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Chemical Composition and Quality Attributes of Fortified Biscuit with Sesame Bran

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Abstract

Sesame bran (SB), a functional by-product of sesame processing, is rich in carbohydrates, dietary fiber, fat, ash, and minerals. Despite its high antioxidant capacity, the use of SB in the development of health-oriented bakery products remains underexplored. This study investigates the potential of incorporating SB as a partial substitute for whole wheat flour (WWF) at levels of 10%, 20%, and 30% in biscuit formulations to enhance their nutritional profile.". Raw materials were estimated for chemical composition, minerals, anti-nutritional factors, antioxidant activity, fatty acids, and amino acids profiles. The effect of different mixtures on the quality of the final product was studied in terms of chemical composition, minerals, antioxidant activity, anti-nutritional factors, baking quality, color measurement, hardness, and sensory evaluation. Data indicated that 10% SB-fortified biscuits recorded the highest scores of sensory parameters including color, taste, appearance, texture and overall acceptability. All fortified biscuits (10, 20 and 30%) recorded a significant difference in terms of ash, fiber, and total carbohydrates. While the 30% SB-fortified biscuits were the only ones that recorded a significant difference regarding the moisture, protein, and fat content compared to the control biscuit. The mineral content (Mg, Ca, Fe and Zn) and antioxidant activity of all fortified biscuit samples showed a significant increase, directly proportional to the SB replacement ratios. Similarly, a significant increase in the phytic acid and tannins content of fortified biscuits was observed. The elevated proximate composition and mineral element values of whole wheat-sesame bran biscuits samples are an indication that it might improve the nutrition status of biscuit consumers upon consumption. The study has revealed the suitability of sesame bran in bakery product production.

Keywords: Food Fortification, Functional Foods, Bakery Products Innovations, Sensory Analysis.

1. Introduction

Food fortification strategies offer a potential solution to address worldwide nutritional deficiency issues, especially in less developed nations. This method can help mitigate problems arising from the insufficient intake of essential nutrients and vitamins, such as iron deficiency and goiter, which predominantly affect women and children [1]. Moreover, there is a noticeable shift towards healthier eating habits and increased research on food additives, including those rich in dietary fibers and exhibiting strong antioxidant properties without the adverse effects typically associated with synthetic compounds [2].

In recent times, nutritionists have prioritized food fortification as a key strategy to increase public awareness about food-related issues [3]. Recently consumers are showing a growing interest in healthier food options that offer positive health benefits, such as enhancing bodily functions or reducing disease risks [4].

The widespread consumption of biscuits, a processed food product, can be attributed to several factors. These include their ready availability, substantial nutritional value, economic pricing, capacity to satisfy various flavor preferences, and extended preservation period. Such characteristics have contributed to the increasing popularity of biscuits among consumers [5]. For example, as an economical and tasty option, they are frequently favored by young people. These snacks present an opportunity for easy fortification with diverse micronutrients, encompassing proteins, vitamins, and minerals [6].

Sesame (Sesamum indium L.) is a globally important oilseed crop, utilized both as a source of edible oil and as a common component in baked goods and confectionery products [7]. The recent increase in sesame seed production has elevated its importance for consumers and its use in numerous healthy and nutritious products. From a nutritional standpoint, sesame is considered a valuable protein source, containing a high ratio of essential and non-essential amino acids compared to other seed proteins. Additionally, it contains many nutrients crucial for maintaining good health. During the complex processing of sesame seeds, the bran, which makes up about 15-18% of the total weight, is extracted for use in animal feed. Another portion is ground into sesame flour for incorporation into healthy food applications [8].

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Sesame bran (SB) is a by-product of the food industry, recognized as a sufficient supply of bioactive components, utilized in the development of low-calorie, high-fiber foods. It is inexpensive, accessible, and produced in enormous quantities. Therefore, it possesses a high nutritive value, serving as a food supplement to enhance and augment the nutritious content of other food products that may be deficient in protein and important minerals. The entire seed exhibited a somewhat higher crude protein content than the de-hulled seed, indicating that the hull (bran) both contained and contributed to the crude protein levels of the seed. The entire seed had a markedly larger crude fiber content compared to the de-hulled sample, offering several health benefits, including the prevention of constipation, colorectal disorders, diabetes, and obesity. Also The hull comprised around fifty percent of the total minerals found in the seed. [9].

Therefore, the purpose of the current research is to investigate the incorporation of sesame bran into biscuit formulations at varying substitution levels with whole wheat flour and to evaluate the impact of these substitution ratios on the quality attributes and physicochemical and sensory properties of biscuits. The effect of incorporating various levels of sesame bran powder into whole wheat flour in biscuit production on the physicochemical and sensory characteristics of biscuits will be assessed.

2. Material and Methods

2.1 Materials

Sesame bran was obtained from El Rashidi El Mizan, 6 October City in Egypt. Whole wheat flour used was" Dobella Brand" and other components salt, sugar, egg, shortening, vanilla powder and bakery powder were purchased from local markets in Alexandria, Egypt. Analytical grade reagents and chemicals were purchased from El-Goumhorya Company, Egypt.

2.2 Preparation of Sesame Bran Powder

Sesame bran was dried in an electrical oven at 60 °C for 20 minutes and then milled using a domestic electric grinder (Moulinex, France) to obtain a fine powder with an estimated particle size ranging between 250–500 μm. The resulting powder was stored in clean bags at 4 °C until use.

2.3 Recipe for Biscuit Production

Table 1: Biscuit Formulas

Samples	Ingredients (g)							
	WWF	SB	SH	Salt	Sugar	Egg	VP	BP
Control	500	-	160	1.50	135	1.50	3.00	15.00
T1	450	50	160	1.50	135	1.50	3.00	15.00
T2	400	100	160	1.50	135	1.50	3.00	15.00
T3	350	150	160	1.50	135	1.50	3.00	15.00

SB= Sesame Bran, WWF= Whole Wheat flour, SH= Shortening, VP= Vanilla Powder, BP= Baking Powder.

Biscuits were prepared using various formulations according to Saba [10] with some modifications. The ingredients, including eggs, shortening, sugar, vanilla sugar, baking powder, salt, and flour, were mixed using the creaming method to form a homogenous dough. The dough was then flattened, sheeted to a uniform thickness, and baked at 160 °C for 15 minutes. After baking, the biscuits were allowed to cool at room temperature, weighed, and stored for 24 hours prior to conducting sensory evaluations.

2.4 Quality Attributes of Biscuits:

The biscuits' physical properties were analyzed after they had been cooled at room temperature. The weight of the samples was measured using a sensitive balance, and the sample volume was determined using the seed displacement method [11].

The specific volume of the samples was calculated according to the AACC method by dividing the volume of the sample in (cm^3) by weight in (g).

Also the study used AACC's method to measure biscuit thickness and diameter, then re-measured and reassembled to obtain the average thickness [12].

The spread ratio was calculated and the average weight of five biscuits was measured in g [13].

2.5 Color Measurement of Biscuit

Color parameters were performed using a high-performance color measurement spectrophotometer (Ultras can® VIS Spectrophotometer, Hunter Associates Laboratory Inc.). The instrument was first calibrated by a conventional white and black plate. The sample was placed at the specimen port; the tri-stimulus values of the color namely; L, a and b were measured where: L: value represents darkness from black (0) to white (100), a; value represents color ranging from red (+) to green (-) and b; value represents yellow (+) to blue (-) [14].

