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Research Article/Araştırma Makalesi

Muffin cakes enriched with the addition of potato peels: physical, chemical, textural and sensory properties

Patates kabukları ilavesiyle zenginleştirilmiş muffin keklerin: fiziksel, kimyasal, tekstürel ve duyusal özellikleri

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ABSTRACT

A considerable amount of potato peel is produced as a byproduct in the production of various potato-based food items. In the present study, the impact of incorporating potato peel powder into wheat flour at concentrations of 0, 10 and 20 % was examined in terms of its effects on textural and physicochemical properties of muffin cakes, given the peel`s nutritional richness and its technological and functional potential. The brightness and yellowness of the muffin samples enriched with potato peel flour also decreased. The total phenolic and antioxidant contents of muffin cakes varied between 0.301-0.510 mg GAE/g and 0.290-1.023 µmol Trolox/g, respectively. The incorporation of potato peel into the cake formulations led to a notable enhancement in both total phenolic content and antioxidant capacity when compared to the control sample. The hardness of the cakes decreased with the addition of potato peel and a soft texture was formed. As a result of this study, potato peel, which is obtained as a significant amount of waste as a result of this study, can positively affect both physicochemical and bioactive properties of cereal products such as cakes and healthy product production can be provided. In addition, such waste products can be used as additives in the food sector and are important in terms of environmental protection.

Key Words: Potato peel flour, muffin cake, functional food, properties of cakes

ÖZ

Patatesin çeşitli ürünlere dönüştürülmesi sırasında önemli miktarda patates kabuğu atık olarak ortaya çıkmaktadır. Bu çalışmada, buğday ununa % 0, % 10 ve % 20 oranlarında patates kabuğu tozu eklenerek üretilen muffin keklerinin teknolojik ve fonksiyonel özellikleri ile besin içeriği açısından tekstürel ve fizikokimyasal özellikleri üzerine etkisinin değerlendirilmesi amaçlanmıştır. Patates kabuğu unu ile zenginleştirilen muffin örneklerinin parlaklığı ve sarılığı da azalmıştır. Muffin keklerinin toplam fenolik ve antioksidan içerikleri sırasıyla 0,301-0,510 mg GAE/g ve 0,290-1,023 µmol Trolox/g arasında değişmiştir. Patates kabuğunun eklenmesiyle kek örneklerinin toplam fenolik içeriğinde ve antioksidan kapasitesinde kontrol örneğine göre önemli bir artış olmuştur. Patates kabuğunun eklenmesiyle keklerin sertliği azalmış ve yumuşak bir doku oluşmuştur. Bu çalışmanın sonucunda önemli miktarda atık olarak elde edilen patates kabuğunun, kek gibi tahıl ürünlerinin hem fizikokimyasal hem de biyoaktif özelliklerini olumlu yönde etkileyebileceği ve sağlıklı ürün üretimi sağlanabileceği ortaya çıkmıştır. Ayrıca bu tür atık ürünler gıda sektöründe katkı maddesi olarak kullanılabilir ve çevre koruma açısından önemlidir.

Anahtar Kelimeler: *Patates kabuğu unu, muffin kek, fonksiyonel gıda, keklerin özellikleri*

Introduction

Bakery products constitute a significant part of the human diet owing to their ease of consumption, variety in presentation, distinctive organoleptic properties, and cost-effectiveness. These products are typically classified into several categories, including biscuits, cookies, cakes, pastries, bread and crisps. Among these, cakes rank just behind biscuits and cookies in terms of popularity and are frequently enjoyed on many occasions (Vinay and Singh, 2024). Muffin cakes, also known as cupcakes, are one of the most desired snacks by many people worldwide, as they are produced in small portions without the need for slicing (Khaleel et al., 2022; Jansone and Kunkulberga, 2023). In parallel with the increasing awareness of healthy eating in recent years, efforts have been made to develop functional and healthier products by using different raw materials and ingredients to enrich the production of cake, which is a product with high energy value, in terms of nutritional fiber, vitamins, minerals, and bioactive components, as in other foods (Karaoğlu et al., 2021; Tuna Ağirbaş et al., 2022).

