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Making Butter and Milk from Plants: An Investigation into Plant-Based Butter as a Novel Approach

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Abstract: Plant-based milk and dairy analogues are gaining increasing attention as sustainable alternatives to animal-derived products, which are often associated with environmental and health concerns. This study aimed to develop and characterize a novel plant-based butter produced from flaxseed milk. Flaxseed was processed to obtain plant-based milk, which was subsequently used to formulate a plant-based butter. The product was evaluated in terms of sensory acceptance, pH, titratable acidity, dry matter, color parameters, and fatty acid composition. Sensory analysis indicated that flaxseed-based butter exhibited acceptable consumer attributes. Fatty acid profiling revealed nine compounds, with lauric acid (38.42%), oleic acid (18.36%), and myristic acid (15.16%) identified as the predominant fatty acids. The findings demonstrate that flaxseed-based butter has promising potential as a sustainable alternative in the category of plant-based dairy products, owing to its favorable sensory properties and suitable fatty acid profile.

Keywords: Butter quality, fatty acid profile, flaxseed milk, plant-based food, sustainability, vegan diet

INTRODUCTION

In recent years, the demand for plant-based dairy alternatives has increased substantially due to environmental concerns, lactose intolerance, and the rise of veganism. Plant-based butter alternatives are particularly relevant because of their favorable lipid profiles and cholesterol-free nature. Various studies have described the sensory, nutritional, and chemical properties of these alternatives, highlighting their potential benefits and market viability. These products have been formulated to meet the increasing demand for dairy-free options due to health, ethical, and environmental reasons. In addition, a number of factors, including lactose intolerance and cow's milk allergies, are contributing to the expansion of the market for plant-based milk substitutes made from various plants. Thematic summary of key scientific studies on plant-based dairy products in present studies is given in the Table 1.

Plant-based alternative milk products are non-dairy drinks made from aqueous plant extracts that are intended to provide a creamy mouthfeel, flavor, aroma, and appearance (Sıddıquı et al., 2024). Plant-based milk alternatives are suspensions derived from the size reduction of plant materials, including cereals, pseudo-cereals, legumes, oilseeds, and nuts, which are extracted in water and subsequently homogenized (Fernandez et al., 2018). This process yields a particle size distribution that resembles the consistency and appearance of bovine milk (Paul et al., 2019). Plant-based milk alternatives can be classified according to the raw materials used: those based on grains like oats, rice, and corn; those based on legumes like soybeans, peanuts, fava beans, and chickpeas; those based on nuts like almonds, coconuts, hazelnuts, and walnuts; those based on seeds like sesame, flaxseed, hemp, and sunflower; and those pseudo-cereals like quinoa, teff, and amaranth (Altınay and Şanlı, 2023). The food industry is looking for opportunities to develop their availability of plant-based replacements in the current market due to the increased interest in plant-based foods.

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Table 1. *Thematic summary of key scientific studies on plant-based dairy products*

Topic	Study & Author (Year)	Significance
Environmental Impact	Ramsing et al., (2023); Kanyama (2021)	Evaluation of carbon & water footprint; environmental sustainability
Microstructure & Emulsion	Olsmats et al., (2025); Quezada et al., (2024)	Structure analysis of milk analogues via USAXS/SAXS; flaxseed-based emulsion stability
Emulsion Stabilization	Vallath et al., (2022); Lapčíková et al., (2024)	Use of ultrasonication and mono-/diglycerides to enhance physical stability
Plant Protein Structuring	Chen et al., (2024); Yiu et al., (2023)	Structural enhancement of emulsions using potato, pea, and soy proteins
Nutrition and Fortification	Craig (2023); Johnson et al., (2025)	B12 and D vitamin enrichment; effects on child health and growth outcomes

In the production of plant-based milk alternative products, pre-treatments such as soaking in water/alkali, peeling, roasting, or germination can be applied to the raw materials to enhance the nutritional and sensory properties of the final product. After the pre-treatments, the plant material to be used is ground in an aqueous environment or dry, and then the coarse particles are separated and filtered (Sethi et al., 2016; Gobbi et al., 2019; Silva et al., 2020; Reyes-Jurado et al., 2023). To improve the quality characteristics of the final product, such as viscosity and taste-aroma, thickeners, sugars and sweeteners, flavoring agents, and oil can be added (Altınay and Şanlı, 2023). Plant-based, water-soluble extracts prepared as milk can be considered a substitute for cow's milk, but they require supplementary components to bring their composition and nutritional quality close to that of cow's milk. This enrichment can be achieved by adding additives or by combining two or more plant-based raw materials (Silva et al., 2020). The nutritional values of plant-based milks may be lower than those of cow's milk (Munekata et al., 2020). Therefore, considering the potential deficiencies in protein, fatty acids, vitamins D and B12, calcium, iron, zinc, and iodine that may be observed in vegan individuals, it is necessary to supplement the deficiencies in plant-based butter produced with alternative foods (Escobar et al., 2022).

