Italian Journal of Food Science, 2026; 38 (1): 60–68

Effect of watermelon flour on the physicochemical and sensory quality attributes of Biscuits

Amani Hamzah Aljahani, Amal Nassir Alkuraieef*

Department of Sports Health, College of Sports Sciences & Physical Activity, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia

***Corresponding Author:** Amal Nassir Alkuraieef, Department of Sports Health, College of Sports Sciences & Physical Activity, Princess Nourah bint Abdulrahman University, P.O. Box 84428, Riyadh 11671, Saudi Arabia. Email: analkuraieef@pnu.edu.sa

Academic Editor: Prof. Antonietta Baiano—University of Foggia, Italy

Received: 19 May 2025; Accepted: 3 August 2025; Published: 1 January 2026

PAPER

Abstract

This study examines the effect of watermelon flour on the physicochemical and sensory properties of biscuits. Wheat-based biscuits were produced by substituting wheat flour with watermelon flour at ratios of 10, 15, and 20%. The products were assessed for proximate composition, color characteristics, mineral content, and sensory attributes. Watermelon and wheat flour contain 8.40% and 6.30% moisture, 6.0% and 10.0% protein, 3.0% and 6.29% fat, 4.45% and 1.45% ash, 7.3% and 1.3% fiber, and 65.5% and 73.5% carbohydrate, respectively. The highest bulk density (0.77 g/mL) was observed in biscuits containing 10% watermelon flour, while the highest water (2.97 g/g) and oil (1.7 g/g) absorption capacities were found in biscuits with 20% watermelon flour. The highest L* (61.09) value was observed in wheat flour biscuits, whereas the highest a* (8.45) and b* (27.12) values were recorded in biscuits with 20% watermelon flour. The highest moisture (12.87%), ash (13.80%), fiber (9.50%), and fat (10.38%) contents were found in biscuits with 20% watermelon flour, whereas the lowest values were observed in the control 100% wheat biscuits. The highest calcium (36.34 ppm), sodium (2.80 ppm), phosphorus (33.35 ppm), and iron (92.08 ppm) contents were recorded in 20% watermelon flour biscuits, while the lowest were found in control biscuits. No significant differences were observed in the sensory attributes among all biscuit formulations. Overall, incorporating watermelon flour at 20% could improve the nutritional and health-related quality attributes of biscuits without negatively affecting consumer acceptance of the developed product.

Keywords: biscuits; physicochemical quality; sensory attributes; watermelon flour

Introduction

Watermelon (*Citrullus lanatus*) is a vital cucurbit fruit cultivated worldwide due to its high nutritional and commercial value. It has food, feed, and pharmaceutical applications and is widely consumed across different population groups because of its nutrition, flavor, sweetness, and health benefits (Quandoh and Albornoz, 2025). According to the Food and Agriculture Organization, global watermelon production in 2023 reached 105 million tons (FAOSTAT, 2025). Watermelon is commonly traded and consumed in fresh-cut form; however, it is highly perishable and has a limited shelf life (Quandoh and Albornoz, 2025). During production, handling, trading, storage, and consumption, large quantities of whole inedible fruits, damaged fruits, seeds, rinds, and peels are generated, which are considered waste or used for animal feed (Zia *et al*., 2021; Nissar *et al*., 2025). These wastes or

 ISSN 1120-1770 online, DOI 10.15586/ijfs.v38i1.3178

byproducts contain substantial amounts of high-quality nutrients (such as minerals, dietary fiber, vitamins, protein, fat, etc.) and phytochemicals (such as carotenoids, flavonoids, and phenolics) that remain largely underutilized (Zia *et al.*, 2021; Nissar *et al.*, 2025). The valorization of watermelon waste into value-added functional foods, nutraceuticals, and pharmaceutical products is of high significance for producers, traders, and consumers, and could promote the sustainability of this important fruit across the food chain (Zia *et al.*, 2021).

Biscuits are among the important ready-to-eat foods that are widely produced and consumed around the world. They are traditionally made from wheat flour as the main ingredient, along with fat and sugar; however, in recent decades, numerous additives have been incorporated into biscuits to enhance their nutritional quality and consumer acceptability (Goubgou *et al.*, 2021). Recently, wheat flour has been substituted with various starchy foods, such as sorghum, potato, rice, buckwheat, pea, and flaxseed flour, for the preparation of biscuits with functional properties and health benefits (Goubgou *et al.*, 2021). In addition, composite flour or blends have been created by mixing wheat flour with flour from other starchy foods at varying ratios to prepare biscuits with high nutritional quality, marketability, and consumer acceptability (Imoisi *et al.*, 2020). In this regard, watermelon byproducts have been considered potential ingredients for making functional food products. Watermelon rind flour has been mixed with wheat flour at various ratios, and the blends have been used to make bread (Imoisi *et al.*, 2020), cake (Al-Sayed and Ahmed, 2013; Bello and Oladeji, 2024), crackers (Arivuchudar, 2023), and cookies (Olaitan *et al.*, 2017; Ashoka *et al.*, 2021). Watermelon seeds or seed protein isolate have also been mixed with wheat flour and used for the production of biscuits (Peter-Ikechukwu *et al.*, 2018), cookies (Wani *et al.*, 2012), and high-protein bread (Wójcik *et al.*, 2023).

