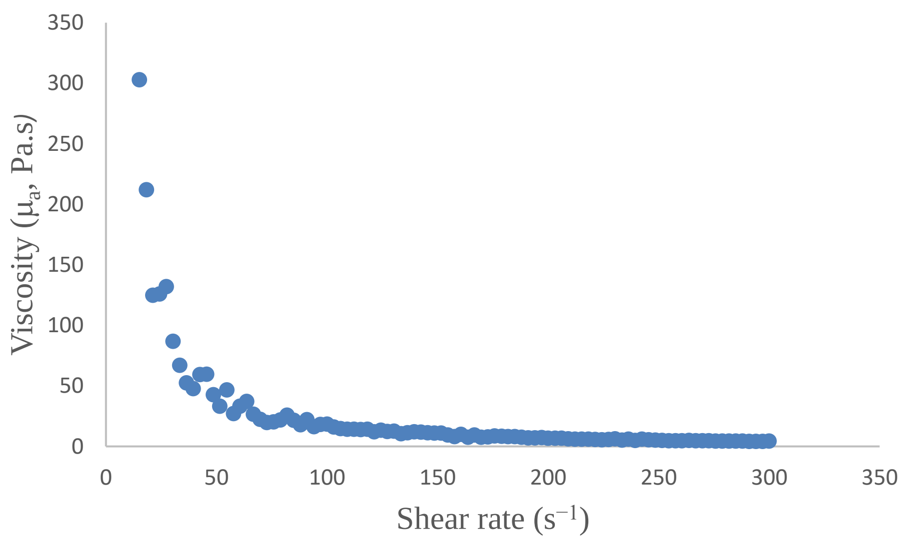

Figure 4.2: Viscosity curve of the DC sample

The flow behavior of hazelnut butter is very important in determining the stability of the product (Leahu et al., 2022). The flow behavior index (n) of the samples that contain date syrup was significantly different and higher than samples that contain sugar ($P < 0.05$).

The K and μa value of DH, DC, and DG samples, which contain date syrup, was higher than the samples prepared with refined sugar ($P > 0.05$). The thixotropy value of SG is significantly different from other samples, DH, DC, DG, SH, and SC showed simillar thixotrophy vlues($P < 0.05$). When the incent and decent shear rate curves of the samples were compared, it was observed that they showed thixotropic properties (Table 4.4).

Table 4.4: K, n, μ_a, and thixotropy values of the samples

Sample	Consistency index (K, $Pa.s^n$)	Flow behavior index (n)	Apparent viscosity (μ_a, Pa.s)	Thixotropy (kPa s^{-1})
DH	47.80±30.35 ^{a}	0.32±0.05 ^{b}	1.87±0.42a ^{a}	313.667±74.84 ^{a}
DC	32.58±16.06 ^{ab}	0.38±0.11 ^{b}	2.7±0.70 ^{a}	283.600±43.59 ^{a}
DG	37.76±7.37 ^{ab}	0.32±0.06 ^{b}	2.74±1.21 ^{a}	286.850±4.59 ^{a}
SH	2.42±2.10 ^{b}	0.77±0.01 ^{a}	0.82±0.25 ^{a}	347.050±3.32 ^{a}
SC	4.23±1.37 ^{b}	0.73±0.04 ^{a}	1.80±0.56 ^{a}	268.133±16.16^a
SG	6.25±3.60 ^{b}	0.84±0.08 ^{a}	2.20±0.24 ^{a}	129.933±10.50 ^{b}

$^{a\text{-}b}$ Values labeled with different letters in a column are different ($P < 0.05$).
DH, prepared with date syrup. DC, with date syrup and collagen. DG with date syrup and green pea protein. SH, with refined sugar. SC, with sugar and collagen. SG, with sugar and green pea protein.

Rheological analysis of chocolate in a study which sugar was replaced with Stevia to produce sugar-free chocolate, showed non-Newtonian shear thinning behavior. Their flow behavior indexes were lower than 1 indicating slight shear thinning behavior above the yield stress (Shah et al., 2010).

The rheological analysis of walnut butter prepared with maple syrup exhibited non-Newtonian shear thinning behavıor and showed excellent stability. (Leahu et al., 2022)

The flow behavior and consistency index results of a study that investigated on rheological properties of chocolate spread in which sugar was replaced with grape pomace are similar to current research. (Acan et al., 2021)

Yıeld stress is a material property denoting minimum shear stress needed to induce the flow i.e. its transition from elastıc to viscous deformation (Afoakwa et al., 2008). Table 4.5 shows that the yield stress of samples and yield stress of samples are not significantly different (P < 0.05).

Table 4.5: Yield stress and overcross values of samples

Samples	Yield stress (Pa)	Overcross G'= G''
DH	0.48±0.35 ^{a}	189.22±0.54 ^{a}
DC	0.22±0.06 ^{a}	106.85±2.52 ^{bc}
DG	0.81±0.46 ^{a}	135.40±30.12 ^{b}
SH	1.24±0.58 ^{a}	18.55±1.20 ^{d}
SC	0.52±0.37 ^{a}	55.64±7.10 ^{cd}
SG	0.36±0.33 ^{a}	25.47±4.68 ^{d}

a-b Values labeled with different letters in a column are different (P < 0.05).

