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EFFECTS OF DIFFERENT FLOURS ON THE TEXTURAL, COLOR, AND NUTRITIONAL PROPERTIES OF POTATO-BASED PUREES

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ABSTRACT
This study investigated how different ratios of einkorn, oat, and chickpea flours affected the protein content, dietary fiber content, color characteristics, and textural qualities of puree formulations made with potato flour. The addition of chickpea flour increased the dietary fiber content from 4.67% to 7.86% and the protein content from 6.29% to 10.64% when compared to the control sample made with only potato flour. According to color analysis, the addition of oat flour enhanced the red and yellow hues (a^* and b^* values, respectively) while decreasing the lightness (L^* value) of the puree. Because oat flour weakened the structure of the puree, texture parameters like firmness, consistency, cohesiveness, and viscosity index significantly decreased as potato flour was reduced. Overall, the results showed that chickpea flour is essential for improving nutrition, whereas oat flour is helpful for changing color and texture. These flours appear to work well together in developing puree products.
Keywords: Potato puree, alternative flours, protein, dietary fiber, color, texture

FARKLI UNLARIN PATATES BAZLI PÜRELERİN TEKSTÜR, RENK VE BESİN ÖZELLİKLERİ ÜZERİNE ETKİLERİ

ÖZ
Bu çalışmada, siyez, yulaf ve nohut unlarının farklı oranlarda kullanılmasının, patates unu ile hazırlanan püre formülasyonlarının protein içeriği, diyet lifi içeriği, renk özellikleri ve tekstürel nitelikleri üzerindeki etkileri incelenmiştir. Nohut unu ilavesi, yalnızca patates unuyla hazırlanan kontrol örneğiyle karşılaştırıldığında, diyet lifi içeriğini %4.67'den %7.86'ya ve protein içeriğini %6.29'dan %10.64'e yükseltmiştir. Renk analizine göre, yulaf unu ilavesi pürenin kırmızı (a^*) ve sarı (b^*) tonlarını artırırken, parlaklık (L^*) değerini azaltmıştır. Yulaf ununun püre yapısını zayıflatması nedeniyle sertlik, kıvam, koheziflik ve viskozite indeksi gibi tekstürel parametreler, patates unu azaltıldıkça önemli ölçüde düşmüştür. Genel olarak, sonuçlar nohut ununun besin değerini artırmada, yulaf ununun ise renk ve tekstürün değiştirilmesinde önemli olduğunu göstermiştir. Bu unların birlikte kullanımı, püre ürünlerinin geliştirilmesinde etkili görünmektedir.
Anahtar kelimeler: Patates püresi, farklı unlar, protein, diyet lifi, renk, tekstür

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INTRODUCTION

The consumption of prepared foods has been clearly impacted by globalization in recent years. Traditional cuisine and home-cooked meals have increasingly been replaced by prepared foods. Interest in prepared foods has grown significantly in comparison to prior years due to technological advancements and rising living standards. In recent years, ready-made foods that offer convenience have gained popularity. As a result, food is becoming more uniform and standardized (Türk et al., 2007).

Because of their nutritional value and ease of preparation, purees stand out as products that provide useful solutions in everyday life. Fruits like avocados and bananas, as well as vegetables like potatoes, carrots, and squash, are frequently eaten pureed (Hayakawa et al., 1977). Mashed potatoes are one of the many processed foods that can be made with potato flour, a very adaptable raw ingredient (Kulkarni et al., 1996).

Mashing and drying boiled potatoes yields potato flour, a gluten-free product. When stored properly, its shelf life can reach 12 to 24 months. This flour is used to improve the flavor, texture, and shelf life of food products; it should not be confused with potato starch. Oat flour is regarded as a functional grain due to its high fiber and antioxidant content, as well as its beneficial effects on cardiovascular health (Topçu et al., 2019). The ancient wheat variety known as einkorn flour (*Triticum monococcum* L.) is notable for its high protein content and low glycemic index, while chickpea flour is a desirable raw material, especially for health advocates, due to its high phenolic compound content and antioxidant capacity (Sayar and Karataş, 2017; Sayaslan et al., 2016). Because of their functional qualities, these flours not only satisfy fundamental nutritional needs but also contribute nutritionally and technologically to the food industry.