Flaxseed is an important oilseed that is rich in high-quality protein and soluble fiber, as well as phytochemicals such as α-linolenic acid, flavonoids, lignans, and phenolic acids. Flaxseed is generally classified as a "functional food," "bioactive food," and/or "endocrine-active food." (Işleroglu et al., 2005). Products produced from flaxseed protein show appropriate emulsion activity, stability, and water absorption (Özcan and Değerli, 2019). Thanks to its high fiber content, it is effective in preventing diseases such as diabetes, heart diseases, colon and rectum cancer, and obesity (Işleroglu et al., 2005). Flaxseed (*Linum usitatissimum*) typically contains 18% to 25% protein by weight. After oil extraction, the resulting defatted flaxseed meal may contain up to 30%–35% protein, making it a valuable source of plant-based protein supplements in food applications (Bhatty and Cherdkiatgumchai, 1990; Özcan and Değerli, 2019). Flaxseed protein contains most essential amino acids and is particularly rich in arginine, glutamine, and branched-chain amino acids (BCAAs). However, its relatively low lysine content suggests it should be combined with other protein sources to ensure a balanced amino acid profile (Oomah and Mazza, 1993). Flaxseed is widely recognized for its rich content of alpha-linolenic acid (ALA, omega-3), lignans, dietary fiber, and plant protein, positioning it as a valuable functional food. Its potential integration into various food matrices, such as bread, pastries, yogurt, and butter substitutes, has been explored in global and regional contexts (Bloedon and Szapary, 2004).

Although traditional Turkish cuisine does not commonly use flaxseed, recent research (e.g., Marpalle et al., 2014) has examined its incorporation into functional bakery products, such as tarhana, simit, and cookies, for enrichment purposes. These studies highlight that flaxseed can improve nutritional density and health claims without significantly altering sensory acceptability.Within the scope of Anatolian food heritage and modern reinterpretation, studies such as how ancient grains and seeds (including flaxseed) can be reintegrated into contemporary Turkish cuisine under the concept of functional traditional foods should be addressed.

Peanuts, legumes, seeds, and beans are high-fat plant-based main sources that contribute to making plant-based butter-like spreads. In addition to their high fat content, these spreads are high in fiber, protein, essential fatty acids, and other nutrients. The main challenges to producing high-quality plant-based butter-like spreads are oil separation, textural and spreadability characteristics, and the product's stability and shelf life. Since the stability and rheological properties of plant-based butter-like spreads are influenced by the amount of oil in the formulation, stabilizers and emulsifiers are typically added to enhance the product quality (Ningtyas, 2023).

The potential use of alternative sources such as whey cream for butter production is being researched; this shows that the dairy industry has a promising path for innovation in the plant-based sector. Butter obtained from whey cream shows the potential to develop a product with higher added value, excellent nutritional properties, and suitable sensory properties (Costa et al., 2022). Bilici (2022); conducted a study on obtaining milk from dry beans as an alternative plant source and producing a new pastry cream from this milk that could serve as a reference for the pastry industry. It has been observed that the milk and cream obtained from it are more delicious and more preferable than the normal pastry cream obtained from animal milk. Overall, the literature shows a strong interest in plant-based butter examples driven by nutritional benefits, sensory appeal, and technological advancements. Ongoing research in this field not only enhances our understanding of these products but also supports the development of new formulations that align with consumer preferences. In this research, the development of a plant-based butter alternative has taken an important step in terms of health, sustainability, and culinary innovation.

The primary objective of this study is to develop a natural, plant-based butter formulation enriched with plant protein as an alternative to traditional animal-derived butter. In response to the increasing consumer demand for healthier and more sustainable dietary options, this research focuses on utilizing flaxseed—a nutrient-dense oilseed rich in protein, soluble fiber, and phytochemicals. A novel recipe was developed using flaxseed milk and other natural ingredients to create a functional plant-based vegan butter product. This study aims to address the limited variety of commercially available vegan products, particularly for individuals adhering to plant-based diets, while also contributing to the reduction of health issues associated with the consumption of animal milk and minimizing environmental impact. The obtained plant-based butter was subjected to both chemical analysis and sensory analysis to evaluate its overall consumer acceptability.