2.6 Hardness of Biscuit

Biscuit hardness was estimated by using a Brookfield instrument (Model TA-CT3), following the AACC method. The hardness was determined using a mass probe and determined the Hardness (N) (average of cycle 1 and cycle 2), as described in the operating instruction manual.
[12].

2.7 Chemical Analysis of Sesame Bran Powder, Whole Wheat Flour and Biscuit Samples

The moisture, fats, crude protein, ash and fiber contents of the raw materials and different biscuit samples were determined on dry basis according to the method of AOAC. [15].

2.8 Minerals Content of Sesame Bran Powder, Whole Wheat Flour and Biscuit Samples

Minerals contents, i.e. Fe, Ca, Mg and Zn, were determined on dry basis by using the atomic absorption spectrophotometer as described in AOAC with standard conditions for each of the elements [15].

2.9 Total Antioxidant Activity of Sesame Bran Powder, Whole Wheat Flour and Biscuit Samples

The free radical scavenging capacity of the sample extracts was measured using a stable 2, 2 diphenyl-1-picrylhydrazyl (DPPH) radical with some modifications [16]. First, the extinction of the disposable cuvette with 250µL of the ethanol $DPPH^{\cdot}$ solution and 2.1mL of 80% ethanol was measured as blank. Then, the 80% ethanol sample extracts (100µL) were added to 250µL of the ethanoic $DPPH^{\cdot}$ solution and 2 mL of 80% ethanol. The mixture was shaken vigorously and allowed to stand at room temperature in the dark for 20 minutes. The decrease in absorbance of the resulting solution was monitored at 517 nm for 20 minutes using a spectrophotometer. The results were expressed as DPPH radical scavenging activity and compared against a standard curve of ascorbic acid.

Antioxidant capacity was calculated as a percentage of discoloration defined as in the following equation:

$$\text{DPPH}\cdot \text{ scavenging activity } (\%) = [(A0- A1)/A0] \times 100$$

Where A0 is the absorbance of the control reaction, and A1 is the absorbance in the extract. Samples were analyzed in triplicate. [16].

2.10 Anti-Nutritional Factors of Sesame Bran Powder, Whole Wheat Flour and Biscuit Samples

The oxalate content of sesame bran, whole wheat, and biscuit samples was determined where the sample was digested in a flask, filtered, and aliquoted. The residue was washed and titrated with methyl orange indicator. The total oxalate content was calculated using the equation TV × 0.0045, where TV is the volume obtained after color change. The oxalate content was then calculated using the formula. On the other hand, tannins were determined where the sample was weighed, distilled water was added, and it was filtered. The filtrate was mixed with $FeCl_3$ in HCl and potassium ferrocyanide, and absorbance was measured using a spectrophotometer at a 725 nm wavelength. The concentration of tannins in the sample was calculated using the following equation: CT= (AT × CS)/AS, where CT is tannins concentration in mg %, AT is absorbance of the test sample, CS is the concentration of tannin in the standard, and AS is absorbance of the standard. But for phytate, 4 g of the sample was soaked in 100 mL of 2% HCl acid for 3 hours and filtered. The 25 mL of the filtrate, 5 mL of 0.3% NH_4SCN, and 53 mL of distilled water were mixed and titrated against 0.01 M standard $FeCl_3$ until a brownish-yellow color persisted for 5 sec. Phytin phosphorus (1 mL = 1.19 mg phytin phosphorous) was determined, and the phytic acid content was calculated by multiplying the value of the phytin phosphorus by 3.55. Phytate content (mg %) = TV (mL) × phytin phosphorous (1.19 g) × 3.55, where TV is the volume obtained after color change [17].

2.11 Amino Acid Profile of Sesame Bran Powder and Whole Wheat Flour by HPLC

The amino acids composition of the samples was determined using HPLC where 100 mg of the sample was mixed with 5 ml H_2O and 5 ml of HCl (Note: final concentration of HCl is 6 M) then heated at 120°C for 24 hrs and then filtered. Finally, 1 ml of the filtrate was dried, suspended in 0.1 M HCl and injected into HPLC instrument model 1100 (Agilent Technologies, CA, USA) system Where, chromatographic separation of amino acids was carried out using a ZORBAX Eclipse AAA column (4.6 × 150 mm, 5 µm particle size). The mobile phase consisted of two solvents: Mobile Phase A, which was 40 mM sodium phosphate buffer (pH 7.8), and Mobile Phase B, a mixture of acetonitrile, methanol, and water in a ratio of 45:45:10 (v/v/v). The flow rate was maintained at 1.0 mL/min, and the column temperature was set to 40°C. A 10 µL sample volume was injected into the HPLC system. Detection was performed using a UV detector at 338 nm, following post-column derivatization with O-thioaldehyde (OPA), which reacts specifically with primary amino acids. The total run time for each sample was approximately 45 minutes [18].

2.12 Fatty Acid Profile of Sesame Bran Powder by GC

The fatty acid composition was determined by the trans methylation of the fatty chains to fatty acid methyl esters (FAMEs) according to the modified method by Zahran and Tawfeuk (2019). The FAMEs were separated with an HP 6890 plus gas chromatography (Hewlett Packard, USA), using a capillary column Supelco™ SP-2380 (60 m×0.25 mm×0.20 µm), (Sigma-Aldrich, USA), Detector (FID) and the injector and detector temperature was 250°C. The column temperature was 140°C (held for 5 min) and rose to 240°C, at a rate of 4°C/min, and held at 240°C for 10 min. The carrier gas was helium at a flow rate of 1.2 mL min-1. The sample volume was 1μL (in n-hexane) and injected through a split injector at a splitting ratio of 100:20. FAMEs were identified by comparing their relative and absolute retention times to those authentic standards of FAMEs (SupelcoTM 37component FAME mix). The fatty acid composition was reported as a relative percentage of the total peak area[19].

2.13 Sensory Evaluation of Biscuit Samples

A study was conducted on different biscuit samples prepared by 100 staff and student members of the High Institute of Public Health (HIPH), Alexandria University. The panelists were randomly selected from the staff and students and were given instructions on sensory evaluation. The testing area was a quiet, temperature-controlled room with good ventilation and lighting. Samples were presented randomly and evaluated for sensory characteristics using a 9-point scale. The participants were not influenced by each other and were arranged in a simple, non-discriminatory manner [20].

2.14 Statistical Analysis

The study used IBM SPSS software to analyze data, using ANOVA, LSD, and Student t-tests for statistical comparisons, with significance determined at a 5% level.

3. Results and Discussion

3.1. Proximate Composition of Sesame Bran and Whole Wheat Flour (On Dry Weight Basis)

Whole wheat flour and sesame bran are considering promising as functional food because they contain considerable nutrients, including protein, fat, fiber and carbohydrate.

Approximate analysis of used whole wheat flour and sesame bran was estimated (on dry weight basis), and the obtained data are presented in Table 2.