According to Trumbo et al. (2002), the recommended daily intake of dietary fiber for a healthy metabolism is 25 grams for women and 38 grams for men. For dietary fiber, recent research has also concentrated on incorporating different vegetable purees or pieces into dairy products (Mälkki, 2005; Rodríguez et al., 2006).

In fact, a study by Demir (2008) sought to increase the nutritional content and quality of noodles by utilizing chickpea flour in varying proportions (10, 20, 30, 40, and 50%). It was found that adding chickpea flour improved the noodles' quality, protein content, and fiber content. According to reports, adding 30% chickpea flour to the noodle formulation would be a beneficial fortification.

Özcan and Yıldız (2016) found that adding vegetable purees to yogurts affected their pH, titratable acidity, sensory qualities, and textural qualities like consistency, hardness, adhesiveness, and viscosity index. Yogurts made with pureed carrots had better textural qualities, but those made with zucchini added had worse texture qualities. As a result, it was found that adding vegetable puree significantly enhances the set-type yogurts' textural qualities and may be applied to the creation of functional dairy products.

The goal of this study is to create substitute puree products that will help people eat more nutritious and useful foods. In order to achieve this, different ratios of einkorn, oat, and chickpea flours were added to potato flour to create purees with higher protein and fiber content. The color and textural qualities of the finished products were investigated because the addition of new ingredients to the formulation will alter the composition of potato puree, resulting in notable changes to the final product's characteristics (Bayarri et al., 2011).

MATERIALS AND METHODS

Materials

Potato flour, einkorn flour, oat flour, chickpea flour, mono-diglyceride mixture, salt, and skimmed milk powder from Smart Kimya (İzmir, Türkiye) as well as palm oil from Nilkim Teknik Kimya (Bursa, Türkiye) were the raw materials used to make the puree.

Production of puree samples

The method used by Perdani et al., (2020) was adapted and applied in the production of potato purees. To examine the effects of different flours in potato puree production, while only potato

flour was used as a control sample, 1000 g flour mixes were prepared using different flours (einkorn flour, chickpea flour, oat flour) and their blends by reducing the amount of potato flour by 20% and 40%. These substitution levels were determined based on preliminary trials, which indicated that such ratios enable the evaluation of the nutritional contributions of alternative flours while preserving acceptable textural and sensory properties. The 300g of prepared flour mixtures were combined with 1500 mL of purified water, 0.5% mono-diglyceride, 1% salt, 7% palm oil, and 1% skimmed milk powder. Puree was made by bain-marie cooking for five minutes at 80°C. Three replicates of the puree production process were carried out.

Crude Fiber and Protein Content

The AACC method 32-10 (AACC, 2000) was used to determine the crude fiber content and AOAC Official Method 920.87 (AOAC, 2002) was used to determine the protein content of the flour mixtures used in the production of puree.

Color Analysis

Color analysis of puree samples was performed using a Konica Minolta CR-400 color measurement device (Konica Minolta Sensing Inc., Osaka, Japan). Each sample was measured three times in parallel from three different locations, and the average of the collected data was used to determine the color values.

Textural Analyses

Textural properties of the produced puree samples, such as firmness (g), consistency (g.sec), cohesiveness (g), and index of viscosity (g.sec), were determined using Back Extrusion (A/BE) equipment (Pre-test speed: 1 mm/sec, Test speed: 1 mm/sec).

Statistical Analysis

The puree was produced in triplicate, and all measurements were performed in triplicate for each test. Data analysis was conducted using SPSS 22.0 statistical software (SPSS Inc., Chicago, USA). Multiple comparisons of the means were performed using Duncan's test.

RESULTS AND DISCUSSION

Crude fiber and protein content

A detailed investigation was conducted into the effects of varying ratios of einkorn, chickpea, and oat flours in puree formulations on the amounts of protein and dietary fiber (Table 1). When compared to the other formulations, the control group (100% potato), which was made up entirely of potato flour, had the lowest protein (6.29%) and dietary fiber (4.67%) contents. This implies that despite having a high starch content, potato flour provides only a small amount of fiber and protein.

Protein content increased slightly in formulations with 80% potato and 20% added flour (oat and einkorn), reaching 7.48% and 7.54%, respectively. But when chickpea flour was added, the protein content increased more significantly, reaching 9.29%. This finding indicates that the nutritional density of semi-solid food matrices, like purees, can be considerably increased by adding chickpea flour, a protein-rich ingredient.