MATERIALS and METHODS

Materials

During the preparation process of the milk, flaxseed (*Linum usitatissimum*), (Yayla®, origin: Kazakhstan) obtained from the market in Iğdır was used as a material. For coloring, turmeric has been the deficiencies in protein, fatty acids, vitamin D and B12, calcium, iron, zinc, and iodine preferred. To balance its density, olive oil (Yudum) was used as a vegetable oil, coconut oil (Wefood) to enhance its flavor, vinegar as an acidity regulator, salt to extend its shelf life, and nutritional yeast (Naturiga) for its high protein and fiber content as well as its dairy product flavour. Considering that may be seen in vegan individuals, the content and deficiencies of plant-based butter to be produced with these alternative foods have been tried to be completed.

Methods

Plant-based milk and butter production

In the preparation stage of the plant-based milk, as per the recipe we used, approximately 100 mL of plant-based milk is obtained by soaking 200 gr of seeds overnight at refrigerator temperature to increase yield. Then, the water was drained and washed with clean water. Subsequently, the mixture was blended using a high-speed homogenizer, and about 1 liter of water was added as a supplemental material. The blending process was carried out in a blender. It was rested in a container for 3 hours. Finally, it was strained with the help of a cloth. The pulp has been separated, and our plant-based milk is prepared in this way (Bilici, 2022; Daryani et al., 2024).

During the butter production stage, the flaxseed milk was mixed with 200 mL coconut oil, 50 mL olive oil, 4 g nutritional yeast, 8 g salt, 5 mL apple cider vinegar, and 2 g turmeric. The mixture was emulsified using a homogenizer (Stilevs blender set,1500 W) and frozen at -18 °C for 2 hours. After this period, the plant-based butter was fully set and ready for use (Oracz, 2025).

Chemical Analyses

Water content

The water content of the samples was analyzed according to the TS 1331/T1 Butter Standard (TSE, 2015).

pH

Butter samples were melted and measured in a water bath (WiseBath) not exceeding 40 ºC using a digital pH meter (Mettler Toledo). The pH meter was calibrated before analysis. pH 4.00, pH 7.00, and pH 10.00 buffer solutions were used for calibration (AOAC,1992).

Titration acidity

Approximately 5 g of butter sample was weighed for the purpose of determining the titration acidity value. After mixing 50 mL of alcohol and ether (1:1), 2 drops of 1% phenolphthalein were added, and the titration process was carried out with 0.1 N NaOH solution. The titration acidity of the oil was measured in terms of lactic acid percentage (TSE, 2015).

Color

Butter samples were measured for color at different points on their surfaces using a colorimeter (Konica Minolta CR-400, Japan). By averaging the values, for example, color measurements will be expressed using the CIE ($L*$, $a*$, $b*$) color system. The $L*$, $a*$, and $b*$ values represent lightness, greenness/reddishness, and blueness/yellowness, respectively.

Efficiency

The yield of the produced butter (%) has been calculated as shown in the Equation.1 below (Aydemir, 2024).

$$Efficiency = {}^{T}/_{S} * 100 \quad (1)$$

Here;

T = Amount of Butter (g), S = Amount of Milk (g)

Sensory analysis

The produced plant-based butter samples were subjected to a sensory analysis test by a panel of 40 participants (students and faculty members). Panelists were informed prior to the sensory analysis. Panelists tested the samples in terms of appearance, color, smell, taste, consistency, spreadability, and overall acceptability while conducting the sensory analysis. Panelists evaluated the analyses by rating them on a scale of 1-5 (1=did not like at all, 5=liked very much). The 5-point sensory scale (5-point hedonic scale) method allows for the evaluation of the product's acceptability and quality characteristics (Bilici, 2022).

Fatty acid composition

The analysis of fatty acid composition was conducted using gas chromatography as a service obtained from the Iğdır University ALUM Application and Research Center. The operating parameters of the device are as follows: injection block (SPL): 225 °C, split: 1/10, flow mode: linear velocity, column temperature program: 100 °C-4 min. Temperature increase: 3 °C- 1 min (240 °C- 20 min), detector temperature: 250 °C, sampling rate: 40 m/s (AOAC, 2000) have been set.

Statistical analysis

In the butter samples, all analyses were performed in triplicate (n=3), and the data are expressed as mean ± standard deviation.