From the obtained results it can be seen that, the mean values of whole wheat flour were 10.31, 2.17, 14.62, 2.28, 9.35 and 71.58% for moisture, ash, protein, fat, fiber and total carbohydrates respectively compared to 6.50, 18.90, 7.50, 12.76, 19.45 and 41.38% which observed by sesame bran for the same aforementioned parameters respectively.

According to the statistical analysis, whole wheat flour recorded the highest values of moisture, protein and total carbohydrate content with significant differences ($P \leq 0.05$) compared to the moisture, protein and total carbohydrate content which observed in sesame bran.

The mentioned results by Talha and Mohamed (2011), who reported that sesame bran comprises 95.43% dry matter, 4.76% fat, 13.80% protein, 20.34% crude fiber, 34.09% ash, and 22.00% nitrogen-free extract [21].

Also, Ortega-Hernández et al. (2018) studied the approximate analysis of sesame bran and reported that it contained 0.60% moisture, 91.0% soluble fiber, 29.80% soluble fiber, 38.90% total fiber, 15.0% fat, 9.40% protein, 27.20% ash and 47.80% total carbohydrates. These findings are close to the study results in percentage of fat, ash, carbohydrate and protein [22].

According to de Melo et al. (2018), sesame bran contains 25% total dietary fiber, including 22% insoluble fiber and 3% soluble fiber. The utilization of this by-product aligns with consumer demand for healthy, high-fiber foods. Additionally, it adheres to eco-nutrition principles due to its sustainable production method with minimal processing [23].

Table 2: Proximate composition of sesame bran and whole wheat flour (on dry weight basis)

Samples	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fiber (%)	Total carbohydrates (%)
WWF	10.31a±0.16	2.17b±0.01	14.62a±0.03	2.28b±0.02	9.35b±0.13	71.58a±0.18
SB	6.50b±0.05	18.90a±0.02	7.50b±0.03	12.76a±0.06	19.45a±0.23	41.38b±0.29
t	23.434*	756.643*	185.915*	158.443*	38.139*	88.694*
p	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

WWF= Whole Wheat Flour, SB= Sesame Bran

t: Student t-test. *: Statistically significant at $p \leq 0.05$. Data was expressed as mean ± SEM. Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

3.2. Mineral Content of Sesame Bran and Whole Wheat Flour (On Dry Weight Basis)

Table 3 showed the minerals content (magnesium, calcium, iron and zinc) of whole wheat flour (WWF) and sesame bran (SB).

It could be noticed that the sesame bran showed higher values of all tested elements with a clear difference compared to the minerals content of WWF, where SB recorded the highest values of Mg, Ca, Fe and Zn (490.0, 13060.0, 13.53 and 2.39 mg/100 respectively). Conversely, the lowest values were recorded by WWF (133.74, 35.09, 3.01 and 1.98 mg/100, respectively). According to DeMello et al. (2018), Sesame is recognized as a source of various minerals; hence, the elevated ash content of the press cake (bran) indicates that it is a more substantial source of total minerals compared to the whole seeds, which is aligned with the study results [23].

On the other hand Khalaf et al., (2019) reported the minerals content of whole wheat flour and they reported that, it contained 54.0 mg/100g calcium, 14.80 mg/100g sodium, 133.00 mg/100g potassium, 128.00 mg/100g phosphorus, 149.00 mg/100g magnesium, 3.30 mg/100g zinc and 2.50 mg/100g iron on dry weight basis which is higher than that obtained by the present study [24].

Another study by Zouari et al., (2016), revealed that sesame bran contained 11.33 mg/100g of calcium, 641.30 mg/100g of magnesium, 7.29 mg/100g of zinc and 54.63 mg/100g of iron. Despite the values of magnesium, zinc and iron obtained by them are higher than the present study, concentration of calcium of ours is higher [25].

Table 3: Minerals content of sesame bran and whole wheat flour (on dry weight basis)

Samples	Mg (mg/100g)	Ca (mg/100g)	Fe (mg/100g)	Zn (mg/100g)
WWF	133.74b±4.35	35.09b±1.03	3.01b±0.04	1.98b±0.05
SB	490.0a±9.65	13060.0a±23.39	13.53a±0.32	2.39a±0.10
t	33.645*	556.369*	32.134*	3.578*
p	<0.001*	<0.001*	0.001*	.023*

WWF Whole Wheat Flour, SB= Sesame Bran
Student t-test. *: Statistically significant at $p \leq 0.05$ Data was expressed as mean ± SEM.Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

3.3. Anti-Nutritional Factors of Whole Wheat Flour and Sesame Bran

Phytic acid, oxalate and tannins were determined as anti-nutritional factors in used wheat flour and sesame barn, the obtained results are shown in Table 4. From the data it can be seen that no significant differences between the oxalate content of WWF (4.83 mg/g) and other observed in SB (4.95 mg/g), while the phytic acid content of SB showed higher value (42.10 mg/g) with significant difference compared to WWF (5.03 mg/g). Also, SB significantly recorded the highest value of tannins (13.70 mg/g) in contrast to the lowest value (0.01 mg/g) which observed by WWF. Our findings indicate that sesame bran includes significant levels of anti-nutrients, which will inform strategies for their reduction or deletion from the samples to maximize their nutritional benefits when utilized as a food fortificant. Numerous conventional approaches and technology exist to mitigate the levels of these anti-nutrients. A variety of processing procedures and technologies, including fermentation, germination, heating, autoclaving, and soaking, are employed to diminish the anti-nutrient content in foods. Utilizing multiple strategies, either independently or in conjunction, can effectively diminish the concentration of anti-nutrients in food products. Consequently, the quality of food crops such as cereals, seeds and grains can be enhanced through various processing techniques, particularly fermentation [26].
Also, according to Makinde and Akinoso (2014) reported a significant reduction in phytate and oxalate content of sesame seed flour during germination, roasting and cooking [27].

Table 4: Anti-nutritional factors of whole wheat flour and sesame bran

Samples	Pythic acid	Oxalate (mg per g)	Tannins
WWF	5.03b±0.05	4.83a±0.05	0.01b±0.00
SB	42.10a±1.40	4.95a±0.07	13.70a±0.78
t	26.412*	1.492	17.574*
p	<0.001*	0.210	0.023*

WWF Whole Wheat Flour, SB Sesame Bran
t: Student t-test. *: Statistically significant at $p \leq 0.05$. Data was expressed as mean ± SEM. Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

3.4. Antioxidant Activity of Whole Wheat Flour and Sesame Bran

The antioxidant activity of whole wheat flour and sesame bran was evaluated, with the results showing a significant difference between them. They are represented in table 5. Where, WWF recorded (25.78 ppm ascorbic acid equivalent), while SB exhibited a much higher value of (4097.30 ppm ascorbic acid equivalent). This finding of the present study are aligns with research by Hafez (2018), who reported that sesame sieved waste exhibited the highest level of antioxidant activity at (870,000 ppm) compared to defatted sesame cake (400,000ppm). The high antioxidant activity in sesame sieved waste was attributed to its elevated total phenolic content, which enabled strong hydrogen donation and scavenging of hydroxyl radicals [28]. In support of this, Abozed et al. (2014) found that the antioxidant activity of whole wheat was 23.90 ppm, which is slightly lower than our finding. This variation is due to the extraction solvents and types of wheat, which severely influenced the total phenolics and antioxidant activity of whole wheat according to them. On the other hand, Research findings indicated that the bran portion of wheat contained a higher concentration of total phenolic compounds and demonstrated superior radical scavenging capabilities compared to the whole grain. As a result, incorporating whole wheat products into food processing is highly advised to maximize potential health advantages [29].