Additionally, watermelon peel flour has been blended with wheat flour and used to make biscuits (Hussain *et al.*, 2024). All the aforementioned studies have demonstrated that incorporating watermelon byproducts (rind, seeds, or peel) into bakery products enhances the physicochemical, nutritional, and functional quality attributes of the developed products without significantly affecting their sensory quality. The utilization of watermelon byproduct flour in biscuits is limited to a few studies (Peter-Ikechukwu *et al.*, 2018; Hussain *et al.*, 2024), and different mixing ratios of wheat flour and watermelon flour were employed in these studies. Therefore, this study was conducted to evaluate the effect of various concentrations of watermelon flour on the physicochemical, nutritional, and sensory quality attributes of biscuits.

Materials and Methods

Materials

Watermelon was purchased from the local fruit and vegetable market in Riyadh City, Saudi Arabia. The samples were rinsed several times with tap water to remove dust and dirt. They were then cut into small pieces using a stainless-steel knife and dried at 50°C until reaching a constant weight (24 h). The dried pieces were milled to pass through a 40 mm sieve, sealed in an air-tight container, and stored at -20°C for further use. Other ingredients for making biscuits, including ammonium bicarbonate, buttermilk, egg, skimmed milk powder, sodium bicarbonate, sugar, and vanilla, were obtained from the local market. High-quality chemicals were procured from Sigma-Aldrich (Sigma, MO, USA).

Biscuit preparation

The standard procedure for preparing semi-hard biscuits (peti-pier type, Al-Kuraieef, 2021) was used to make biscuits using a composite flour of wheat and watermelon at different levels of watermelon substitution (0, 10, 15, and 20%). The concentration of watermelon flour was selected based on preliminary pilot-scale baking trials, and the ingredients listed in Table 1 were used for the formulation of the developed biscuits. The biscuit dough was prepared according to AACC Standard Method 10-54 (AACC International, 2001) for creaming, mixing, and cutting the dough into biscuits of various sizes (5 mm thickness × 20 mm diameter). The biscuits were baked at 180°C for 12–15 minutes until they reached an acceptable appearance (Figure 1).

Proximate analyses

The proximate composition of watermelon flour, wheat flour, and biscuits made from the wheat–watermelon composite flour was determined using official standard methods. The AOAC (1995) method numbers 977.11 (oven drying), 923.03 (dry ashing), 955.04 (Kjeldahl), 960.39 (Soxhlet), and 991.43 (gravimetric) were used to determine the moisture, ash, protein, fat, and fiber contents, respectively, of watermelon flour, wheat flour, and biscuit samples in triplicate analyses.

Total carbohydrate

Carbohydrate content (%) was calculated using BeMiller and Low's (1998) difference method as follows: Carbohydrate (%) = 100% – [ash (%) + moisture (%) + protein (%) + fat (%).

Table 1. Formulation of biscuits prepared with varying proportions of wheat flour and watermelon flour.

Ingredients (100 g)	WBC	WMB 10%	WMB 15%	WMB 20%
Wheat flour (g)	100	90	85	80
Watermelon flour (g)	–	10	15	20
Sugar (g)	30	30	30	30
Buttermilk (g)	15	15	15	15
Skimmed milk powder (g)	0.5	0.5	0.5	0.5
Ammonium bicarbonate (g)	0.66	0.66	0.66	0.66
Sodium bicarbonate (g)	0.33	0.33	0.33	0.33
Egg (g)	24	24	24	24
Vanilla (tsp)	1	1	1	1

WBC: wheat flour (100), WMB 10%: watermelon flour and wheat flour (10:90), WMB 15%: watermelon flour and wheat flour (15:85), and WMB 20%: watermelon flour and wheat flour (20:80).

Figure 1. Photographs of biscuits prepared with varying levels of watermelon powder.

Determination of surface color

The Commission Internationale de L'Eclairage (CIE) surface color attributes (L^*, lightness; a^*, redness; and b^*, yellowness) of the developed biscuits were assessed using a Minolta CR-400 colorimeter (Konica, Tokyo, Japan). After calibrating the colorimeter with a white plate, triplicate analyses were conducted for each biscuit sample.

Determination of minerals

The atomic absorption method, as described by Shahidi *et al.* (1999), was used to determine minerals (namely calcium, iron, sodium, and magnesium) in composite flour and biscuit samples. Briefly, the samples were subjected to ashing at 550°C in a muffle furnace, followed by digestion using a mixture of distilled water, HCl, and HNO_3 (3:2:1 v/v), and the mineral concentrations were expressed as parts per million (ppm). Phosphorus was measured using a colorimetric method (Fila *et al.*, 2013). After mixing 0.5 mL of digested sample with 4.0 mL of double-distilled water (ddH_2O), 3.0 mL of 750 mM H_2SO_4, 0.4 mL of 10% (w/v) ammonium heptamolybdate tetrahydrate [$(NH_4)_6Mo_7O_{24}{\cdot}4H_2O$], and 0.4 mL of 2% (w/v) ascorbic acid, the mixture was allowed to stand at room temperature for 20 min before measuring absorbance at 660 nm, following the molybdenum–blue method of Murphy and Riley (1962).