RESULTS and DISCUSSION

The quality parameters of the produced butter sample were evaluated. The butter sample was examined for pH, titration acidity, water content, color, yield, fatty acid composition, and sensory analysis. According to earlier research, the most popular plant-based butter substitute is peanut butter, according to an American survey. New types, including soy, almond, cashew, pistachio, and sesame oil substitutes, are being created lately in response to peanut allergy (Plamada et al., 2023). Nonetheless, it seems that there aren't many scientific studies on plant-based butter. Ongoing studies in this field should provide best practices for developing and producing high-quality plant-based butter alternatives.

The pH, water content, titration acidity, and yield values of the samples are given in Table 2. The water content of the plant-based butter was found to be 28.63%, pH 4.66, titration acidity (lactic acid) 0.19%, and yield 65.86%.

The pH values of plant-based butter samples are critical parameters that affect their stability, sensory properties (taste, texture, etc.), and overall quality. Research shows that the pH value of plant-based oils can very significantly depending on the materials used and the production methods applied. The pH range obtained in this study is an indicator of the stability and quality of the butter because more acidic environments can inhibit the growth of spoilage microorganisms, thereby extending the shelf life. In contrast, Bilici (2022) calculated the pH values of pastry cream samples in a study on plant-based pastry cream obtained from dry bean milk, finding them to be in the range of 6.35 to 6.85. Additionally, Fatemizadeh et al., (2017) emphasized that traditional butter products have a higher pH value; this can lead to increased microbial activity and spoilage over time due to the proliferation of acid-producing bacteria.

Table 2. *Chemical analysis results of plant-based butter*

Parameter	Unit	Concentration
pH		4.66±0.03
Titration acidity	grams lactic acid / 100 g	0.19±0.02
Water content	grams / 100 grams	28.63±0.83
Yield value	grams / 100 grams	65.86±1.04

In animal butter samples, pH values, qualities, stabilities, and safety are important indicators. These values can be affected by various factors such as the type of milk used, processing methods, and storage conditions. The research conducted by Ahmed et al., (2022) found that the pH values of cooking butter samples ranged from 5.0 to 7.3, with an average of 6.02. Additionally, a comparative study was conducted on butter produced from different animal milks (cow, sheep, and goat), and it was found that the pH values significantly changed over a 90-day storage period (Çakmakçı and Kahyaoğlu, 2018). This suggests that pH can serve as an important quality control measure throughout the shelf life of butter. Idoui et al., (2013) reported a pH range of 3.92 to 4.31 in their studies on traditional butter produced from goat milk. Eser and Inanç (2022) produced Anatolian buffalo butter using different methods in their studies and found the pH value of the milk to be 6.54, while the pH value of the churned butter was 5.01, lower than that of the cream butters (5.07-5.36). Ayar et al., (2006) and Eser and Inanç (2022) found higher pH values in their studies on butter compared to this study. It has been determined that the results of this study are similar to the studies conducted by Sağdıç et al. (2004), Idoui et al. (2010), and Idoui et al. (2013).

Daryani et al. (2024) report that unfermented plant-based milks—such as soy, almond, and oat milks—typically exhibit pH values between 6.60 and 6.83, which closely resemble that of bovine milk (pH ~6.7). Tachie et al. (2023) offer a comprehensive review that includes pH implications, noting that acidity regulation is a crucial factor in formulation stability, microbial safety, and consumer acceptance—even though concrete pH values are context-dependent. Tapia (2025) examines how fermentation-induced acidity influences flavor development in plant-based butter analogs, noting that key aroma compounds form when the pH drops below 5—though pH tends to rise above 5 after 24 hours of fermentation.

The titration acidity of plant-based and animal-based butter is an important parameter that reflects the quality and freshness of the product. While there is no limit for acidity in the Turkish Food Codex Butter, Other Dairy Fat-Based Spreadable Products, and Ghee Regulation, the TS 1331-Butter Standard states that the titratable acidity (in terms of lactic acid) should not exceed 0.27 (TSE, 2015). According to the obtained results, our sample complies with the standard. In some studies (Fındık, 2011; Akgül, 2015; Sevmiş et al., 2020), the titration acidity values of the animal butters determined were higher than the results of the current study. In Erzurum butter, the titration acidity was determined to be 0.14-0.28% for those obtained from family businesses and 0.11-0.32% for those obtained from dairies (Çelik and Bakırcı, 2000). The results of the current study are consistent with the study conducted on Erzurum butter and Ankara butter (titration acidity 0.043-0.163) (Atamer and Kaptan, 1982). The titration acidity of the milk was found to be 0.19%, while in buffalo butter, it ranged from 0.18% to 0.41%. The titration acidity values of sweet and sour cream butters were found to be similar to the results of this study, while the titration acidity of churned butter was found to be high (Eser and Inanç, 2022). These findings are also important for plant-based butters, as differences in formulation and content composition can similarly affect acidity levels. Overall, acidity measured by titration serves as a vital quality control criterion for both plant-based and animal-based butter samples and this can have a significant impact on flavor, texture, and shelf life. Ongoing research in this field will continue to enhance our understanding of how titration acidity affects the overall quality of butter products and will guide producers in optimizing formulations and storage conditions.

