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SENSORY AND NUTRITIONAL EVALUATION OF BISCUITS FROM BLENDS OF WHEAT FLOUR, WHEAT POLLARD FLOUR AND DEFATTED SOY FLOUR

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ABSTRACT

Protein-energy remains a major challenge in many developing countries where wheat-based snacks are widely consumed, but often nutritionally poor. This study aimed to develop and evaluate the sensory and nutritional properties of biscuits enriched with wheat pollard and defatted soy flour as partial substitutes for wheat flour. Ten formulations were designed using Design-Expert software (Simplex centroid, Special cubic model) with varying proportions of wheat flour (70-100%), wheat pollard (0-30%), and defatted soy flour (0-30%). Biscuits were baked at 180°C for approximately 15 minutes, until a uniform golden-brown color and firm texture were achieved, and then sensory evaluation was done by 30 panelists using 7-point hedonic scale. Proximate assessment followed AOAC methods, color was measured with a Minolta Colorimeter, and total phenolic content was determined by the Folin-Ciocalteu method. Sensory attributes were significantly ($p<0.001$) affected by the incorporation of wheat flour and defatted soy flour compared to the 100% wheat flour biscuits. The most acceptable formulation (overall acceptability = 6.1) contained 90% wheat flour, 5% wheat pollard, and 5% defatted soy flour, while higher pollard levels reduced preference. Protein content reached 17.04 g/100 g in biscuits containing 30% defatted soy flour; the wheat pollard increased the fiber and ash contents. Moisture was lowest in the 85% wheat flour + 15% defatted soy flour formulation. Partial substitution decreased carbohydrate content from 64 g/100 g (control) to 52.41 g/100 g (70% wheat flour and 30% defatted soy flour), whereas energy values (478.9-498.7 kcal/100 g) met World Food Program recommendations. Wheat pollard significantly enhanced total phenolic content due to its high intrinsic phenolics (339.44 mg GAE/100 g). Incorporating 5% wheat pollard and 5% defatted soy flour increased total phenolics by 45% compared with 100% wheat flour biscuits, with the highest value (298.9 mg GAE/100 g) in formulation F7 with 20% defatted soy flour and 5% wheat pollard substitution. These findings demonstrate that wheat pollard and defatted soy flour can improve the nutritional and functional quality of biscuits while maintaining consumer acceptability, providing a promising approach to address protein-energy malnutrition in developing countries.

Key words: Biscuit, Wheat pollard, Phenolic content, Protein enrichment, defatted soy

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INTRODUCTION

Biscuits are the most consumed snack in the world with an average consumption of 13kg per capita per year [1]. Biscuits are basically very low-nutrient snacks, although they are widely consumed by all ages [2,3]. Biscuits are used as emergency food in disaster areas, and biscuits are also widely used in school meals for children to help them meet their daily nutritional requirements; for instance, in Bangladesh, the provision of a 75 g packet of fortified biscuits (300 kcal/100 g) per child per school day significantly improved iron, vitamin A, and iodine status among primary school pupils [4,5]. Unfortunately, in most cases, the biscuits found on the market are based solely on refined wheat flour, which is characterized by low protein content (6-9%), limited essential amino acids; particularly lysine, and poor dietary fiber, vitamins, and minerals because the bran and the germ are removed during milling [6]. This makes such biscuits energy-dense but nutritionally imbalanced, characterized by high sugar and refined carbohydrate content with a high glycemic index and limited micronutrients, which has been associated with increased risk of non-communicable diseases (NCDs) such as obesity, diabetes, and cardiovascular complications [7–9]. Although several studies have fortified biscuits using cereal brans or legume flours to enhance their nutritional value, most have focused on single ingredients such as soybean or wheat bran [2,3,5]. However, the combined use of wheat pollard and defatted soy flour and their interactive effects on the sensory, nutritional, and antioxidant properties of biscuits remain insufficiently explored.

Scientific advances and access to basic food knowledge have increasingly raised consumer awareness of healthy diets over the past two decades [10,11]. This has prompted the biscuit industry to improve the nutritional and sensory properties of the biscuit on the market by incorporating potentially nutritious flours to partially substitute the wheat flour [12,13].

There is growing interest in the use of cereal industry by-products in bakery products to enhance their nutritional value [13]. Wheat pollard is a by-product of wheat processing that is very rich in protein (lysine), dietary fiber, energy and micronutrients [14]. Wheat pollard is mainly used in animal feed despite its high nutritional content, which can help combat food insecurity in humans. De Groote *et al*. [15] report that wheat pollard has a protein content of 15.6%, 7.1% fiber, a fat content of 4.2%, and lysine and methionine contents of 0.57% and 0.26% respectively. Composed mainly of wheat aleurone, wheat pollard is rich in phenolic compounds known for their antioxidant properties, helping to reduce the risk of cardiovascular diseases, obesity, type 2 diabetes and some types of cancer [16].