Bulk Density (BD) determination

The bulk density of wheat–watermelon composite flour and biscuits with different levels of watermelon in the composite flour was measured using the measuring cylinder packing method, as described by Onabanjo and Ighere (2014). In brief, an empty 10 mL measuring cylinder was initially weighed and then filled with the sample to a 10 mL volume, followed by gentle tapping on the bench to achieve a constant volume. The mass of the measuring cylinder containing the sample was then recorded. The bulk density (BD) was calculated as the mass per volume of the sample (g/mL).

Water absorption capacity (WAC) determination

The water absorption capacity (WAC) of wheat–watermelon composite flour and biscuits with different levels of watermelon in the composite flour was measured as described by Oyeyinka *et al.* (2014). Briefly, a graduated centrifugal tube was weighed, and 1 g of the sample was added to the tube, mixed well with 10 mL of distilled water, allowed to stand for 1 min, and then centrifuged at 5000 rpm for 30 min. After discarding the supernatant, the tube was weighed, and the mass gained was considered as the WAC of the sample, expressed as g absorbed water/g sample.

Oil absorption capacity (OAC) determination

The method described by Oyeyinka *et al*. (2014) was used to measure the oil absorption capacity (OAC) using a graduated centrifugal tube of known weight. A 1 g sample was added to the tube, mixed with 10 mL of refined soybean oil, allowed to stand for 30 min at room temperature, and then centrifuged at 2000 rpm for 30 min. The supernatant was discarded, and the oil absorbed by the flour was weighed. The OAC was calculated as g oil absorbed/g sample.

Sensory analysis

A panel of 20 trained members was used to analyze the sensory quality attributes (flavor, color, taste, crispness, and overall acceptability) of the biscuits. The analysis was conducted under appropriate conditions in a Sensory Evaluation Laboratory. A 10-point hedonic scale was used for sensory evaluation, where 10 indicates "like very much" and 1 indicates "dislike very much" (Watts *et al*., 1989).

Statistical analysis

The data from triplicate samples were analyzed statistically using the Statistical Package for the Social Sciences (SPSS) 20.0 software (SPSS Inc., Chicago, IL, USA). One-way analysis of variance (ANOVA) and Duncan's Multiple Range Test were used to determine statistical significance at $p < 0.05$. The results were presented as mean values of three individual replicates ± standard deviation.

Results and Discussion

Proximate composition of wheat and watermelon flour

The results in Table 2 show the percentages of moisture, protein, fat, ash, fiber, and carbohydrate in wheat and watermelon flour samples. Higher ($P < 0.05$) protein, fat, and carbohydrate contents were observed in wheat flour compared to watermelon flour, whereas watermelon flour showed higher ($P < 0.05$) moisture, ash, and fiber contents than wheat flour. These findings indicate a difference in the proximate composition between the raw materials used to prepare the biscuits. The variations are likely due to differences in genotypes, environmental conditions, and growing practices. Comparable levels of moisture, ash, protein, and fiber have been reported by Nisar *et al*. (2020). In addition, Abyssinian purple wheat flour contains 10.76% moisture, 8.5% protein, 3.03% fat, 7.3% fiber, 5.5% ash, and 64.85% carbohydrates (Kassegn, 2018), which is partially comparable to our findings. It has also been reported that melon peel from different melon types is a good source of ash, fiber, and carbohydrate content (Hussain *et al*., 2024), which aligns partially with the findings of this study. Furthermore, varying amounts of protein, ash, fiber, fat, and carbohydrates have been reported in the rind of different types of watermelon (Al-Sayed and Ahmed, 2013; Ashoka *et al*., 2021; Sadiq *et al*., 2022).

Technological properties of biscuits

The results of the bulk density (BD), water absorption capacity (WAC), and oil absorption capacity (OAC) are presented in Table 3. The highest ($P < 0.05$) BD was observed in biscuits with 10% watermelon flour, followed by those made from wheat flour only. BD is a crucial parameter in food manufacturing, as it reflects the capacity of packaging materials and is influenced by various factors, including surface properties, particle size, geometry, solid density, starch content, composition, and the measurement method (Awuchi *et al*., 2019). High BD indicates the suitability of the flour for food preparations, whereas low BD indicates its suitability for complementary foods (Suresh and Samsher, 2013). The high BD of biscuits made from wheat flour only or wheat flour with 10% melon flour could be attributed to the type and composition of starch in wheat flour and the size of the flour particles (Awuchi *et al*., 2019). Increasing the levels of watermelon flour in the biscuit formulations concurrently ($P < 0.05$) increased the WAC and OAC, reaching maximum levels in biscuits containing 20% watermelon flour, followed by those containing 15% and 10% watermelon flour. The lowest ($P < 0.05$) WAC and OAC were observed in biscuits made using wheat flour only, without the addition of watermelon flour. The protein and starch in food affect the WAC and OAC of the final product (Bello and Oladeji, 2024); therefore, the variation in the WAC and OAC of biscuits made with composite flour of wheat and watermelon is likely due to differences in starch and protein composition between wheat and watermelon flour (Awuchi *et al*., 2019; Suresh and Samsher, 2013). In agreement with our results, Imoisi *et al*. (2020) reported that as the concentration of watermelon rind flour increases in bread formulations, the WAC and OAC also increase concurrently. In addition, the WAC and OAC of a composite flour made from cocoyam and watermelon rind flour

Table 2. Proximate composition (%) of wheat flour and watermelon flour.