The water content of butter samples is another important factor that affects their quality, stability, and sensory properties. Butter is primarily based on milk fat, but it also contains varying amounts of water, protein, and other components. Understanding the water content of animal and plant-based butters is important for evaluating their overall quality and shelf life. The water content in traditional animal butter is generally regulated by food standards. According to the European Council Regulation (No. 2991/94), butter must contain at least 80% milk fat and no more than 16% water (Warrier et al., 2014). This regulation ensures that while preserving the unique texture and flavor of butter, it minimizes the risk of spoilage. In this study, for example, the water content was found to be 28.63%. Vioque-Amor et al. (2023) found the moisture content in different types of commercially produced butter in Spain to be around 14.99%, while they reported it to be 58.89% for low-fat butter made from cow's milk. The water content of the butter samples made from goats', ewes' or cows'were determined 15.20, 14.40 and 15.65%,respectively (Sağdıç et al., 2004). Kahyaoğlu and Musaoğlu (2022) determined the moisture content of the samples as the lowest 12.02% and the highest 21.86%. Moisture and impurities values of butter samples ranged from 16 to 35.73% and 9.25 to 12.25% respectively. The moisture level in all butter samples is higher than the international standard (0.05% to 2%). (Idoui et al., 2013). Sağdıç et al. (2004), Kahyaoğlu and Musaoğlu (2022) found lower water content in their studies on butter compared to this study, while the results of Idoui et al. (2013) are consistent with this study. For animal butter, regulatory standards determine acceptable moisture levels to ensure product integrity, while plant-based butters may exhibit varying water content depending on the formulation. With the studies to be conducted, the product formulation can be optimized, and research can continue for plant-based butters. The water content of plant-based margarine can vary depending on its formulations. The water content of vegetable oils can vary widely depending on the type of oil and emulsifier used (Costa et al., 2019).

Yield is the ratio of the amount of product obtained to the amount of raw material. It has been calculated based on the quantities of milk and butter. The yield values of butter samples are critical indicators because they directly affect the efficiency, effectiveness, economic sustainability, and quality of the final product in the butter production process. These values can vary significantly depending on various factors such as the source of milk or cream, the extraction methods used, and specific processing conditions. In animal butter production, yield values can be affected by the type of milk used. For example, in a study by Becskei et al. (2020), a significant difference in the yield of butter obtained from buffalo milk and cow cream was demonstrated. This is related to the higher fat content and more stable fat composition in buffalo milk, which provides better emulsification and less fat hydrolysis during processing. The study confirmed that buffalo butter not only has a higher yield but also exhibits greater stability, making it a preferred option in certain markets. Additionally, Aydemir (2024), who examined the efficiency of butter produced from butter and milk fat, reported that the cream obtained from butter had a fat content between 78.23% and 79.97%. This study emphasizes the importance of the composition of the initial materials in determining the yield and quality of the final butter product. Additionally, yield values can also be affected by processing conditions. For example, Siddique et al. (2011) reported that when standardized cream with a fat level of 35% was whipped at 10°C, a fat yield of 88% was achieved. This finding suggests that optimizing the churning conditions can significantly increase butter yield, which is critical for maximizing production efficiency. In this study, the yield of plant-based butter was found to be an average of 65.86%. Şahin et al. (2014) investigated the relationship between somatic cell count and milk composition by dividing 149 Anatolian buffalo into two groups based on somatic cell count. In the group with low somatic cell counts, the fat content was found to be 5.356%. In the group with high somatic cell counts, the fat content was calculated as 6.163%. Eser and Inanç (2022) found the yield of churned butter to be 8.5%, while the yield of cream butter was reported to be lower than this study, at 7-8.75%. The yield values of the butter samples are influenced by various factors such as the type of milk or cream used, extraction methods, and processing conditions.