Potato (*Solanum tuberosum* L.) standarts as the World`s fourth leading food crop following rice, wheat, and maize. It constitutes a significant component of the global food supply, with an annual production exceeding 370,436,581 tons (Makori et al., 2022). Today, potato consumption patterns are gradually changing from fresh formulations derived from fast food habits in developed countries to processed formulations (e.g. mashed potatoes, potato chips, etc.) (Moradi et al., 2024). Potato peel is a significant byproduct of the potato processing industry, accounting for nearly 10% of the total waste produced. While a portion of the this biomass is utilized in low-value applications such as livesyock feed, organic fertilizers or biogas generation, a significant amount is still disposed of without further use. Potato peel is the source of phenolic compounds such as chlorogenic acid, caffeic acid, gallic acid, ferulic acid and protocatechuic acid in its structure and can be used as an alternative to synthetic antioxidants. Chlorogenic acid accounts for between 49% and 61% of the total phenolics (Sampaio et al., 2021; Goyi et al., 2023; Saeed et al., 2024). Nonetheless, potato peel contains a vriety of bioactive and nutritional compouns, including polysaccharides, vitamins, proteins and minerals, making it a promising resource for value-added applications. Therefore, the conversion of this biological residue into value-added products can add value to the production chain by reducing environmental impact as well as contributing to the valorization of potato processing industry waste (Singh et al., 2020; Brahmi et al., 2022; Ma et al., 2022; Goyi et al., 2023; Sadadekar et al., 2023). In this study, we aimed to evaluate the properties of the final product obtained by adding dried potato peel powder containing dietary fiber and bioactive components to muffin cake samples. For this purpose, the powder product obtained by drying potato peel during muffin cake production was added to the cakes at three different concentrations (0, 10, and 20%), and the changes in the products were examined in terms of textural, sensory and physicochemical aspects.

Material and Methods

Yellow potato peels, known as agire, grown specifically in Afyon, were used. The potatoes we received from the producer were washed and peeled. The potato peels obtained were dried in an oven (Nüve, MF120, Turkey) at 55°C for 4 hours and ground in a mill (Arzum AR1034 Clipper) and passed through sieves (10 mesh) to turn into powder (10 mesh). All analyses have been replicated triplicate (Figure 1).

Figure 1. Potato peel flour

Properties of potato peel flour

The color parameters (L*, a* and b*) of potato peel flour (PPF), produced by milling dried potato peels, were assessed using a colorimeter (Konica-Minolta, CR400, Tokyo, Japan). Bulk density of flour samples was measured following the procedure outlined by Aslan Türker et al., (2023) while water and oil absorption capacities were determinated based on the method described by Tlay et al., (2023).

Muffin cake production

The cakes were prepared according to the standardized cake procedure with some modifications. 260 g sugar, 150 ml water and 120 ml oil were mixed at 5 minutes using a Braun HM 3100 WH laboratory mixer (Germany). Then 270 g wheat flour, baking powder and potato peel powder- replacing 0%, 10%, or 20% of the wheat flour- were added and mixed. Approximately 30-35 g of the prepared cake doughs were transfferd and baked in non-stick muffin pans at 180 ^{o}C for 25 min (Figure 2).

Figure 2. Muffin cakes with added potato peel flour

Muffin Cake Analyses

Physicochemical properties of muffin cakes

Moisture determination of muffin cake samples produced with potato peel powder was carried out in an oven (Nüve, MF120, Turkey) at 105 ºC according to the AOAC (1990) method. The baking efficiency of samples was determinated by calculating the ratio of the weight after baking to the weight before baking, and the results were given as a percentage (%) (Göksel Saraç et al., 2022).

Colour values of muffin cakes

The colour change of cake samples containing PPF at different ratios (Control, 10P% and 20P%P) was measured using a colour analyzer (Konica Minolta, model CR-400, Mississauga, ON, Canada) and the crumb and crust colour values were reported as *L*, a** and *b*.*

Uniformity, symmetry and volume index values of muffin cake samples

Muffin cake samples were analyzed using the American Cereal Chemists Association Method 10-91 (2000) template method to determine the cooking efficiency (%), volume index, symmetry index, and uniformity index. Cooled cake samples were carefully cut vertically from their centers and readings were performed using a template created with the lengths (mm) of |BBˈ|, |CCˈ| and |DDˈ| specified in the method with the help of millimeter paper and were calculated (Göksel Saraç et al., 2022).