Sample	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate
Wheat flour	6.30^b±0.01	10.0^a±0.16	6.29^a±0.02	1.45^b±0.02	1.30^b±0.01	73.50^a±0.23
Watermelon flour	8.40^a±0.01	6.0^b±0.16	3.00^b±0.02	4.45^a±0.02	7.30^a±0.01	65.50^b±0.23

The mean values in each column with different superscript letters are significantly different at P < 0.05. The presented data are the mean value of three replications ± standard deviation.

Table 3. Technological properties of biscuits prepared with varying concentrations of watermelon flour.

Parameter	Formulated biscuits			
	WBC	WMB 10%	WMB 15%	WMB 20%
BD (g/mL)	0.766^b±0.00	0.770^a±0.00	0.763^c±0.00	0.720^d±0.00
WAC (g/g)	1.65^d±0.00	2.00^c±0.00	2.72^b±0.00	2.97^a±0.00
OAC (g/g)	1.15^d±0.00	1.32^c±0.00	1.58^b±0.00	1.70^a±0.00

The mean values in each row with different superscript letters are significantly different at P < 0.05. The presented data are the mean value of three replications ± standard deviation. WBC: wheat flour (100), WMB10%: watermelon flour and wheat flour (10:90), WMB15%: watermelon flour and wheat flour (15:85), WMB20%: watermelon flour and wheat flour (20:80). BD: bulk density; WAC: water absorption capacity; OAC: oil absorption capacity.

Table 4. Surface color attributes of biscuits prepared with varying concentrations of watermelon flour.

Parameter	Formulated biscuits			
	WBC	WMB 10%	WMB 15%	WMB 20%
L*	61.09^a±0.23	60.53^b±0.09	60.42^c±0.08	59.30^d±0.19
a*	7.09^d±0.17	7.31^c±0.20	8.12^b±0.24	8.45^a±0.20
b*	25.12^d±0.14	25.35^c±0.06	26.45^b±0.19	27.12^a±0.23

The mean values in each row with different superscript letters are significantly different at P < 0.05. The presented data are the mean value of three replications ± standard deviation. WBC: wheat flour (100), WMB10%: watermelon flour and wheat flour (10:90), WMB15%: watermelon flour and wheat flour (15:85), WMB20%: watermelon flour and wheat flour (20:80).

increased concurrently with the increase in watermelon rind extract in the blend (Bello and Oladeji, 2024). The increase in WAC is generally linked to enhanced solubility and leaching of amylose and starch, as well as losses in the crystalline structure (Imoisi *et al.*, 2020). The increase in OAC is typically associated with increased protein hydrophobicity and non-polar side chains that bind to oil molecules, thereby entrapping the oil in the flour (Imoisi *et al.*, 2020).

Surface color attributes of biscuits

The results on the color attributes of wheat-watermelon composite flour biscuits are presented in Table 4. The visual appearance of the developed biscuits is shown in Figure 1, indicating that the biscuit formulations have an acceptable appearance. Biscuits made with 100% wheat flour exhibited the highest L* (lightness) values (P < 0.05), and L* decreased significantly (P < 0.05) as the watermelon flour concentration increased, reaching its lowest point at 20% watermelon inclusion. In contrast, a* (redness) and b* (yellowness) values increased progressively with the increase in watermelon concentration, reaching the highest levels in biscuits fortified with 20% watermelon flour (P < 0.05). The lowest a* and b* values were observed in biscuits made with wheat flour only. These findings suggest that incorporating watermelon into biscuits had a marked negative effect on lightness and a positive effect on redness and yellowness. Bolaji *et al.* (2022) reported that the incorporation of watermelon seed flour into white bread formulations increased all the color attributes of the product. Wójcik *et al.* (2023) observed that watermelon seed flour increased the lightness and redness of low-carbohydrate, high-protein bread and did not affect the yellowness of the product. Al-Sayed and Ahmed (2013) stated that increasing the level of watermelon rind flour in cake formulations increased redness values while reducing the lightness and yellowness values of the crust and crumb. The incorporation of watermelon flour likely altered the product's color both because of the flour's natural pigments and the formation of Maillard reaction products between proteins and carbohydrates during baking (Al-Sayed and Ahmed, 2013; Wani *et al*., 2012).