Table 5: Antioxidant activity of whole wheat flour and sesame bran

Samples	Antioxidant activity of raw materials (ppm ascorbic acid equivalent)
WWF	25.78±1.61
SB	4097.30±8.76
T	-
P	-

WWF= whole wheat flour, SB= sesame bran.

3.5. Amino Acid Profile of Whole Wheat Flour and Sesame Bran

Data in table 6 represented the amino acids content (g/100 g protein) of whole wheat flour (WWF) and sesame bran (SB) in addition to the difference rate between them (%). With regard to the essential amino acids (EAAs) these findings indicated that SB protein showed higher values of branched chain amino acids (BCAAs) including valine, isoleucine and leucine compared to WWF protein which recorded lower values of BCAAs, where SB has a valine content that is 50.61% higher than the valine content that found in WWF. SB also recorded a relative increase in both isoleucine and leucine (26.48% and 45.53%, respectively) compared to the isoleucine and leucine content of WWF. Concerning sulfur amino acids (cysteine and methionine), WWF recorded 1.89 g/100 protein of cysteine compared to 3.12 g/100 protein for SB protein with a relative increase of 65.08%, While SB showed a relative decrease -3.69% in methionine content compared to the methionine content of WWF protein. Also, SB protein recorded lower values of phenylalanine, threonine and histidine with relative decreases of -23.32 %, -33.77 %, and -30.27%, respectively, compared to phenylalanine and histidine content of WWF protein. However, SB protein showed a clear increase in lysine content compared to the lysine content of WWF protein with a relative increase of 318.02%.

Generally, SB protein recorded a higher value of total essential amino acids (40.33 g/100g protein) compared to 33.51 g/100g protein) that was observed by WWF with a relative increase of 20.35%.

As for non-essential amino acids (NEEAA), SB protein showed lower values of aspartic acid, glutamic acid and proline (8.03, 13.41 and 5.03 g/100g protein, respectively) with relative decreases of -17.13, -14.97 %, and -49.45% compared to the same aforementioned amino acids content of whole wheat flour.

On the contrary, the SB protein contained higher values of serine (4.05 g/100 protein), glycine (6.21 g/100 protein), arginine (8.33 g/100 protein) and alanine (4.11 g/100 protein) compared to 3.01, 5.53, 5.39 and 3.15 g/100g protein, which were recorded by WWF protein. Consequently, the SB protein recorded a relative decrease -4.57% of total non-essential amino acids, where SB protein recorded 49.17 g/100 protein of total NEAAs compared to 51.52 g/100g protein for WWF protein.

Consequently, sesame seed cake is frequently utilized as a protein supplement in the animal feed industry. Furthermore, it serves as an exceptional addition to various food products to enhance protein quality and content [30].

According to Abbas et al. (2022) the defatted sesame seeds exhibit appreciable quantities of high-quality proteins with a balanced amino acid profile (1.76–3.10 g/100g histidine, 1.52–4.34 g/100 isoleucine, 3.86–7.54 g/100g leucine, 1.11–3.34 g/100 lysine, 2.55–5.20 g/100 valine and 2.55–4.38 g/100g threonine). These findings are in harmony with ours [8].

In comparison to whole wheat flour, sesame bran boasts a greater concentration of these amino acids, rendering it a more advantageous, inexpensive option for individuals aiming to enhance muscle performance, bolster antioxidant defenses, and support tissue repair. Incorporating sesame bran into the diet and food products may enhance exercise performance and contribute to the maintenance of overall health. This nutrient-rich profile establishes sesame bran as a functional food beneficial for both muscle and metabolic health [31, 32].

Table 6: Amino acid profile of whole wheat flour and sesame bran

Amino Acids	Amino acids profile (g/100 g protein)		Relative increase (%)
	Whole wheat flour	Sesame bran	
Valine	4.07	6.13	50.61
Isoleucine	3.55	4.49	26.48
Leucine	5.14	7.48	45.53
Cysteine	1.89	3.12	65.08
Methionine	2.17	2.09	-3.69
Tyrosine	3.29	3.64	10.64
Phenylalanine	4.76	3.65	-23.32
Lysine	1.11	4.64	318.02
Threonine	4.59	3.04	-33.77
Histidine	2.94	2.05	-30.27
Total EAA	33.51	40.33	20.35
Aspartic acid	9.69	8.03	-17.13
Serine	3.01	4.05	34.55
Glutamic acid	15.77	13.41	-14.97
Glycine	5.53	6.21	12.30
Arginine	5.39	8.33	54.55
Alanine	3.15	4.11	30.48
Proline	9.95	5.03	-49.45
Total NEAA	51.52	49.17	-4.57

3.6. Fatty Acid Profile of Sesame Bran

As presented in Table 7, sesame bran is characterized by a unique fatty acid composition, prominently featuring monounsaturated fatty acids (MUFA) 48.07%, with oleic acid (C18:1n9c) representing 48.07% of its total fatty acids. Following this, polyunsaturated fatty acids (PUFA), particularly linoleic acid (C18:2n6c), account for 39.04%. The presence of these MUFAs and PUFAs is associated with cardiovascular health benefits, including enhancements in cholesterol levels and reductions in inflammation, thereby positioning sesame bran as a heart-healthy lipid source. In contrast, saturated fatty acids (SFA)12.88%, primarily palmitic acid (C16:0) and stearic acid (C18:0), constitute a modest 8.37% and 4.51 %,

respectively, which is beneficial considering the link between high saturated fat consumption and increased cardiovascular risk.
The fatty acid balance in sesame bran highlights its potential as a valuable ingredient for food fortification aimed at promoting cardiovascular health and supplying essential fatty acids [8].
Also, Elleuch et al. (2007), indicated that sesame by-products from halaweh processing contain fatty acids (MUFA) 44.50, with oleic acid (C18:1n9c) representing 43.07% of its total fatty acids. Following this, polyunsaturated fatty acids (PUFA) 36.12%, particularly linoleic acid (C18:2n6c), account for 35.61%. while saturated fatty acids (SFA) represent 19.37%, which is in harmony with our study [33].