Total phenolic contents and antioxidant activities

For the extraction of phenolic compounds in the cake samples, shredded cakes were homogenized with methanol (80% v/v) at a ratio of 1:5 (w / v) (Amado et al., 2014). The obtained extracts were used for the analysis of DPPH free radical scavenging activity and total phenolic substance amount. The total phenolic substance content of the samples was quantified using the Folin-Ciocalteu assay, with results expressed as milligrams gallic acid equivalents per gram (mg GAE/g). Antioxidant activity was assessed spectrophotometrically based on the DPPH radical scavenging method. The results were expressed as DPPH (micromole Trolox/g) (Brand-Williams et al., 1995).

Total soluble and insoluble dietary fiber content

In order to determine the change in dietary fiber content of cake samples with potato peel added, it was determined with Megazyme Total Dietary Fiber kit following the methods numbered 985.29 (AOAC, 2019).

Textural Properties

The hardness, flexibility, internal adhesiveness, gumminess, chewiness and elasticity values of samples containing potato peel flour were determined by measuring with a texture measuring device (T.A.HD Plus Stable Micro Systems, England). A 36 mm diameter P/36R probe and 50 N load cell were used in the device and all measurements were performed with at least five repetitions (Dedebaş and Çebi, 2024).

Sensory Analysis

Sensory evaluations were performed to determine consumer preferences of muffin cakes enriched with different amounts of potato peel. The panelists were selected from 20 food technology students who had taken the Sensory Analysis course at Bolvadin Vocational School and had previously practiced. Before the tastings, the panelists attended a short training course covering tasting techniques and standard protocols. The panelists were asked to make a hedonic evaluation of the muffin cake samples in terms of crust color, internal pore structure, internal color, taste and aroma, smell, mouthfeel and general liking parameters between 1-9.

Statistical Analyses

At the end of the study, one-way analysis of variance (ANOVA) and Tukey's HSD test were performed in the SPSS Statistics 17.0 package program to evaluate the data.

Results and Discussion

Properties of potato peel flour

The moisture, ash, color, bulk density and water and oil absorption values of PPF obtained by drying potato peels are reported in Table 1. The moisture and ash content of the potato peel flours were determined to be 6.20% and 7.85%, respectively. In previous studies, Perez-Chabela et al., (2022), Singh et al., (2023), Kaur et al., (2022), Tlay et al., (2023) and Akter et al., (2023) determined the moisture and ash values of potato peel flours as 4.95%-8.07%, 6.32%-7.89%, 8.78%-4.28%, 8.35%-9.11% and 7.61%-9.64%, respectively. L*, a*, and b* color values of the potato peel flours were 55.46, 8.33, and 16.28, respectively. From the literature review, it is thought that the difference or similarity of moisture, ash, and color values with the results obtained is due to the different drying techniques

Bulk density values of PPF were 0.60 g/cm^3. The high bulk density indicates that flour is suitable for food formulation. It is also thought to be due to the natural fibrous structure of potato peel flour. In a similar study, the bulk density values of potato peel flours prepared in the sun and using a cabinet dryer were 0.36 and 0.64 g/ml, respectively. The water absorption capasity value is a measure of the ability of the flour to associate with water. Oil absorption capasity is desirable to preserve the taste of baked products with high fat loss during processing (Admasu et al., 2024). As shown in Table 1, the water and oil absorption capacity values of PPF were found to be 3.10 g/g and 1.84 g/g, respectively. Tlay et al., (2023) reported the water and oil absorption values of potato peel flours obtained by drying in ovens containing hot air as 2.58 g/g and 1.24 g/g, respectively. In another study, water and oil absorption capacity values of flour obtained from sweet potato peels were determined as 3.27 g/g and 1.29 g/g, respectively. When the water and oil absorption values of potato peel flour are compared with studies in the literature, it is thought that this difference in values is due to the type of potato used or the drying temperature (Çağlar et al., 2025).

Table 1. Properties of potato peel flour

Properties		
Ash (%)		6.20 ± 0.09
Moisure (%)		7.85 ± 0.54
Color	*L**	55.46 ± 0.02
	*a**	8.33 ± 0.00
	*b**	16.28 ± 0.05
Bulk density (g/cm^3)		0.60 ± 0.00
Water absorption		3.10 ± 0.07
Oil absorption		1.84 ± 0.03

Physicochemical properties of muffin cakes

The ash values of cakes enriched with potato peel varied between 0.34 and 2.60. As the addition of potato peel increased, the ash content of the muffin cakes increased. In the study conducted by Tlay et al., (2023) it was reported that the ash content of biscuit samples containing 3%, 5%, 7%, 10%, 30% and 50% potato peels increased due to the fibrous structure of the potato peel. The % moisure contents of the control, 10%, and 20% samples were 20.82%, 18.92%, and 14.55%, respectively. A decrease in % moisure content occurred with the addition of potato peel, and it is thought that this decrease was due to the high fiber content of potato peels. In a literature review, it was stated that as the volume of the cakes increased, the moisture content decreased because of the easier evaporation of water from the spongy and fibrous structures (Movahhad et al., 2016). Although the volume of our muffins increased with the addition of potato peels, there was a decrease in the moisture content.