Proximate composition of biscuits

The proximate composition of biscuits as affected by the incorporation of different levels of watermelon flour is presented in Table 5. The highest ($P < 0.05$) levels of moisture, ash, fiber, and fat were observed in biscuits containing 20% watermelon flour, followed by those with 15% watermelon flour, while the lowest ($P < 0.05$) values were recorded in biscuits made with wheat flour only. The highest levels of protein and carbohydrate were observed in biscuits made from wheat flour only, whereas the lowest levels were found in biscuits made using composite flour containing 20% watermelon flour. These findings indicate that incorporating watermelon flour into biscuit formulations concurrently increased moisture, ash, fiber, and fat, while reducing protein and carbohydrate contents. This increase is likely due to the higher levels of moisture, ash, and fiber, and lower levels of protein in watermelon flour compared to wheat flour, as shown in Table 2. Previous reports have indicated that the incorporation of watermelon seed or peel flour has varied effects on the proximate composition of the final products. Peter-Ikechukwu *et al.* (2018) reported that increasing the level of watermelon seed flour in biscuit formulations increased the protein, ash, fiber, and fat content, while reducing the carbohydrate content of both the blend and the biscuits. Hussain *et al*. (2024) reported that increasing the levels of watermelon peel flour in biscuit formulations concomitantly increased the moisture, ash, fiber, fat, and carbohydrate content, while reducing the protein content of biscuits fortified with 5% and 10% watermelon peel powder. Imoisi *et al.* (2020) stated that increasing the levels of watermelon rind flour in wheat bread formulations significantly affected the proximate composition, as it increased the ash, protein, and carbohydrate content while reducing the moisture and fat content of the bread. Variations in the developed food products may explain these discrepancies, including the genotypes employed, cultivation and environmental conditions, and postharvest processing methods of the fruit. Overall, the increased levels of moisture, ash, fiber, and fat in the developed watermelon-based biscuits in the current study are of high importance from both nutritional and technological perspectives. Fradinho *et al.* (2015) found that increased moisture retention in biscuits enriched with melon peel powder enhanced both their textural properties and shelf stability. In the developed biscuits, higher ash content indicates increased mineral levels, highlighting their nutritional significance given the vital roles minerals play in physiological processes (Hussain *et al*., 2024). Fiber is known for its beneficial effects on digestive system health; therefore, increased levels of fiber in biscuits incorporated with watermelon flour could have significant nutritional and health potential. It has been reported that watermelon peel flour influences the gut microbiota and leads to increased production of short-chain fatty acids with high health-promoting potential. Gómez-García *et al.* (2022) demonstrated that watermelon peel flour modulates gut microbiota and enhances short-chain fatty acid production. Accordingly, the elevated fat content in the biscuits developed in this study—when derived from heart-healthy unsaturated oils such as extra-virgin olive oil (rich in oleic acid, 70–85% of total fatty acids; Di Mattia *et al*., 2020), safflower oil (rich in linoleic acid, mean 70.66%; Matthäus *et al*., 2015), and flaxseed oil (rich in α-linolenic acid, 39.35–60.11%; Koçak, 2024)—could confer additional health benefits.

Mineral contents of biscuits

The mineral contents of biscuits as affected by the incorporation of watermelon flour into the biscuit formulations

Table 5. Proximate composition (%) of biscuits prepared with varying concentrations of watermelon flour.

Parameter	Formulated biscuits			
	WBC	WMB10%	WMB15%	WMB20%
Moisture	$8.50^{d}\pm0.00$	$9.50^{c}\pm0.00$	$10.67^{b}\pm0.02$	$12.87^{a}\pm0.15$
Ash	$1.31^{d}\pm0.02$	$4.35^{c}\pm0.19$	$9.85^{b}\pm0.44$	$13.80^{a}\pm0.17$
Fiber	$1.30^{d}\pm0.01$	$1.59^{c}\pm0.02$	$4.71^{b}\pm0.45$	$9.50^{a}\pm0.60$
Fat	$9.36^{c}\pm0.02$	$9.80^{b}\pm0.02$	$10.12^{a}\pm0.14$	$10.38^{a}\pm0.17$
Protein	$12.00^{a}\pm0.16$	$11.90^{a}\pm0.21$	$10.89^{b}\pm0.00$	$10.56^{c}\pm0.01$
Carbohydrate	$60.92^{a}\pm0.23$	$56.40^{b}\pm0.23$	$39.70^{c}\pm1.07$	$31.25^{d}\pm0.35$

The mean values in each row with different superscript letters are significantly different at $P < 0.05$. The presented data are the mean value of three replications ± standard deviation. WBC: wheat flour (100), WMB10%: watermelon flour and wheat flour (10:90), WMB15%: watermelon flour and wheat flour (15:85), WMB20%: watermelon flour and wheat flour (20:80).

are presented in Table 6. The addition of watermelon flour influenced the mineral composition in various ways. Increasing the concentration of watermelon flour in the biscuit formulations concomitantly increased the levels of all minerals, except magnesium, which decreased as the amount of watermelon flour added increased ($P < 0.05$). The highest ($P < 0.05$) amounts of calcium, phosphorus, and iron were observed in biscuits made from composite flour containing ≥15% watermelon flour, whereas the lowest ($P < 0.05$) values were recorded in biscuits made from wheat flour only. Sodium was higher ($P < 0.05$) in biscuits containing watermelon flour than in those made with wheat flour only. Magnesium was highest ($P < 0.05$) in wheat flour biscuits, and its concentration decreased concurrently as the level of watermelon in the biscuits increased. Increasing the levels of melon peel powder in biscuits increased the quantities of calcium, magnesium, iron, potassium, and zinc in the developed products (Hussain *et al*., 2024), which is partially consistent with the findings of this study. In addition, the amounts of calcium, magnesium, potassium, phosphorus, and iron in wheat-watermelon flour cookies significantly increased as the levels of watermelon peel flour increased in the blend (Olaitan *et al*., 2017). Moreover, the incorporation of watermelon rind flour into sponge cake resulted in higher levels of calcium, phosphorus, and iron compared to the control cake without watermelon peel flour (Ashoka *et al*., 2023), which aligns with the findings of this study. Calcium contributes to bone health and structure, phosphorus is essential for energy production, iron supports the quality and quantity of hemoglobin and myoglobin, and sodium is required for normal bodily function and overall health (Chakrabarty *et al*., 2019; Mente *et al*., 2021; Ali, 2023). Therefore, the increase in calcium, sodium, phosphorus, and iron content in biscuits following the addition of watermelon flour indicates high health potential, highlighting the use of watermelon flour in food products to enhance their mineral content and nutritional quality.