The color parameters of the analyzed butter sample, *L** coordinate (lightness), *a** coordinate (red-green), and *b** coordinate (yellow-blue), are shown in Table 3. The color values of the butter samples are fundamental quality parameters that significantly affect consumer acceptance and perception. The color of butter is essentially determined by the presence of carotenoids, particularly β-carotene, which gives it a yellow tone. The intensity of these pigments can vary depending on various factors such as the type of milk used, the animals' diet, and the processing methods applied. Additionally, the shelf life of butter is closely related to the stability of its color. Mehdizadeh et al. (2019) stated that oxidative changes during storage affect the sensory properties of butter, such as its color. As butter undergoes oxidation, its color may fade or change, which can lead to consumer rejection. Therefore, it is very important to maintain the color integrity of butter to ensure its marketability.

Table 3. *Color parameters of plant-based butter*

Parameter	Results
*L**	78.76±1.82
*a**	(-) 5.48±1.10
*b**	30.66±1.57

In this study, the *L** value of the plant-based butter sample was determined to be 78.76, the *a** value (-) 5.48, and the *b** value (+) 30.66. Bilici (2022) found the *L** values of the pastry creams obtained from plant-based dry beans to be between 63.02 and 67.32, the *a** values between (+)5.02 and (+)5.52, and the *b** values between (+)10.86 and (+)11.06. Kahyaoğlu and Musaoğlu (2022) reported the *L** and *a*, b** values as 82.98, -2.94, and +21.51, respectively, in butter samples produced in the central villages of Kastamonu province. When the studies are examined, the *L*, a*, b** values in Trabzon butter were determined to be 72.08-88.22; (-)0.89- (-)4.42; (+)21.73- (+)45.12 (Akgül, 2015), and in Erzurum butter, they were determined to be 79.76- 86.51; (-)5.21- (-)2.15; (+)13.80- (+)42.18 (Çakmakçı et al., 2020). Considering the average values, it has been observed that the *L** and *a*, b** values determined in this study are in harmony with the values in the other studies.One of the main factors affecting color is the type of fat used. For instance, formulations containing olive oil tend to produce a more yellow hue, while those with coconut oil result in lighter colors. Natural color additives, particularly turmeric, have been shown to significantly enhance the b* (yellowness) value, making the product visually closer to conventional butter The pH level also plays a key role in color stability; compounds such as anthocyanins and phenolics tend to be more color-stable at lower pH values (Kahyaoğlu and Musaoğlu, 2022).

In Table 4, the acceptability and quality characteristics of the plant-based butter sample were evaluated using a 5-point hedonic scale method.

Table 4. *Sensory evaluation scores of plant-based butter*

Sensory Evaluation	***Score***
Color	4.65 ± 0.66
Taste	4.46 ± 0.84
Odor	4.56 ± 0.74
Appearance	4.61 ± 0.80
Spreadability	4.49 ± 0.87
Overall Acceptance	4.61 ± 0.69

1-5 score (1=I didn't like it at all, 5=I liked it a lot)

According to the sensory analysis results of the panelists, the highest scores were determined in color, appearance, and odor, while the lowest scores were in taste and spreadability. The overall acceptability average of the product was found to be 4.61. These findings are consistent with the results of Wang et al. (2025), who emphasized the role of emulsifiers and oil blending in achieving desirable texture.

This analysis contains various sensory characteristics such as taste, aroma, texture, and appearance that affect the overall perception of the product. One of the key factors in sensory evaluation is flavor; this is influenced by elements such as the composition of the butter, fat content, and the presence of volatile components. According to Aydin and Kahyaoğlu (2020), flavors are emphasized as one of the most important factors for consumer acceptance of butter. Texture is another important sensory characteristic that affects consumer preference. The texture of butter can be influenced by the fat composition and processing methods. Ullah et al. (2020) emphasized the importance of preserving the desired textural properties in butter formulations for ensuring consumer satisfaction. The appearance of butter, especially its color, is an important sensory characteristic. Silva et al. (2023) found that the organoleptic properties of sheep butter, including its color, were well received by consumers. This situation highlights the importance of visual appeal in butter products. The color of butter is often associated with freshness and quality; vibrant yellow tones generally indicate higher levels of carotenoids, which is a desirable characteristic in many markets.

Sensory analysis is important not only for traditional milk fats but also for newly emerging plant oil products. In his study, Bilici (2022) produced three different soy milk samples with the same content but varying in weight, and from these milks, he obtained three different pastry creams with the same content. The sensory analysis results among the panelists indicated that the most liked pastry cream was the one obtained from the soy milk produced from 300 grams of soybeans. The general opinion of the panelists was that it was more delicious and more preferable than the control (animal origin) cream.