Color characteristics of muffin cakes

The crumb and crust L* (brightness, 100: white, 0: black), a* (red/green), and b* (yellow/blue) color values of the muffin cakes with potato peel, which is an important quality factor among the consumer taste criteria, are represented in Table 2. The color values of the control, 10P %, and 20P % muffin samples were measured in two regions: crumb and crust color. The L*, a *, and b *values of the crumb color of the muffin cake samples varied between 49.66-65.06, 2.97-6.94 and 18.95-22.86, respectively, and there was a statistically significant difference between the samples ($p<0.05$). With the addition of potato peel, the L* and b* values, which express the crumb glossiness of the muffin cakes, decreased, while the redness value (a*) increased compared to the control sample.

The L*values of the crust color of the muffin cakes produced by adding potato peel (control, 10P %, and 20P %) were determined to be 50.64, 47.02, and 41.88, respectively, and a statistically significant difference was observed between the samples. It was observed that the brightness of the samples with 10P% and 20P% potato peel addition decreased compared to that of the control sample. The crust color a* and b* values of muffin cake samples varied between 14.27-19.16 and 32.60-23.59, respectively, and these values decreased with the addition of potato peel. In a study, it was reported that the addition of 4%, 6%, and 8% potato peel dried in the sun and in a cabinet dryer affected the crust and crumb color of the cakes produced, and the color difference between the samples increased as the percentage of potato peel increased (Akter et al., 2023). In a study indicated that the color change of pasta made from potato peel byproducts ranged from 8.40 to 19.31. (Namir et al., 2022). The color change observed in muffin cakes is thought to be due to the effect of high-temperature drying methods on potato flour, triggering the Maillard reaction during cooking by causing a color change in the peel, thus resulting in a noticeable color formation (Çağlar et al., 2025).

Table 2. Crumb and crust color values of muffin samples

Samples	Crumb color			Crust color		
	L*	***a****	***b****	***L****	***a****	***b****
Control	65.09^a±1.70	2.97^c±0.20	22.86^a±0.28	50.64^a±1.57	19.16^a±0.41	32.60^a±0.81
10%P	56.02^b±0.39	$5,84^b$±0.19	19.18^b±1.35	47.02^b±0.47	16.47^b±0.85	26.19^b±1.54
20%P	49.66^c±2.53	6.94^a±0.46	18.95^b±0.47	41.88^c±1.70	14.27^c±0.87	23.59^b±1.05

Different letters in the same column mean significantly (p <0.05). 10P %: Muffin cake 10% PPF; 20P %: Muffin cake 20% PPF

Uniformity, symmetry and volume index values of muffin cake samples

Table 3 presents the cooking efficiency, volume index, symmetry index, and uniformity index values of muffin cakes prepared with varying levels of addition. The volume index values ranged from 8.80 to 11.05. This parameter provides insight into the overall volume of the muffins and is influenced by several factors, including batter consistency, mixing speed and duration, as well as baking conditions such as time and temperature (Göksel Saraç et al., 2022). The volume index increased as the amount of potato peel flour increased. The symmetry index provides information about the profile of cake surfaces (Ataman and Gül, 2020). The symmetry index values of the muffin cakes containing control, 10P%, and 20P% potato peel were determined 2.75, 3.15, and 1.85, respectively, and the positive symmetry value indicated that the cake surface was puffy. While all the muffin samples were puffed, there was no statistically significant difference between the samples. However, the uniformity index of the cake samples was close to zero, which indicates homogeneity. Although the uniformity values of all analyzed cake samples were close to zero, there was no statistically significant difference between the samples.