Stronger synergistic effects were seen in terms of both protein and fiber in formulations that used triple flour combinations. The highest protein contents in the study were found in the 60% potato - 20% einkorn - 20% chickpea and 60% potato - 20% chickpea - 20% oat formulations, with respective protein contents of 10.64% and 10.49%. A similar pattern was observed for dietary fiber: the addition of einkorn (5.49%), oats (5.75%), and chickpea flour (6.74%) resulted in a significant increase in fiber content. The 60% potato, 20% chickpea, and 20% oat sample had the highest fiber value (7.86%), indicating that chickpea flour greatly adds both protein and fiber to the mixture.

Similar studies in the literature support these effects of chickpea flour. According to Atudorei et al. (2022) chickpea flour improved dough rheology and raised the protein and fiber contents of bread formulations, increasing the product's nutritional density. In a similar vein, Demir (2008) found that adding 30% chickpea flour to noodle formulations produced the best results and markedly raised the protein and fiber contents.

Additionally, the fiber fractions of sprouted chickpea flour improved technological functionality and could offer functional contributions in complex food systems, according to a study by Bresciani et al. (2024).

These findings show that when mixed with other grains like oats and einkorn, chickpea flour not only improves nutritional density in the creation of functional foods but also helps create more complex and balanced formulations by producing synergistic effects. The noted increases, particularly in the triple formulations, emphasize how crucial it is to use a variety of ingredients when creating functional products that are high in fiber and protein.

Table 1. Effect of different flour additions on the protein and dietary fiber content of potato-based purees

Sample	Protein content %	Dietary Fiber %
100%Potato	6.29±0.02[a]	4.67±0.07[a]
80%Potato-20%Einkorn	7.54±0.05[b]	5.49±0.14[b]
80%Potato-20%Chickpea	9.29±0.04[d]	6.74±0.11[c]
80%Potato-20%Oat	7.48±0.06[b]	5.75±0.12[b]
60%Potato-20%Einkorn-20%Chickpea	10.64±0.14[e]	7.54±0.12[d]
60%Potato-20%Einkorn-20%Oat	8.84±0.08[c]	6.59±0.12[c]
60%Potato-20%Chickpea-20%Oat	10.49±0.14[e]	7.86±0.11[d]

[a]Values followed by different letters in the same column are statistically different from each other ($P < 0.05$).

Color Analysis Results

Examining the color parameters, it was found that the various flour types used in the puree samples significantly altered the values for *L** (lightness), *a** (redness/greenness), and *b** (yellowness) (Table 2). The formulation with the highest *L** value (77.75) and the lightest color was the control sample, which contained only potato flour. This is explained by the fact that potato flour has a naturally light color. On the other hand, *L** values decreased when einkorn (68.92), oat (66.32), and chickpea (73.37) flours were added; samples made with oat flour in particular were darker. The sample with 80% potato and 20% oat flour had the lowest *L** value (66.32).

In terms of *a** values, the control sample showed a dominant green tone with a negative value (-3.51). This green tone was lessened by the addition of einkorn and chickpea flours, producing more neutral hues. Positive *a** values, on the other hand, indicated a shift toward reddish tones in formulations containing oat flour. With an *a** value of 0.23, the 60% Potato–20% Einkorn–20% Oat formulation was the most reddish sample.

Regarding the *b** values, every sample showed positive values, suggesting a predominance of yellow. With a *b** value of 10.06, the control sample displayed a moderate level of yellowness, whereas the addition of oat flour resulted in noticeably higher levels of yellowness. The formulation with the highest *b** value (13.99) was 60% Potato–20% Einkorn–20% Oat, indicating the significant color impact of oat flour. As demonstrated by the 60% Potato–20% Chickpea–20% Oat formulation, which had a high *b** value of 11.86, chickpea flour also made the mixture more yellow.

Overall, the lightness and hue of the color parameters in the puree systems were changed by the addition of einkorn, chickpea, and oat flours. The ingredient that had the biggest impact on the color profile was oat flour, which resulted in a significant increase in yellowness (an increase in *b**), reddening (an increase in *a**), and darkening (a decrease in *L**). These results are consistent with those of Bresciani et al. (2024), who observed that the presence of chickpea and oat flours in bakery products increased the intensity of yellow tones, which in turn affected sensory perception.