Plant-based butters and milks may exhibit beany, earthy, or bitter notes due to the inherent composition of legumes or seeds, especially in flaxseed- or soy-based formulations (Altınay and Şanlı, 2023). Additionally, the lower lipid complexity compared to dairy fat contributes to differences in mouthfeel and creaminess (Fernandes et al., 2018). The choice of plant raw material, oil phase (e.g., coconut, sunflower, shea butter), and use of natural additives (such as turmeric for color, nutritional yeast for umami) significantly influence sensory scores. While coconut oil helps enhance texture and melting behavior, strong flavors must be masked through emulsifier systems or flavor modulators (Sethi et al., 2016; Idoui et al., 2010). Studies indicate that spreadability and appearance scores in optimized formulations are comparable to traditional dairy butter, yet flavor and odor may still lag slightly behind, indicating the need for continued refinement in flavor standardization (Altınay and Şanlı, 2023; Fernandes et al., 2018).

The fatty acid composition, nutritional value, sensory properties, and health effects of butter samples are important parameters. Whether of animal or plant origin, butter contains a complex mixture of fatty acids that can vary significantly depending on factors such as the type of milk or cream used, the animals' feeding methods, and the processing techniques applied. In the analysis of the fatty acid compositions of butter samples, 9 distinct fatty acids were identified. The fatty acid profile (expressed as a percentage) is presented in Table 5. The identified fatty acids are categorized into groups as follows: SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; ωFA, omega fatty acid

Table 5. *The average fatty acid composition of palnt-based butter (%)*

The fatty acids	Fatty acid groups	%
C6:0 Caproic acid	SFA	0.692 ±0.033
C8:0 Caprylic acid	SFA	7.953 ±0.267
C10:0–Capric acid	SFA	5.165 ±0.127
C12:0–Lauric acid	SFA	38.424 ±0.098
C14:0–Myristic acid	SFA	15.162 ±0.288
C16:0–Palmitic acid	SFA	8.709 ±0.039
C18:0–Stearic acid	SFA	2.899 ±0.061
C18:1C (n-9)–Oleic acid ω9	MUFA/ ω9FA	18.364 ±0.544
C18:2C(n-6)–Linoleic acid ω6	PUFA	2.541 ±0.120

*SFA: saturatedfattyacids, MUFA: mono-unsaturated fatty acids, PUFA: poly-unsaturated fatty acids, ωFA: Omega fatty acids

In the samples, the highest fatty acid percentage was lauric acid (38.424%), while the lowest was caproic acid (0.692%). With 18.364%, oleic acid and 15.162% myristic acid were the acids with the highest values after lauric acid.

One of the primary nutritional advantages of plant-based alternatives lies in their rich content of unsaturated fatty acids, particularly monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA). According to Singh et al. (2023), most plant-derived substitutes contain a lower saturated fatty acid content compared to dairy fats, and are enriched with omega-3 (α-linolenic acid) and omega-6 (linoleic acid) fatty acids. This not only supports cardiovascular health but also enhances anti-inflammatory responses.In a review by Zhu et al. (2023), the lipid profiles of commercial plant-based products were shown to vary greatly depending on the plant source used- e.g., soy-, oat-, and nut-based milks and spreads exhibit diverse fatty acid ratios, influencing both shelf life and metabolic effects. Products incorporating flaxseed or chia exhibited the most favorable omega-3 profiles.Further, Moshtaghian et al. (2024) reported that most Swedish market alternatives lacked the shorter-chain saturated fatty acids found in dairy (e.g., butyric acid), but compensated through higher levels of essential fatty acids (EFAs). The health effects are generally positive, although some products made with coconut or palm oil had elevated saturated fat levels. Finally, Wang et al. (2025) employed NMR spectroscopy to identify specific phospholipids and triglycerides in plant vs. dairy milk, showing a more diverse short-chain profile in dairy, and higher levels of phosphatidylcholine (PC) and phosphatidylethanolamine (PE) in soy-based products important for brain health and emulsification.