Table 3. Cooking efficiency, volume index, symmetry index, uniformity index of cakes

Samples	Cooking Efficiency (%)	Volume Index (mm)	Symmetry Index (mm)	Uniformity Index (mm)
Control	83.45^a±0.28	8.80^b±0.85	2.75^a±0.64	0.25^a±0.07
10P%	84.32^a±0.88	8.85^b±0.07	3.15^a±0.70	0.20^a±0.00
20P%	84.80^a±0.08	11.05^a±0.07	1.85^a±0.35	0.25^a±0.01

Different letters in the same column mean significantly (p <0.05). 10P %: Muffin cake 10% PPF; 20P %: Muffin cake 20% PPF

Total phenolic contents and antioxidant activities of muffin cakes

Total phenolic content and antioxidant activation values of muffin cake samples containing different ratios of potato peel (control, 10%, and 20%) are shown in Figure 3. The total phenolic and antioxidant contents of muffin cakes varied between 0.301–0.510 mg GAE/g and 0.290-1.023 µmol Trolox/g, respectively. While the total phenolic content and antioxidant activity values of the muffin cakes increased with the addition of potato peel, the highest values were found in muffin cakes containing 20% potato peel. This increase is thought to be due to the antioxidant properties of potato peel and the melanoidin pigment formed during cooking (Bressa et al., 1996; Kaur et al., 2022). Similarly, in a similar study, it was reported that antioxidant activity and total phenolic content increased as the potato peel powder ratio increased in biscuits produced by adding potato peel and wheat flour at different ratios (3,5,7,10,30 and 50 %) (Tlay et al., 2023). In another study, with the addition of potato peel powder to cookies (1-7%), antioxidant and total phenolic content increased proportionally with the increase in potato peel powder (Kaur et al., 2022).

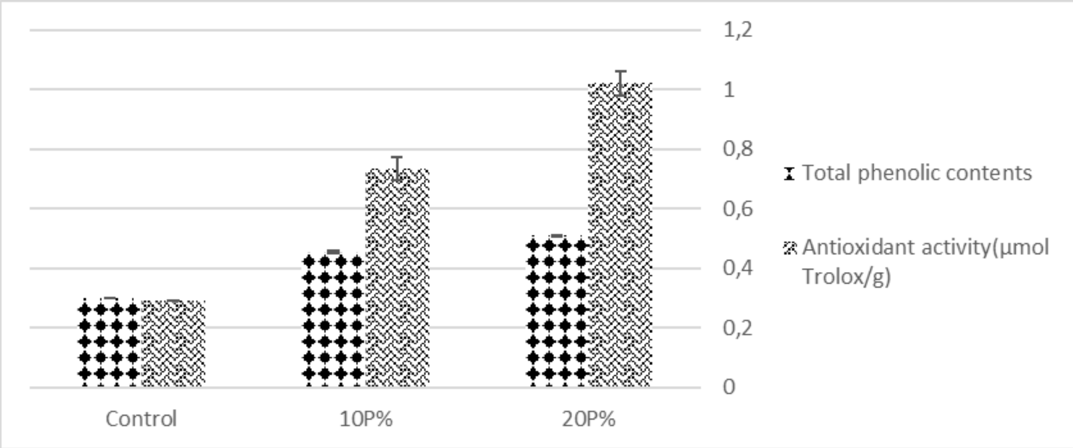

Figure 3. Total phenolic contents and antioxidant activity of cakes

Dietary fiber content of samples

The dietary fiber content of potato flours obtained by etuv of potato peels was 19.1 g/100 g. Similarly, in a study by Saeed et al., (2024), the fiber content was found to be 18.8%/100 g as a result of drying potato peels in a hot air oven at 55 °C. The dietary fiber content of muffin samples increased significantly ($p<0.05$) after the use of potato peel powder at different ratios compared to that of the control. While the dietary fibre content of the control sample was 1.76 g/100 g, it was found 1.84 g/ 100 g and 2.14 g/100 g in muffins containing 10% and 20% PKU, respectively. The results obtained were similar to those a of study conducted by Tlay et al., (2023). In another study, the highest fiber content was found at 9% (1.37%) owing to the rich fiber content of potato peel in the waffle premix formulation prepared with mixtures containing 3.6% and 9% potato peel to wheat flour (Singh et al., 2023).