Sensory evaluation of biscuits

The results on the sensory quality attributes (color, taste, flavor, crispness, and overall acceptability) of biscuits are presented in Table 7. Overall, there were no significant differences in any of the attributes between biscuit samples, suggesting that the incorporation of watermelon flour into biscuit formulations did not negatively affect the sensory quality of the developed biscuits.

Table 6. Mineral contents (ppm) of biscuits prepared with varying concentrations of watermelon flour.

Parameter	Formulated biscuits			
	WBC	WMB 10%	WMB 15%	WMB 20%
Calcium	27.90^{c}±1.06	34.50^{b}±0.03	35.75^{a}±0.35	36.34^{a}±0.03
Sodium	2.30^{b}±0.14	2.60^{a}±0.14	2.70^{ab}±0.14	2.80^{a}±0.14
Phosphorus	29.22^{d}±0.35	30.63^{c}±0.35	32.30^{b}±0.35	33.35^{a}±0.35
Magnesium	135.75^{a}±0.21	134.25^{b}±0.21	133.05^{c}±0.21	131.25^{d}±0.21
Iron	90.12^{c}±0.17	91.24^{b}±0.17	92.05^{a}±0.35	92.08^{a}±0.35

The mean values in each row with different superscript letters are significantly different at $P < 0.05$. The presented data are the mean value of three replications ± standard deviation. WBC: wheat flour (100), WMB10%: watermelon flour and wheat flour (10:90), WMB15%: watermelon flour and wheat flour (15:85), WMB20%: watermelon flour and wheat flour (20:80).

Table 7. Sensory attributes of biscuits prepared with varying concentrations of watermelon flour.

Parameter	Formulated biscuits			
	WBC	WMB 10%	WMB 15%	WMB 20%
Color	7.30^{a}±1.07	8.66^{a}±0.57	8.00^{a}±1.28	8.00^{a}±1.18
Taste	9.55^{a}±1.07	9.00^{a}±0.48	9.00^{a}±0.56	9.33^{a}±2.08
Flavor	9.30^{a}±1.42	9.33^{a}±1.06	9.10^{a}±1.14	9.00^{a}±1.03
Crispness	8.00^{a}±1.25	9.35^{a}±1.05	8.66^{a}±0.63	9.00^{a}±0.84
Overall acceptability	9.66^{a}±0.36	9.43^{a}±0.52	9.23^{a}±1.46	8.90^{ab}±1.46

The mean values in each row with different superscript letters are significantly different at $P < 0.05$. The presented data are the mean value of three replications ± standard deviation. WBC: wheat flour (100), WMB10%: watermelon flour and wheat flour (10:90), WMB15%: watermelon flour and wheat flour (15:85), WMB20%: watermelon flour and wheat flour (20:80).

Interestingly, high (≥8.0) likeness scores were reported for all assessed sensory attributes, indicating that the panelists well accepted the developed products in terms of color, taste, flavor, crispness, and overall acceptability. Previous studies have shown that the incorporation of watermelon peel or seed flour influences sensory attributes in different ways. Wani *et al*. (2012) reported no significant differences in appearance, color, aroma, or taste between cookies fortified with watermelon protein isolate and unfortified control cookies. Hussain *et al*. (2024) observed that control biscuits had higher scores for all sensory attributes compared to biscuits fortified with watermelon peel powder. Olaitan *et al*. (2017) reported no significant differences in texture, flavor, or crispness scores, but noted a gradual reduction in appearance and overall acceptability of wheat-based cookies as the level of watermelon rind flour increased in the product formulation. Overall, the findings of this study demonstrate that incorporating watermelon flour into biscuits can enhance their nutritional and health quality without adversely affecting consumer acceptability.

Conclusion

In this study, a suitable formulation for biscuit production using watermelon flour was developed. Watermelon flour is nutrient-rich and can serve as a beneficial ingredient for producing functional biscuits. Biscuits formulated with 10–20% watermelon flour exhibited higher levels of water absorption capacity, oil absorption capacity, redness, yellowness, moisture, ash, fiber, fat, calcium, sodium, phosphorus, and iron, and lower levels of lightness, protein, carbohydrates, and magnesium compared to control biscuits without watermelon flour, indicating enhanced nutritional quality. Overall, the incorporation of watermelon flour into biscuit formulations can improve the nutritional and health-related quality attributes of the product without adversely affecting sensory properties or consumer acceptability.

Author Contributions

All authors contributed equally to this article.

Conflict of Interest

The authors declare no conflict of interest.