Table 7: Fatty acid profile of sesame bran

Fatty acids	**Area %**
	Sesame bran
Palmitic acid (C16:0)	8.372
Stearic acid (C18:0)	4.510
Oleic acid (C18:1n9c)	48.073
Linoleic acid (C18:2n6c)	39.043
Σ SFA	12.882
Σ MUFA	48.073
Σ PUFA	39.043

SFA= saturated fatty acids; UFA= unsaturated fatty acids; PUFA=Poly unsaturated Fatty Acid

B: Evaluation of Biscuit Samples

3.7. Chemical Composition of Whole Wheat Flour Biscuit and Sesame Bran-Fortified Biscuits (10, 20 and 30%) on

Table 8 presented the gross chemical composition of whole wheat flour (control) biscuit and other treated biscuits which were fortified with different replacement ratios (10, 20 and 30%) of sesame bran as whole wheat flour substitution.
According to the obtained results, the control biscuit (100% whole wheat flour) recorded the lowest values of moisture (3.69%), ash (1.62%), fat (21.13%) and crude fiber (6.16%) with the highest values of protein (10.41%) and total carbohydrates (60.68%).
According to the statistical data, no significant differences between the control biscuit and SB-fortified biscuit at 10 and 20% replacement levels in terms of the moisture content, whereas the highest values of moisture content significantly observed by the samples contained 30% SB (5.26%). This explained the ability of high fiber content to retains higher moisture content of biscuit samples that contain higher fiber ratios [34].
Where, A gradual increase in ash, fat and fiber content was observed with the increasing level of SB in prepared biscuits. Statistically, all samples were in a significant difference regards the ash content where the lowest value (1.62%) was recorded by the control biscuit compared to the highest value of ash content (4.67%) which observed by 30% SB-fortified biscuit.
Data revealed there were no substantial variations between the control sample (21.13%) and the 10% SB-supplemented biscuit (21.96%) concerning the fat content, while 20 and 30% SB-supplemented biscuit recorded higher values of fat contents with significant differences compared to the fat content of the control biscuit.
On the other hand, all treated samples (10, 20 and 30% SB-supplemented biscuit) recorded maximum values of fiber content with significant differences compared to the fiber content of the control.
The control sample had the highest protein level (10.41%) with substantial differences only compared to the sample contained 30% SB (9.43%). Also, the control sample exhibited the greatest total value of total carbohydrates (60.68%), where the total carbohydrates were in a proportional decrease with the increasing level of SB in prepared biscuits, noting that all samples were in a significant difference concerning the total carbohydrate contents.
The impact of substituting with defatted sesame flour on the chemical composition of biscuits was studied by Gernah and Anyam et al. (2014), and they found that there was a significant increase ($p<0.05$) in moisture, crude fat, crude fiber, and ash contents ,while carbohydrate content decreased significantly ($p<0.05$) with an increase in defatted sesame flour, and this aligns with our findings [35].
The results of the present study also are in agreement with those obtained by Hafez, H. H. (2018), who found that sesame processing waste increased the fat, ash, and fiber content in bakery products, while total carbohydrates and calories decreased in the supplemented crackers compared to the control sample [28].
Sesame bran-fortified biscuits present a markedly enhanced nutritional profile when compared to those produced solely with whole wheat flour, especially regarding their mineral, fiber, and carbohydrate composition. Furthermore, the increased fiber content in sesame bran contributes positively to digestive health by encouraging regular bowel movements, alleviating constipation, and fostering a healthy gut microbiome [36].

Table 8: Chemical composition of whole wheat flour biscuit and SB-fortified biscuits (10, 20 and 30%)

Samples	Moisture	Ash	Protein	Fat	Fiber	Total carbohydrates
	(%)	(%)	(%)	(%)	(%)	(%)
T1	3.69b±0.05	1.62d±0.05	10.41a±0.30	21.13b±0.24	6.16c±0.15	60.68a±0.40
T2	3.97b±0.14	2.64c±0.14	10.12ab±0.23	21.96bc±0.19	6.81b±0.15	58.47b±0.16
T3	4.30b±0.37	3.65b±0.14	9.82ab±0.15	22.70ab±0.29	7.43a±0.24	56.40c±0.38
T4	5.26a±0.14	4.67a±0.16	9.43±b0.18	23.45a±0.38	7.93a±0.19	54.52d±0.42
F	10.623*	99.208*	3.518	12.109*	16.412*	54.916*
p	0.004*	<0.001*	0.069	0.002*	0.001*	<0.001*
LSD at 0.05	0.684	0.429	0.729	0.932	0.617	1.168

T1: Biscuit control, T2: Biscuit with 10% Sesame Bran, T3: Biscuit with 20% Sesame Bran, T4: Biscuit with 30% Sesame Bran.
F: one-way ANOVA test. *: Statistically significant at p ≤ 0.05. Data was expressed as mean ± SEM. Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

3.8. Minerals Content of Whole Wheat Flour Biscuit and Sesame Bran-Fortified Biscuits (10, 20 and 30%)

Data in Table 9 provided details about the mineral composition of biscuits made with varying proportions of sesame bran,
The analysis concentrates on four key minerals: magnesium (Mg), calcium (Ca), iron (Fe), and zinc (Zn). The following can be observed, the control biscuit significantly recorded the lowest values of magnesium (75.87 mg/100g), calcium (34.76 mg/100g) and iron (1.88 mg/100g) while no significant differences between zinc content (1.59 mg/100g) and zinc content of 10% SB-supplemented biscuit (1.74 mg/100g). Noting that, the magnesium levels in the biscuits exhibit a notable increase as the percentage of SB increases from 10% to 30%. The observed values of magnesium vary from 75.87 mg/100g in WWF to 134.00 mg/100g in 30% SB-biscuit, indicating a positive relationship between the concentration of SB and the magnesium content.
The calcium content exhibits a significant rise with the incorporation of higher levels of SB, escalating from 34.76 mg/100g in WWF to 2110.86 mg/100g in 30% SB-biscuit. This increase represents the most considerable change among all minerals evaluated.
Additionally, the iron concentration demonstrates a favorable trend alongside the increasing SB levels, rising from 1.88 mg/100g in WWF to 3.62 mg/100g in 30% SB-biscuit.
Although this increase is evident, it is not as pronounced as that of calcium. Similarly, zinc displays an upward trajectory in correlation with the rising SB percentage, increasing from 1.59 mg/100g in WWF to 2.70 mg/100g in 30% SB-biscuit. While this rise is less dramatic than that of calcium, it nonetheless reflects a distinct positive trend.
Given that the P-value is substantially lower than the 0.05 threshold, it indicates that the variations in mineral content are statistically significant. This finding implies that the addition of SB has a considerable effect on the mineral levels in the biscuits. The evidence corroborates the hypothesis that an increase in SB content leads to elevated mineral levels, presumably due to the greater mineral concentration found in SB relative to WWF.
According to Om et al. (2020), sesame seeds were processed into flour utilizing five distinct methods: defatting, heating, roasting, germination, and fermentation. The processed sesame seed flour was included with wheat flour at four levels (5%, 10%, 15%, and 20%) together with other components to create cookies. The overall mineral content of the cookies, specifically calcium, magnesium, and iron, ranged from 2220.9 to 2916.9 mg/100g), 257.219 to 278.587 mg/100g), and 30.573 to 45.550 mg/100g), respectively. Cookies containing 5% fermented sesame seed flour exhibited elevated bio accessible zinc and magnesium levels of 97.856% and 97.907%, respectively. Which are in harmony with our results [37].
The increase in the sesame bran substitution level led to an increase in the mineral content, specifically in the levels of Mg, Ca, and Fe. It may be used as an inexpensive alternative in the preparation of the School nutrition meals in order to control school-aged children malnutrition according to Van Stuijvenberg et al.(2001) [38].