Table 2. Effect of einkorn, chickpea, and oat flour additions on the color characteristics of potato-based purees

Sample	*L**	*a**	*b**
100%Potato	77.75±0.31[f]	-3.51±0.27[a]	10.06±0.10[c]
80%Potato-20%Einkorn	68.92±0.30[c]	-0.39±0.03[c]	11.56±0.11[d]
80%Potato-20%Chickpea	73.37±0.23[e]	-0.76±0.11[b]	9.41±0.14[b]
80%Potato-20%Oat	66.32±0.22[a]	0.39±0.01[c]	8.86±0.19[a]
60%Potato-20%Einkorn-20%Chickpea	73.52±0.56[e]	-0.84±0.16[b]	13.37±0.88[e,f]
60%Potato-20%Einkorn-20%Oat	67.14±0.36[b]	0.23±0.03[d]	13.99±0.56[f]
60%Potato-20%Chickpea-20%Oat	71.39±0.03[d]	-0.07±0.01[e]	11.86±0.38[d,e]

[a]Values followed by different letters in the same column are statistically different from each other ($P < 0.05$).

Textural Analysis Results

Significant variations were found in all additive formulations when compared to the control group when the effects of various flour additives on the textural characteristics of potato-based puree samples were investigated (Table 3). Firmness (209.8 g) and consistency (2978 g·s) were highest in the control sample (100% potato), which was made entirely of potato flour. This is because potato flour contains a lot of starch, which absorbs water and creates a thick, gel-like substance. Such a structure raises the puree's firmness and consistency values by increasing its compactness and viscosity index (Hasmadi et al., 2020).

This starch density was diluted in samples made with different flours, which led to a looser structure. Particularly, the formulations with oat flour had the lowest firmness and consistency values. The sample with the weakest textural characteristics was the 80% Potato–20% Oat formulation (82.6 g firmness, 1376 g·s consistency). The 60% Potato – 20% Einkorn – 20% Oat and 60% Potato – 20% Chickpea – 20% Oat formulations came next. These results show that oat flour's texture-softening effect is largely consistent across formulation composition. Oat flour's high β-glucan content is linked to this effect. This soluble fiber can absorb a lot of water, but it cannot form strong gels. This results in a more fluid product with less consistency because it causes weak bonding structures and a low viscosity index within the puree matrix.

Similar patterns were also found in cohesiveness data. The cohesiveness value of the control group (–308.3 g) was significantly negative, suggesting a dense and uniform product structure. On the other hand, formulations with additional flours displayed a looser structure and fewer negative values. The 60% potato, 20% chickpea, and 20% oat sample had the lowest cohesiveness value (–64.2 g). This suggests that the components have a lower ability to bind together, which makes the structure more prone to breaking down.

The viscosity index also showed notable declines. Formulations containing oat flour displayed significantly lower viscosity index values than the control sample (–487.6 g), which was made entirely of potato flour. Specifically, the formulation with the lowest viscosity index was the 60% potato, 20% einkorn, and 20% oat (-54.8 g). The impact of fiber components on the physical bonding structures inside the puree matrix is directly tied to these findings.

These findings suggest that when diluted with additive different flours, the starch-dominated structure of potato flour results in notable reductions in physical qualities. However, the type of flour used affected how much these decreases occurred. The texture-softening effect of oat flour was the strongest, while that of einkorn and chickpea flours was less pronounced. One of the main causes of these structural variations is the way that fiber and protein fractions interact with water and their ability to gel. Accordingly, a study by Buzera et al. (2024) found that noodle

formulations that partially substituted wheat flour for potato flour showed comparable decreases in hardness and viscosity parameters. The rheological effects of the substitute flours and starch dilution were blamed for this decline.