In animal fat, the predominant fatty acids are generally saturated fatty acids such as palmitic acid (C16:0) and stearic acid (C18:0), as well as monounsaturated fatty acids like oleic acid. Vioque-Amor et al. (2023) observed in their study, which examined sheep milk, goat milk, and salted, unsalted (CB) samples as well as low-fat cow milk, that capric acid (C10:0) was the most abundant short-chain fatty acid in the analyzed commercial butters. They reported that butter made from cow's milk, except for low-fat versions, contained higher levels of medium-chain fatty acids such as lauric (C12:0), myristic (C14:0), and palmitic (C16:0) acids compared to butter made from sheep and goat milk. In all types of butter analyzed, oleic acid (C18:1 cis 9) was as the predominant unsaturated fatty acid. The source of the milk not only affects the texture parameters but also influences the color of the butter and components related to properties such as aroma and taste. Eser and Inanç (2022) determined that in their studies on buffalo butter, the highest fatty acid percentage was palmitic acid (36.066%), while the lowest was heneicosanoic acid (C21:0) (0.130%).

Since it makes up the largest percentage of butter fat, palmitic acid (C16:0), a medium-chain saturated fatty acid, has the greatest impact on the physical and rheological characteristics of butter. Linoleic acid (C18:2n6c) is the most abundant polyunsaturated fatty acid (PUFA). Because of its advantages as an energy source, anti-carcinogenic qualities, and helpful function in lowering bad cholesterol (LDL) levels, oleic acid is well known as one of the precursors of other long-chain fatty acids (Vioque-Amor et al., 2023).

Additionally, the fatty acid composition of butter can be influenced by the dietary intake of the animals. Chen et al. (2004) stated that the feed given to dairy cows affects the fatty acid profile of milk fat, which in turn affects the texture and flavor of the resulting butter. This relationship highlights the importance of animal nutrition in determining the quality of dairy products. In addition to the common fatty acids found in traditional butter, certain types of butter, such as butter enriched with specific dietary fats, can exhibit unique fatty acid profiles. Plant-based oils exhibit different fatty acid compositions depending on the source of the oils used. Flaxseed oil is notably rich in polyunsaturated fatty acids, primarily alpha-linolenic acid (ALA, C18:3 n-3), which constitutes approximately 50–60% of its total fatty acid content, followed by linoleic acid (C18:2 n-6, ~15–20%), oleic acid (C18:1 n-9, ~12–18%), palmitic acid (C16:0, ~5–7%), and stearic acid (C18:0, ~2–4%) (Oomah et al., 1993; Kajla et al., 2015). Additionally, the fatty acid composition of butter can influence its health effects. For example, the presence of trans fatty acids (TFAs) in butter has been a cause for concern due to its association with adverse health effects. Radtke et al. (2016) emphasized that the type and amount of fatty acids in butter can affect lipid metabolism and cardiovascular health. Therefore, understanding the fatty acid composition of butter is of vital importance for consumers who want to make informed dietary choices. Differences in fatty acid profiles can arise from the type of milk or cream used, the animals' diet, and the processing methods.

CONCLUSION

In recent years, consumers have been demanding natural plant-based products in their diets due to their health awareness and nutritional properties. This issue is quite important for improving the quality of life for future generations. In our country and around the world, butter has become an indispensable part of our diet at every meal. With this study, the production of plant-based/vegan butter containing plant protein has been considered as an alternative source instead of traditional animal-based proteins, along with a new recipe example. In this way, the need for plant-based protein will be met against the supply of animal products, and the harmful effects on the environment will also be reduced. At the same time, our aim has been to diversify the limited product options for vegan individuals. As a result of the daily increase in vegan and vegetarian dietary trends, efforts have been made to increase scientific research on the effects of vegan diets on human health and to explore alternatives for the production and market release of animal products. The functionality of products like flaxseed in the kitchen and their importance for Turkish culinary culture have been emphasized. It is predicted that flaxseed milk and butter will be appealing to those who want to eat healthily and prefer vegan or vegetarian diets. In this study, the aim was to increase the areas of use for flaxseed because it is a fatty seed that is high in protein and soluble fiber and rich in phytochemicals. The reason for preference is also that recipes prepared with plant-based protein sources can prevent diseases caused by animal milk. The production of more alternative plant-based products for sustainable agriculture can leave a more livable nature and physiology for future generations. With this recent study, a scientific research work on plant-based butter has been added to the literature. Because when the literature in this field was examined, it was found that there were very few studies, almost none. However, no scientific studies have been found using flaxseed milk and this recipe. In line with this study, emulsifier optimization can be further refined to enhance the applicability of the product in industrial food production. Future research involving cost-effectiveness analysis, microbial stability, and shelf-life testing could broaden the practical applications and acceptance of this method.

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AUTHOR CONTRIBUTIONS

The authors contributed equally to this study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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