Table 9: Minerals content of whole wheat flour biscuit and SB-fortified biscuits (10, 20 and 30%)

Samples	Minerals Content of Prepared Biscuits (mg/100g)			
	Mg	**Ca**	**Fe**	**Zn**
T1	75.87d±2.84	34.76d±1.71	1.88d±0.11	1.59c±0.10
T2	95.46c±3.84	729.25c±12.10	2.37c±0.10	1.74c±0.08
T3	116.64b±7.09	1418.96b±15.73	2.90b±0.12	2.12b±0.18
T4	134.00a±4.93	2110.86a±22.45	3.62a±0.21	2.70a±0.23
F	52.444**	7086.51**	55.438**	105.80**
P	0.001	<0.0001	0.0009	<0.0001
LSD at 0.05	13.716	41.710	0.394	0.190

T1: Biscuit control, T2: Biscuit with 10% Sesame Bran, T3: Biscuit with 20% Sesame Bran, T4: Biscuit with 30% Sesame Bran.
F: one- way ANOVA test. *: Statistically significant at p ≤ 0.05. Data was expressed as mean ± SEM.Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

3.9. Anti-Nutritional Factors of Whole Wheat Flour Biscuit and Sesame Bran-Fortified Biscuits (10, 20 and 30%)

Table 10 showed the anti-nutritional factors of whole wheat flour (WWF) biscuit and others fortified with different replacement ratios (10, 20 and 30%) of sesame bran (SB).

According to the obtained results, it can be noticed that the control biscuit(100%WWF) recorded the lowest values of all anti-nutritional factors (0.78 mg/g phytic acid, 0.65 mg/g oxalate and 0.001 mg/g tannins).

According to the statistical analysis, the replacement of WWF by 10, 20 and 30% of SB led to an increase in phytic acid and tannins contents of the resulting biscuits with significant differences compared to the control one. Where, the phytic acid and tannins content were gradually increased with the increasing level of SB in prepared biscuit with significant differences between all biscuit samples. Thus, the highest values of phytic acid and tannins were observed by 30% SB-fortified biscuit (7.16 and 3.08 mg/g, respectively).

Nevertheless, there are no notable variations in oxalate levels between the control sample and 10% SB-fortified biscuit.

By comparing the anti-nutrient concentrations in raw sesame bran and their proportions in fortified biscuit samples, it was observed that they were lower in the final product. This reduction may be attributed to the effects of baking. The observed reduction in phytate content may be largely attributed to the creation of insoluble complexes involving phytate and other constituents, including phytate-protein and phytate-protein-mineral complexes. Alternatively, the inositol hex phosphate could be hydrolyzed into penta- and tetra-phosphate forms, as noted by Kamalasundari et al. (2019)[39].

A study conducted by Akusu et al. (2020) indicated that sesame seed flour was substituted for wheat flour at four levels (5%, 10%, 15%, and 20%) along with other ingredients to manufacture cookies. The sesame seed flour was treated using various procedures, including defatting, heating, roasting, germination, and fermentation. The results indicated that raw sesame seeds included anti-nutrient levels of 1.21 mg/100g for phytate, 87.47 mg/100g for oxalate, and 29.45 mg/100g for total phenol. Furthermore, processing procedures showed a substantial reduction (P<0.05) in the levels of these investigated anti-nutrients [37].

Table 10: Anti-nutritional factors of whole wheat flour biscuit and SB-fortified biscuits (10, 20 and 30%).

Samples	Anti-Nutritional Factors (mg/g)		
	Phytic Acid	Oxalate	Tannins
T1	0.78d	0.65b	0.001d
T2	2.97c	0.69b	0.96c
T3	4.45b	0.74a	1.92b
T4	7.16a	0.78a	3.08a
F	2626.84	16.57	1990.73
P	<0.0001	0.01*	<0.0001
LSD at 0.05	0.205	0.053	0.115

T1: Biscuit control, T2: Biscuit with 10% Sesame Bran, T3: Biscuit with 20% Sesame Bran, T4: Biscuit with 30% Sesame Bran.
F: one-way ANOVA test. *: Statistically significant at $p \leq 0.05$. Data was expressed as mean ± SEM.
Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

3.10. Antioxidant Activity of Whole Wheat Flour Biscuit and Sesame Bran-Fortified Biscuits (10, 20 and 30%):

Data in table 11revealed that, the lowest value of antioxidant activity was observed by the control biscuit sample (13.89 ppm ascorbic acid equivalent), while the replacement of whole wheat flour with different levels (10, 20 and 30%) of sesame bran (SB) led to significant increase in the antioxidant capacity of prepared biscuit samples with significant differences between all biscuit samples.

Therefore, the highest values of biscuit antioxidant (749.62 ppm ascorbic acid equivalent) were recorded by 30% SB-fortified biscuit, followed by 422.22 ppm ascorbic acid equivalent) for 20% SB-fortified biscuit, then (258.56 ppm ascorbic acid equivalent) which recorded by 10% SB-fortified biscuit. As reported by Hafez, H. H. (2018), who supports our findings, sesame processing by-products, such as defatted sesame cake (from oil extraction) and sesame sieved waste from tahini processing, are valuable sources of minerals, crude fiber, and antioxidants. These by-products can be utilized to produce healthy wheat flour crackers and gluten-free corn flour crackers for individuals with celiac disease. The resulting products are considered preferable and acceptable for consumers seeking nutritious alternatives [28].

Thus, sesame bran-enriched biscuits demonstrate a markedly enhanced antioxidant capacity in comparison to conventional whole wheat flour biscuits, attributable to their abundant phenolic compounds, lignans, and sesamin content. These antioxidants play a crucial role in neutralizing free radicals within the body, thereby mitigating oxidative stress, which is a significant factor in the aging process and the development of chronic illnesses such as cardiovascular disease, cancer, and neurodegenerative conditions [40].

Table 11: Antioxidant activity of whole wheat flour biscuit and SB-fortified biscuits (10, 20 and 30%).

Samples	Results
	DPPH (ppm ascorbic acid equivalent)
T1	13.98d
T2	258.56c
T3	422.22b
T4	749.62a
F	995.10
P	<0.0001
LSD at 0.05	38.460

T1: Biscuit control, T2: Biscuit with 10% Sesame Bran, T3: Biscuit with 20% Sesame Bran, T4: Biscuit with 30% Sesame Bran.
F: one-way ANOVA test. *: Statistically significant at $p \leq 0.05$. Data was expressed as mean ± SEM.
Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

3.11. Baking Quality of Whole Wheat Flour Biscuit and Sesame Bran-Fortified Biscuits (10, 20 and 30%)

According to the presented data in table 12, the control sample showed the lowest values of weight and diameter (9.45 g and 6.09 cm), respectively with no significant differences compared to 10% SB- fortified biscuit (10.12 g and 6.27 cm, respectively), while the highest values of weight and diameter (12.51 g and 6.77 cm, respectively) were recorded by 30% SB-fortified biscuit with significant differences compared to the control.

For the statistical analysis, no significant differences between the control sample and others (10, 20 and 30% SB-fortified biscuits) regards the biscuit volume (cm3) and thickness (cm). Also, no significant differences between the control sample and others (10, 20% SB-fortified biscuits) in terms of the specific volume of biscuit whilst, the lowest value of specific volume (1.45 cm3/g) was recorded by 30% SB-fortified biscuit with significant differences compared to the control.

However, the spread ratio values were in a gradual increase with the increasing level of SB in prepared biscuits, where the lowest value of spread ratio (9.60%) was observed by the control sample in contrast to the highest value (13.40%) which recorded by 30% SB-fortified biscuit with significant differences between all biscuit samples.