Funding

The authors extend thanks to the Princess Nourah bint Abdulrahman University Researchers Supporting Project number (PNURSP2025R249), Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia.

References

Adeoye, I.B., Olajide-Taiwo, F.B., Adebisi-Adelani, O., Usman, J.M., & Badmus, M.A. (2011). Economic analysis of watermelon-based production system in Oyo State. Nigeria Journal of Agricultural and Biological Science, 6, 53–59.

Ali, A.A.H. (2023). Overview of the vital roles of macro minerals in the human body. Journal of Trace Elements in Medicine and Biology, 4, 100076. https://doi.org/10.1016/j.jtemin.2023.100076

Al-Kuraieef, A.N. (2021). Study on the effect of incorporation of irradiated sunflower flour on the physicochemical and sensory properties of biscuits during the storage period. Food Research, 5(2), 191–200.

Al-Sayed, H.M.A., & Ahmed, A.R. (2013). Utilization of watermelon rinds and sharlyn melon peels as a natural source of dietary fiber and antioxidants in cake. Annals of Agricultural Sciences, 58, 83–95. https://doi.org/10.1016/j.aoas.2013.01.012

AOAC. (1995). Official methods of analysis. Washington, DC: Association of Official Analytical Chemists.

AACC International. (2001). Approved methods of analysis (10th ed., Method 10-54: Soft-dough biscuit preparation).

Arivuchudar, R. (2023). Nutritional and sensory characterization of watermelon rind powder incorporated crackers. Bioscience, Biotechnology Research Asia, 20(1), 263–269.

Ashoka, S., Shamshad, S., Rajaram, B., & Ray, M. (2021). Effect of watermelon (Citrullus lanatus) rind flour incorporation on nutritional and organoleptic attributes of cakes. Mysore Journal of Agricultural Sciences, 55, 31–35.

Awuchi, C.G., Igwe, V.S., & Echeta, C.K. (2019). The functional properties of food and flour. International Journal of Advanced Academic Research, Sciences, Technology and Engineering, 5(11), 139–160.

Bello, F.A., & Oladeji, B.S. (2024). Physicochemical and antioxidant properties of cocoyam, African yam bean and watermelon rind flour blends and consumer acceptability of its cake. IPS Journal of Nutrition and Food Science, 3(3), 214–221.

BeMiller, J.N., & Low, N.H. (1998). Carbohydrate analysis. In S. S. Nielsen (Ed.), Food analysis (2nd ed., pp. 167–187). Gaithersburg, MD: Chapman and Hall.

Bolaji, O.T., Adeyeye, S.A.O., & Ogunmuyiwa, D. (2022). Quality evaluation of bread produced from whole wheat flour blended with watermelon seed flour. Journal of Culinary Science & Technology, Article 2068466. https://doi.org/10.1080/15428052.2022.2068466

Chakrabarty, K., & Chakrabarty, A.S. (Eds.). (2019). Micronutrients. In Textbook of nutrition in health and disease (pp. 75–122). Springer. https://link.springer.com/chapter/10.1007/978-981-15-0962-9_4

Di Mattia, C.D., Sacchetti, G., Mastrocola, D., & Pittia, P. (2020). Bioactive compounds and quality of extra virgin olive oil. Antioxidants, 10(5), 689. https://doi.org/10.3390/antiox10050689

FAOSTAT. (2025). Food and Agriculture Organization of the United Nations data. https://www.fao.org/faostat/en/#data/QCL (Accessed: May 10, 2025).

Fila, W.A., Itam, E.H., Johnson, J.T., Odey, M.O., Effiong, E.E., Dasofunjo, K., & Ambo, E.E. (2013). Comparative proximate compositions of watermelon (Citrullus lanatus), squash (Cucurbita pepo L.), and rambutan (Nephelium). International Journal of Science and Technology, 2, 81–88.

Fradinho, P., Nunes, M.C., & Raymundo, A. (2015). Developing consumer acceptable biscuits enriched with psyllium fiber. Journal of Food Science and Technology, 52, 4830–4840. https://doi.org/10.1007/s13197-014-1549-6.

Gómez-García, R., Sánchez-Gutiérrez, M., Freitas-Costa, C., Vilas-Boas, A.A., Campos, D.A., Aguilar, C.N., et al. (2022). Prebiotic effect, bioactive compounds and antioxidant capacity of melon peel (Cucumis melo L. inodorus) flour subjected to in vitro gastrointestinal digestion and human faecal fermentation. Food Research International, 154, 111045. https://doi.org/10.1016/j.foodres.2022.111045

Goubgou, M., Songré-Ouattara, L.T., Bationo, F., Lingani-Sawadogo, H., Traoré, Y., & Savadogo, A. (2021). Biscuits: A systematic review and meta-analysis of improving the nutritional quality and health benefits. Food Production, Processing and Nutrition, 3, 26. https://doi.org/10.1186/s43014-021-00071-z

Hussain, A., Laaraj, S., Tikent, A., Elfazazi, K., Adil, M., Parveen, S., Bouhrim, M., Mothana, R.A., Noman, O.M., Eto, B., Yaqub, S., Fatima, H., & Firdous, N. (2024). Physicochemical and phytochemical analysis of three melon fruit (canary melon, watermelon, and muskmelon) peels, and their valorization in biscuits development. Frontiers in Sustainable Food Systems, 8, 1444017. https://doi.org/10.3389/fsufs.2024.1444017

Imoisi, C., Iyasele, J.U., Michael, U.C., & Imhontu, E.E. (2020). The effects of watermelon rind flour on the functional and proximate properties of wheat bread. Journal of the Chemical Society of Nigeria, 45(5), 978–986.