Table 3. Effect of einkorn, chickpea, and oat flour additions on the textural parameters of potato-based purees

Sample	Firmness (g)	Consistency (g.sec)	Cohesiveness (g)	Index of viscosity (g.sec)
100%Potato	209.8±7.6^{f}	2978±55.2^{g}	-308.3±26.3^{f}	-487.6±12.5^{e}
80%Potato-20%Einkorn	108.5±5.9^{d,e}	1758±32.6^{e}	-151.4±13.1^{e}	-106.9±12.5^{b}
80%Potato-20%Chickpea	114.9±4.4^{e}	1898±32.4^{f}	-136.1±11.6^{d,e}	-219.9±11.9^{d}
80%Potato-20%Oat	82.6±3.5^{c}	1376±31.4^{c}	-119.1±11.7^{c,d}	-113.4±21.5^{b}
60%Potato-20%Einkorn-20%Chickpea	103.4±2.7^{d}	1651±27.3^{d}	-92.9±13.0^{b,c}	-165.6±21.2^{c}
60%Potato-20%Einkorn-20%Oat	67.6±2.6^{a}	1052±20.5^{a}	-82.1±11.7^{a,b}	-54.8±17.8^{a}
60%Potato-20%Chickpea-20%Oat	72.5±2.1^{b}	1166±23.6^{b}	-64.2±11.3^{a}	-164.6±24.8^{c}

[a]Values followed by different letters in the same column are statistically different from each other ($P < 0.05$).

However, multi-component (dual additive) formulations showed balancing effects on both structural and nutritional properties, exhibiting synergistic effects. Specifically, oat flour's texture-softening effect was somewhat lessened by the addition of protein and fiber-rich ingredients made from a combination of einkorn and chickpea flours. This result is consistent with the findings of Yüksel and Campanella (2018), who found that doughs made with a flour blend comprising potato, cranberry bean, and einkorn flours demonstrated functional compatibility and rheological stability.

Overall, this study shows that the physical and nutritional qualities of potato-based puree products are greatly impacted by the combinations of alternative grain and legume flours. Although chickpea flour is notable for its nutritional value, oat flour is essential for altering texture and color. These results imply that it is feasible to create technologically stable and nutritionally beneficial products that satisfy consumer demands by utilizing various flour types in precise ratios and in complementary combinations.

Correlation between Nutritional and Textural Properties

The detailed and varied impacts of adding einkorn, chickpea, and oat flours to potato-based puree matrices are illustrated by the comparative assessment of nutritional content and textural qualities based on graphical data and formulation compositions (Figure 1). As can be seen, the ternary formulations showed the greatest increases in protein and dietary fiber content when chickpea flour was added, with values increasing to 10.64% and 7.86%, respectively. But along with this nutritional boost, there was a noticeable loss of textural integrity, especially when it came to firmness, consistency, cohesiveness, and viscosity index. Nutrient-dense additions have a tendency to dilute the native starch matrix of potato flour, producing structurally softer products, as evidenced by the graphs showing an inverse relationship between protein/fiber content and these texture-related parameters. As indicated by its correlation with the lowest firmness and viscosity values among the flours examined, oat flour demonstrated the most noticeable softening effect. This behavior is explained by the oat β-glucans' physicochemical makeup, which weakens the puree's internal structure by absorbing large amounts of water without forming robust gel networks (Bresciani et al., 2024; Topçu et al., 2019).