Generally, the observed reduction in specific volume and the corresponding increase in the spread ratio of wheat biscuits enhanced with sesame bran can be attributed to various factors associated with the physical and chemical characteristics of sesame bran (SB).

This is in agreement with findings by Gernah and Anyam et al. (2014), who studied the impacts of substituting wheat flour with defatted sesame flour on the physical properties of biscuits (90:10, 80:20, and 70:30), with 100% wheat flour serving as a control. They observed a general increase in the weight of the biscuits, ranging from 9.35 to 9.86 g, as the proportion of defatted sesame flour increased, although the difference was not statistically significant ($p>0.05$). Additionally, they reported a significant ($p<0.05$) increase in diameter and spread factor, accompanied by a decrease in thickness with increased sesame flour, with values ranging from 4.30 to 4.83 cm, 30.07 to 58.19cm, and 1.43 to 0.83 cm, respectively [35].

Similarly, Zouari et al. (2016) noted that incorporating sesame peel flour significantly affected the diameter, thickness, and spread factor of cookies. As the substitution level of white wheat flour increased, the cookies' width expanded from (6.21 ± 0.15 to 6.63 ± 0.14 cm), while thickness decreased from (2.7 ± 0.1 to 1.83 ± 0.03 cm), resulting in an increase in spread factor from (2.61 ± 0.1 to 4.13 ± 0.07) [25].

Table 12: Baking quality of whole wheat flour biscuit and SB-fortified biscuits (10, 20 and 30%).

Samples	Weight (g)	Volume (cm^3)	Specific volume (cm^3/g)	Diameter (cm)	Thickness (cm)	Spread ratio (%)
T1	9.45c±0.39	18.52a±0.33	1.97a±0.21	6.09b±0.08	0.64a±0.06	9.60d±0.15
T2	10.12c±0.23	18.33a±0.15	1.82ab±0.12	6.27bc±0.13	0.60a±0.06	10.53c±0.26
T3	11.19b±0.18	18.77a±0.34	1.68ab±0.06	6.54ac±0.08	0.56a±0.08	11.68b±0.33
T4	12.51a±0.16	18.14a±0.06	1.45b±0.10	6.77a±0.13	0.51a±0.06	13.40a±0.31
F	26.799*	1.144	2.792	7.665*	0.742	36.123*
p	<0.001*	0.388	0.109	0.010*	0.556	<0.001*
LSD at 0.05	0.842	0.821	0.431	0.352	0.211	0.888

T1: Biscuit control, T2: Biscuit with 10% Sesame Bran, T3: Biscuit with 20% Sesame Bran, T4: Biscuit with 30% Sesame Bran.
F: one- way ANOVA test. *: Statistically significant at $p \leq 0.05$. Data was expressed as mean ± SEM. Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

3.12. Color Measurement of Whole Wheat Flour Biscuit and Sesame Bran-Fortified Biscuits (10, 20 and 30%)

Color parameters for the top and bottom surfaces of whole wheat flour biscuits and sesame bran-fortified biscuits, with fortification levels of 10%, 20%, and 30%, are presented in Figure 1. These measurements provide insights into the color changes occurring during baking, which may affect consumer acceptance and the final product's visual appeal.

According to the statistical analysis, the lightness of biscuit was negatively affected by the increasing level of SB in prepared biscuit, where the highest L* value (lighter) significantly recorded by the control biscuit (63.05), conversely, the lowest L* value (darker) was recorded by 30% SB-fortified biscuit (50.18) with significant differences compared to all biscuit samples.

Meanwhile, the lowest a* value (less reddish) was significantly recorded by the control biscuit. Otherwise, the a* values were gradually increased (more reddish) with the increasing level of SB in prepared biscuit with significant differences between all biscuit samples. However, the highest value of yellowness (b*) significantly recorded by the control biscuit (33.73), while no significant differences between 10% SB-fortified biscuit and 20% SB-fortified biscuit concerning the yellowness values (31.37 and 30.31, respectively), whereas the 30% SB-fortified biscuit recorded the lowest value of yellowness (28.54) with significant differences compared to all biscuit samples.

This is in agreement with Zouari et al. (2016), they studied the effect of sesame peel addition to white wheat flour for cookies production and they reported that, the incorporation of sesame peels flour led to a reduction in lightness (L*) and an increase in redness (a*) when compared to white wheat flour cookies, where, the surface color of the cookies exhibited a significant decrease ($p \leq 0.05$) in both lightness (L*) and yellowness (b*), with values dropping from (64.07 ± 0.66 to 36.23 ± 0.27) and from (38.7 ± 0.54 to 11.42 ± 0.07), respectively, at a 50% inclusion level of sesame peels flour, with a notable increase in redness (a* values) from(4.27 ± 0.03 to 10.79 ± 0.62) was observed, with statistical significance ($p < 0.05$). This change can be attributed to the incorporation of sesame peels flour at varying levels, which replaced wheat flour [25].

The coloration of cookies primarily occurs during the baking process, driven by the Millard reaction between reducing sugars and proteins. Additionally, the processes of starch dextrinization and caramelization, which are facilitated by heat, also contribute to the final color of the cookies [41].

Table 13: Color measurement of whole wheat flour biscuit and SB-fortified biscuits (10, 20 and 30%)

Samples	L* (lightness)	a* (redness)	b* (yellowness)
T1	63.05a±0.24	5.15d±0.12	33.73a±0.47
T2	58.20b±0.45	6.25c±0.19	31.37b±0.40
T3	55.01c±0.44	7.00b±0.23	30.31b±0.12
T4	50.18d±0.57	8.52a±0.26	28.54c±0.42
F	149.63*	47.09*	33.02*
P	<0.01*	<0.01*	<0.01*
LSD at 0.05	1.44	0.67	1.23

T1: Biscuit control, T2: Biscuit with 10% Sesame Bran, T3: Biscuit with 20% Sesame Bran, T4: Biscuit with 30% Sesame Bran.
F: one- way ANOVA test. *: Statistically significant at $p \leq 0.05$. Data was expressed as mean ± SEM. Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

3.13. Hardness of Whole Wheat Flour Biscuit and Sesame Bran-Fortified Biscuits (10, 20 and 30%)

Table 13 represented the hardness (N) values of the control biscuit (100% whole wheat flour) and other treated samples which replaced whole wheat flour (WWF) by different replacement levels (10, 20 and 30%) of sesame bran (SB).

Where, the obtained results revealed that the lowest value (19.78 N) of hardness was significantly recorded by the control biscuit sample.

Data also indicated that the hardness values were proportionally increased to the increase in the SB levels in prepared biscuit samples, where the highest value (33.83 N) of hardness was observed by 30% SB-fortified biscuit with significant differences. These results are in harmony with Zouari et al. (2016), who stated that the hardness of the cookies containing sesame peels flour was significantly ($p \leq 0.05$) higher than that made from white wheat flour ranging from 49.69 ± 1.48 at 0% of replacement to 82.96 ± 4.16 at 50% of substitution. The increased hardness observed in cookies made from composite flours with varying levels of sesame bran may be attributed to the elevated concentrations of fibers present [25]. The increased hardness observed in biscuits produced with a combination of whole wheat flour and sesame bran, as opposed to those made solely with whole wheat flour, can be attributed to multiple interrelated factors. Firstly, the elevated fiber content present in sesame bran diminishes the elasticity of the dough and its ability to retain gas [42]. Additionally, the coarse texture of the bran contributes to an increase in dough stiffness. Furthermore, the bran's capacity to absorb water results in a lower moisture content within the dough. Lastly, there may be interference with gluten development. Collectively, these alterations culminate in a denser and firmer texture, rendering the biscuits more rigid than those made exclusively with whole wheat flour [43].