Textural properties of muffin cakes

Textural analysis is concerned with measuring the mechanical properties of a product, mostly a food product, and its sensory properties as judged by a human. Textural properties of muffin cake samples are given in Table 4. With the addition of potato peel, the hardness, springiness, cohesiveness, gumminess, chewiness, and resilience of muffin cakes decreased compared to the control sample without PPF. When the hardness and elasticity of the muffin cakes were examined, it was observed that there was a statistical difference between the samples. It is thought that this decrease in the textural properties of the muffin samples is due to the fibrous structure of PPF.

Table 4. Texture properties of control, 10P % and 20P % samples

Samples	Hardness (N)	Springiness (cm)	Cohensiveness (g.sec)	Gumminess	Chewiness	Resilience
Control	152.24^{a}±4.08	0.91^{a}±0.02	0.78^{a}±0.06	1269.63^{a}±113.93	1130.21^{a}±16.88	0.41^{a}±0.04
10P %	127.50^{b}±6.43	0.88^{a}±0.00	0.68^{b}±0.01	759.10^{b}±49.95	656.68^{b}±12.17	0.32^{b}±0.01
20P%	94.24^{c}±1.68	0.71^{b}±0.03	0.56^{c}±0.02	741.28^{b}±15.57	534.89^{b}±19.76	0.24^{c}±0.01

Different letters in the same column mean significantly ($p <0.05$). 10P %: Muffin cake 10% PPF; 20P %: Muffin cake 20% PPF

Sensory properties of muffin cakes

The results of the sensory analysis of muffin cake samples containing potato peel powder are shown in Figure 4. Muffin cake samples were evaluated in terms of crust color, internal pore structure, crumb color, aroma, taste, disperbility, and general acceptability parameters. In general, the control sample was more liked than the other samples, whereas the sample containing 10% potato peel was rated highly by the panelists. However, the internal pore structure of the cake samples enriched with potato peel was higher than that of the control samples.

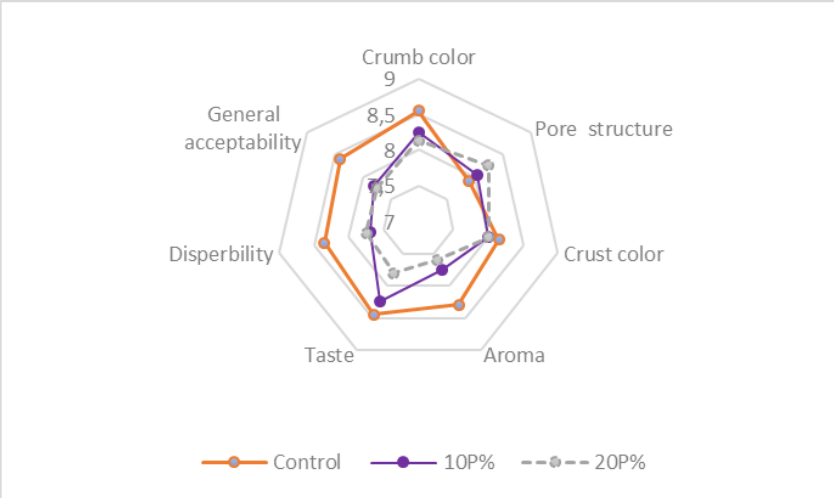

Figure 4. Sensory properties of muffin cakes

Conclusion

In this study, functional muffin cakes rich in health and fiber, which are preferred by consumers, were produced by drying potato peels released as a result of processing potatoes into different products and enriched with PPF. Although the cakes enriched with potato peels had high ash and volume values, the moisture value decreased as the amount of peel flour increased. The softness of the cakes increased as hardness decreased. With the addition of PPF, the fiber, phenolic, and antioxidant contents of the cakes increased. We believe that the findings we obtained as a result of this study will be beneficial for us because potato peels, which have nutritious and suitable technological properties, enable the development of products. Due to its rich content, potato peels are thought to contribute to the production of various diet products and the development of gluten-free alternatives as a low-calorie carbohydrate source, as an alternative to grain products. Furthermore, waste potato peels have the potential to be used as an additive in various food products such as desserts and sauces.

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Conflict of Interest

The authors declare that they have no conflict of interest

Author's Contributions

Conceptualization: T.D; Methodology: T.D; Formal analysis and investigation: S.Y, M.D, D.Y; Writing - original draft preparation: T.D; Writing - review and editing: T.D; Funding acquisition: T.D; Supervision: T.D.

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Availability of Data and Materials

The data that findings of this study are available from the authors upon reasonable request.

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication Not applicable.

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