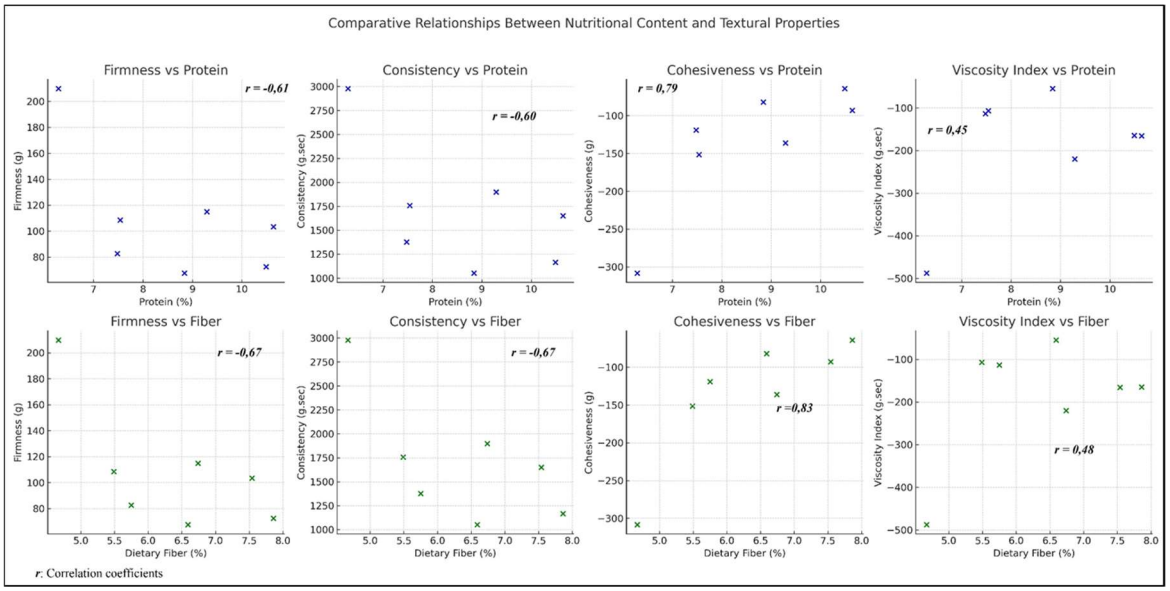

Figure 1. Effect of protein and fiber content on textural properties of purees

The structural properties of einkorn flour, on the other hand, were comparatively less affected by its high protein content, indicating a more balanced interaction between its protein fractions and the puree's starch-protein matrix. A synergistic effect was noted when used in combination, especially in triple-flour blends like 60% potato, 20% chickpea, and 20% oat; this allowed for the preservation of the increased nutritional content while partially reducing negative effects on textural parameters. These results lend credence to the idea that functional food formulations profit from ingredient complementarity, whereby specific ingredients (such as chickpeas for nutritional density and oats for color and rheological modification) can be carefully mixed to create product profiles that are both technically possible and nutritionally superior.

The conclusion that flour type and ratio are important factors influencing the functional and sensory aspects of puree products is ultimately supported by the integration of graphical data with compositional variables. According to the evidence, chickpea flour ought to be given preference in formulations that aim for high protein and fiber delivery, whereas oat flour adds valuable functional fiber and aesthetic appeal despite weakening the structure.

CONCLUSION

This study thoroughly examined how the nutritional and physical qualities of potato-based puree formulations were affected by the addition of einkorn, chickpea, and oat flours in varying proportions. The results showed that because of its high protein and dietary fiber content, chickpea flour in particular stood out as a significant nutritional enrichment agent. The study's highest protein and dietary fiber contents were found in the ternary formulations, specifically in samples made with 60% potato, 20% chickpea, and 20% oat. These samples had protein contents of 10.49% and 7.86%, respectively. This indicates that in functional food design, chickpea flour should be regarded as a powerful nutritional enhancer in addition to a replacement for traditional flours. Similar to chickpea flour, einkorn flour also increased the protein content, but its impact was less pronounced.

The results of the color analysis showed that the appearance of the puree samples was significantly influenced by the oat flour. *L** values decreased and *a** and *b** values increased when oat flour was added, suggesting a change toward darker, reddish, and yellowish colors. Oat flour should be viewed as both a nutritional component and a visual quality modulator because such color

changes can have a direct impact on how consumers perceive a product.
Textural analysis showed that the viscosity index, cohesiveness, firmness, and consistency all significantly decreased when potato flour was partially substituted. Oat flour weakened the product's structural integrity by causing the most noticeable drops in these parameters among the tested flours. Oat fibers' high water-binding capacity and limited gelation potential are the main causes of this effect. Depending on formulation objectives, this softening effect might be advantageous in some product categories but problematic in others.

Synergistic effects between the added flours were noted in multi-component formulations, leading to more functional and balanced product profiles in terms of texture, color, and nutritional composition. The potential of complex flour blends to provide rheological and sensory stability has been supported by prior research that has documented this synergy.

In conclusion, oat flour is essential for regulating textural and visual qualities, whereas chickpea flour ought to be given priority in functional puree formulations for nutritional enrichment. In light of these results, it is highly recommended that alternative cereal and legume flours be used in tandem to create food products that are both technologically stable and nutritionally enhanced.

Future research should consider conducting sensory analyses to establish a correlation between consumer preferences and instrumental measurements. Additionally, shelf-life studies should be used to evaluate structural and microbiological stability. The adaptation of such functional products to industrial production and the investigation of market acceptance through multidisciplinary approaches should also be the focus of future research.

DATA AVAILABILITY

Data analyzed and recorded during the research is included in this article.

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest.

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