Table 14: Hardness of whole wheat flour biscuit and SB-fortified biscuits (10, 20 and 30%).

Samples	Hardness (N)
T1	33.83a±1.46
T2	27.09 b ±1.62
T3	19.78 d ±1.55
T4	33.83a±1.46
F	46.472*
P	<0.001*
LSD at 0.05	2.860

T1: Biscuit control, T2: Biscuit with 10% Sesame Bran, T3: Biscuit with 20% Sesame Bran, T4: Biscuit with 30% Sesame Bran.
F: one- way ANOVA test. *: Statistically significant at $p \leq 0.05$. Data was expressed as mean ± SEM. Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

3.14. Sensory Evaluation of Whole Wheat Flour Biscuit and Sesame Bran-Fortified Biscuits (10, 20 and 30%)

Table 14 showed the sensory evaluation of 100% whole wheat flour (WWF) biscuit samples as control sample and other samples which contained different replacement levels (10, 20 and 30%) of sesame bran (SB) as whole wheat flour substitution, all biscuit samples were evaluated for appearance, taste, smell, texture and over all acceptability using 9-point hedonic scale.

From the obtained data, it could be observed that the control sample significantly recorded the highest scores for all sensorial parameters.

Data also indicated all sensory parameters were gradually decreased with the increasing level of SB in prepared biscuit sample with significant differences between all samples.

On the other side, the control sample scores allowed the sample to be very much like a sample for panelists. Also, 10% of the SB-fortified biscuit was liked very much for taste, smell and acceptability and liked moderately for the biscuit's appearance and texture. Meanwhile, all sensory parameters were like moderately in the case of 20% SB-fortified biscuit. Whereas, 30% SB-fortified biscuit sample was like slightly for all sensory parameters.

According to Zouari et al. (2016), there were no significant differences ($p \leq 0.05$) for aroma and texture sensory attributes between the ratings given to the control and cookies made with an incorporation level of sesame peels flour that did not exceed 30%. Panelists disliked cookies made from 40% to 50%, where the cookies were characterized by dark color, a bitter flavor, and an unpleasant aftertaste; however, they maintained an acceptable texture and moderate crispness. This suggests that despite the high fiber content and mineral richness of cookies made with a significant proportion of sesame peels flour, many consumers may be deterred from consumption due to sensory attributes [25].

Previous research by Elleuch (2012) indicated that sesame testae possess a bitter flavor profile. Furthermore, when defatted testae were added to halawa, sensory panelists expressed a dislike for the flavor of the product containing 2% sesame testae [44].

According to Gernah and Anyam et al. (2014), their Sensory evaluation results were in harmony with ours and showed enhancements in the biscuits' appearance, aroma, and texture, with a decline noted at the highest replacement level (30%). The biscuit containing 10% defatted sesame scored highest for taste and overall likeability. This investigation demonstrates the feasibility of producing nutritious and flavorful biscuits using blended mixtures of wheat and defatted sesame flours. They demonstrated that alterations in the chemical makeup, specifically the rise in moisture, fat, and fiber content, could impact the sensory attributes of biscuits, such as their texture, flavor, and feel in the mouth [35].

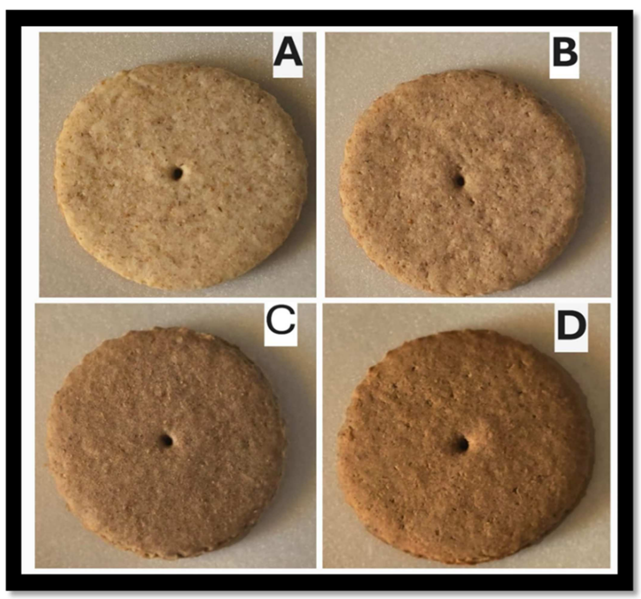

Figure (1): Biscuits made from the different ratios of whole wheat flour: sesame bran flour. Where, (A) 100:0; (B) 90:10; (C) 80:20; (D) 70:30.

Table 15: Sensory evaluation of whole wheat flour biscuit and SB-fortified biscuits (10, 20 and 30%).

Biscuit samples	Sensory evaluation of prepared Biscuit				
	Appearance	Taste	Smell	Texture	Acceptability
T1	8.39a±0.79	8.39a±0.79	8.3a±0.75	8.34a±0.78	8.51a±0.61
T2	7.97b±0.65	8.02b±0.69	8.07b±0.67	7.95b±0.67	8.06b±0.69
T4	7.58c±0.69	7.62c±0.69	7.55c±0.70	7.67c±0.75	7.57c±0.68
T5	6.73d±0.77	6.61d±0.75	6.66d±0.74	6.68d±0.77	6.34d±0.47
F	93.06	109.42	102.45	89.98	225.75
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
LSD at 0.05	0.203	0.203	0.199	0.207	0.172

T1: Biscuit control, T2: Biscuit with 10% Sesame Bran, T3: Biscuit with 20% Sesame Bran, T4: Biscuit with 30% Sesame Bran.
F: one- way ANOVA test. *: Statistically significant at $p \leq 0.05$. Data was expressed as mean ± SEM.Means in the same column with common letters are not significant (i.e. Means with Different letters are significant)

4. Conclusion

Sesame processing wastes, such as sesame bran, are considered good sources of carbohydrates, crude fiber, fat, ash, mineral content, and antioxidants to produce supplemented healthy wheat flour bakery products, such as biscuits, that could be preferable and acceptable to all age groups. By analyzing the results obtained, it is concluded that sesame bran could be incorporated up to a level of 20% in the formulation of biscuits without affecting their overall quality. Sesame bran fortification was more acceptable to the consumers in terms of sensorial parameters, and the physical attributes of varieties of biscuits were similar to the control one. But the increased crude fibers, fat, and mineral content, including Ca, Mg, and Fe, and total antioxidant content, are an added advantage over the existing whole-wheat flour biscuits. Thus, sesame bran could be utilized as a functional by-product in the preparation of biscuits or other economical and value-added bakery products with enhanced functional and nutraceutical potential.

5. Conflicts of interest

"There are no conflicts to declare".

6. Funding sources

None.

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8.References

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