DH, prepared with date syrup. DC, with date syrup and collagen. DG with date syrup and green pea protein. SH, with refined sugar. SC, with sugar and collagen. SG, with sugar and green pea protein.

The Analysis of Variance with crossover values showed that the samples containing collagen, green pea protein, and without protein were not significantly different (P <0.05). On the other hand, replacing sugar with date syrup significantly affected the overcross values.

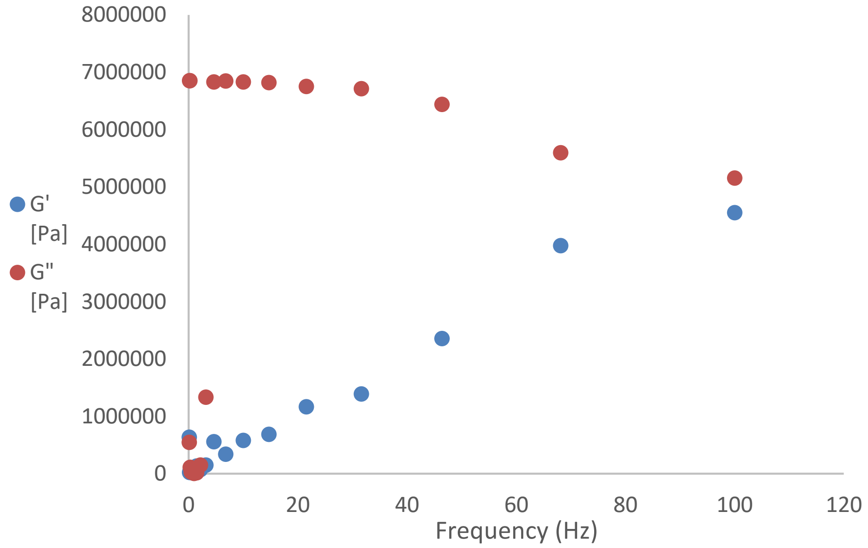

Figure 4.3: G′ G″ values of DC sample

In all samples, the storage or elastic modulus (G″) valueswere higher than the loss or plastic modulus (G′) values which shown in figure 4.3 and this showed that the viscous behavior dominated over the elastic behavior.

5. CHAPTER

CONCLUSIONS

People nowadays prefer to consume less sugar and replace it with alternative sweeteners. The importance of protein consumption, on the other hand, has become apparent in the majority of the world, and people prefer high-protein foods. Alternatives to conventional sweeteners have been sought by researchers, particularly for use in chocolates, cacao-hazelnut spreads, candies, and dairy products. Hazelnut butter with cacao has recently become popular due to its high sugar content.

The goal of this study is to promote hazelnut butter by replacing refined sugar with date syrup due to its high nutritional value and enriching it with green-pea protein and collagen, as well as to analyze the changes in quality. Six different formulations were tested for sensory, color, emulsification stability, rheology, and stress sweep properties.

Sensory analysis revealed that the inclusion of collagen in hazelnut butter did not affect the sensory properties of the samples when compared to the samples that did not contain collagen. The overall acceptability of green pea protein samples was lower than that of collagen samples. The substitution of date syrup for refined sugar reduced the overall acceptability of the samples. The SC samples had higher odor scores than the D and DG samples. The panelists disliked the odor of DG more than the odor of D.

The emulsion stability of the samples was extremely high, ranging from 93% to 99%. The sample, which was made with date syrup and green pea protein, had the highest emulsion stability of 98.86%. The viscosity of all samples decreased with increasing shear rate and showed pseudoplastic flow behavior, and the flow behavior index (n) of samples was similar. The date syrup samples had higher Consistency index (K) values than the refined sugar samples. When the samples' incent and decent shear rate curves were compared, it was discovered that they had thixotropic properties. In all samples, the storage modulus values (G″) were higher than the loss modulus (G′) values and this showed that the viscous behavior dominated over the elastic behavior.

In conclusion, replacing table sugar with date syrup did not negatively affect the sensory properties of samples, therefore can be used as a sweetener in hazelnut butter. While collagen added to hazelnut butter produced satisfactory results, collagen-added samples performed better than samples that contain green pea protein. Overall the rheological properties of enriched samples were not changed in compare to samples withour protein and replaced sugar with date syrup.

APPENDIX

A.1

HEDONIC TEST

Assessor:

Date: 25.11.2022

Product: Hazelnut butter

Instructions:

You are provided with six hazelnut butter cacao spread samples, each labeled with a three-digit code. Assess each sample from left to right and evaluate using the scale given below.

<u>Scale:</u>

9 – like extremely

8 – like very much

7 – like moderately

6 – like slightly

5 – neither like nor dislike

4 – dislike slightly

3 – dislike moderately

2 – dislike very much

1 – dislike extremely

Sample code	Odor	Color	Taste	Texture	Spread-ability	Overall acceptance

Which of the samples do you prefer? ________

Comments:

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