Kassegn, H.H. (2018). Determination of proximate composition and bioactive compounds of the Abyssinian purple wheat. Cogent Food & Agriculture, 4, 1421415. https://doi.org/10.1080/23311932.2018.1421415

Koçak, M.Z. (2024). Phenolic compounds, fatty acid composition, and antioxidant activities of some flaxseed (Linum usitatissimum L.) varieties: A comprehensive analysis. Processes, 12(4), 689. https://doi.org/10.3390/pr12040689

Matthäus, B., Özcan, M.M., & Al Juhaimi, F.Y. (2015). Fatty acid composition and tocopherol profiles of safflower (Carthamus tinctorius L.) seed oils. Natural Product Research, 29(2), 193–196. https://doi.org/10.1080/14786419.2014.971316

Mente, A., O'Donnell, M., & Yusuf, S. (2021). Sodium intake and health: What should we recommend based on the current evidence? Nutrients, 13, 3232. https://doi.org/10.3390/nu1309323

Murphy, J., & Riley, J.P. (1962). A modified single-solution method for the determination of phosphate in natural waters. Analytica Chimica Acta, 27, 31–36.

Nisar, N., Mustafa, F., Tahir, A., Qadri, R., Yang, Y., Khan, M.I., & Wang, F. (2020). Proximate composition, functional properties and quantitative analysis of benzoyl peroxide and benzoic acid in wheat flour samples: Effect on wheat flour quality. PeerJ, 8, e8788. https://doi.org/10.7717/peerj.8788

Nissar, J., Sidiqi, U.S., Dar, A.H., & Akbar, U. (2025). Nutritional composition and bioactive potential of watermelon seeds: A pathway to sustainable food and health innovation. Sustainable Food Technology, 3, 375.

Olaitan, N.I., Eke, M.O., & Agudu, S.S. (2017). Effect of watermelon (Citrullus lanatus) rind flour supplementation on the quality of wheat-based cookies. The International Journal of Engineering and Science, 6(12), 38–44.

Onabanjo, O.O., & Ighere, D.A. (2014). Nutritional, functional and sensory properties of biscuit produced from wheat-sweet potato composite. Journal of Food Technology Research, 1, 111–121.

Oyeyinka, S.A., Oyeyinka, A.T., Karim, O.R., Toyeeb, K.A., Olatunde, S.J., & Arise, A.K. (2014). Biscuit making potentials of flours from wheat and plantain at different stages of ripeness. Croatian Journal of Food Science and Technology, 6, 36–42.

Peter-Ikechukwu, A.I., Omeire, G.C., Kabuo, N.O., Eluchie, C.N., Amandikwa, C., & Odoemenam, G.I. (2018). Production and evaluation of biscuits made from wheat flour and toasted watermelon seed meal as fat substitute. Journal of Food Research, 7(5), 112–123.

Quandoh, E., & Albornoz, K. (2025). Fresh-cut watermelon: Postharvest physiology, technology, and opportunities for quality improvement. Frontiers in Genetics, 16, 1523240. https://doi.org/10.3389/fgene.2025.1523240.

Sadiq, I.S., Saminu, M.Y., Zainab, L., Adeleye, A.O., Sanni, L.E., & Dandalma, Z.A. (2022). Proximate analysis and phytochemical screening of watermelon (Citrullus lanatus) pulp, peels and seeds. Dutse Journal of Pure and Applied Sciences, 7, 174–182. https://doi.org/10.4314/dujopas.v7i4a.18

Shahidi, F., Chavan, U.D., Bal, A.K., & McKenzie, D.B. (1999). Chemical composition of beach pea (Lathyrus maritimus L.) plant parts. Food Chemistry, 64, 39–44.

Suresh Chandra, Samsher Singh, & Durvesh Kumari. (2015). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. Journal of Food Science and Technology, 52(6), 3681–3688. https://doi.org/10.1007/s13197-014-1427-2

Wani, A.A., Sogi, D.S., Singh, P., Sharma, P., & Pangal, A. (2012). Dough-handling and cookie-making properties of wheat flour–watermelon protein isolate blends. Food and Bioprocess Technology, 5, 1612–1621. https://doi.org/10.1007/s11947-011-0655-1

Watts, B. M., Ylimaki, G. L., & Jeffery, L. E. (1989). Basic sensory methods for food evaluation. Ottawa: The International Development Research Centre.

Wójcik, M., Bienczak, A., Woźniak, P., & Różyło, R. (2023). Impact of watermelon seed flour on the physical, chemical, and sensory properties of low-carbohydrate, high-protein bread. Processes, 11, 3282. https://doi.org/10.3390/pr11123282

Zia, S., Khan, M.R., Shabbir, M.A., & Aadil, R.M. (2021). [Title missing]. Trends in Food Science & Technology, 114, 275–291.