Soy flour is an excellent source of inexpensive vegetable protein, lecithin, vitamins, minerals and fiber that can help combat malnutrition worldwide. Supplementing cereal proteins with legume proteins is one of today's most recommended options for combating protein-energy deficits [17]. Eliminating or reducing fat increases the protein content of defatted soy flour.

This study attempted to assess the suitability of using wheat pollard and defatted soy flour at different levels (5, 10, 15, 20 and 30%) on biscuits sensory attributes, safety and improvement of biscuits nutritional values.

MATERIALS AND METHODS

Raw materials

The wheat flour and wheat pollard were supplied by Capwell Industries. The defatted soy flour was purchased from an industry called PromisaDor that specializes in the production of soy flour. The rest of the ingredients, including sugar, baking powder, sunflower oil, Palm Fat Ammonium Bicarbonate and Sodium Acid Pyrophosphate, were purchased from the local market in Nairobi.

Biscuit preparation

Previous studies have claimed that a partial substitution of wheat flour with up to 30% defatted soy flour guaranteed much better products in terms of taste, texture and overall appearance [18]. Ten biscuit formulations were developed using Design-Expert v.13 (Trial Version) following the simplex-centroid mixture design (Special Cubic model). Wheat flour (70-100%), wheat pollard (0-30%), and defatted soy flour (0-30%) were combined to yield a 100 g mix for each formulation. The control sample contained 100% wheat flour (F0), while composite formulations included, for example, 90:5:5 (F2), 80:10:10 (F4), 70:15:15 (F8), and 70:0:30 (F9) proportions of wheat flour: wheat pollard: defatted soy flour, respectively. The complete list of F0-F9 formulations is presented in Table 1.

In each formulation, the dry ingredients (wheat pollard flour, defatted soy flour, wheat flour, and baking powder) were first combined and sifted twice to ensure uniform distribution of the leavening agents. Palm fat, serving as the shortening to improve texture, tenderness, and flavor was melted at 45°C before being transferred to a mixing bowl. Lecithin, used as an emulsifier together with sugar, were added to the melted fat and mixed with ammonium bicarbonate, and sodium acid pyrophosphate (SAPP) until the mixture looked creamy. The latter two served as leavening agents; ammonium bicarbonate decomposing upon heating to release CO_2 for a light, crisp texture, and SAPP reacting with bicarbonate to ensure controlled gas release and uniform rise. All non-flour ingredients (sugar, fat, lecithin, SAPP, ammonium bicarbonate and backing powder) were held constant across formulations to ensure that observed variations were attributed solely to differences in flour composition. The flour mixture was added to the cream in small increments and stirred thoroughly. The soft dough was formed by adding a small amount of water. The dough was flattened out and cut into small rectangles using a biscuit cutter. The biscuits were baked in a preheated electric oven for 10-15 minutes at 180ºC for uniform baking.

Sensory Evaluation

The sensory properties of the biscuits, including appearance, color, smell, crunchiness, taste, flavor, texture, mouthfeel and overall acceptability, were evaluated using an affective test. The panel consisted of 30 untrained adult participants (students and staff members) of both sexes from the University of Nairobi's Department of Food Science, Nutrition, and Technology, where the sensory analysis was conducted. Thus, before beginning the sensory exercise, the panelists were asked to sign a consent form informing them about the nature of the biscuit samples they would be reviewing. The biscuit samples were evaluated using Larmond's [19] 7 hedonic scale of 1 (don't like very much) to 7 (like very much). Water was utilized to compensate for taste differences across the samples examined.

Determination of biscuits colors

A hunting lab colorimeter (Minolta, Tokyo, Japan) was used to determine the color of the biscuit samples. Each time, the instrument was standardized with a white ceramic plate and a black ceramic plate. The color was measured directly on the sample at various spots. The reflected color value (L*, a*, and b*) were computed directly, where L* indicates lightness (0 = black, 100 = white), a* represents the red-green coordinate (positive = red, negative = green), b* represents the yellow-blue coordinate (positive = yellow, negative = blue) while the derived color parameters, chroma (c*) and hue angle (h°) were calculated as follows:

$$\mathrm{c}^* = \sqrt{(a^*)^2 + (b^*)^2} \quad h° = \arctan\left(\frac{b^*}{a^*}\right)$$

For each formulation, three biscuits were analyzed, with three readings per biscuits taken at random surface points (n = 9), which enhanced statistical robustness and measurement accuracy.

Determination of proximate properties of biscuits

Standard analytical procedures (AOAC) [20] were used to determine the flours' and biscuits' proximate composition. Moisture content was determined by the oven-drying method (AOAC 44-15A), ash content by incineration in a muffle furnace (AOAC 08-01), crude fat by the Soxhlet method (AOAC30-25), crude fiber by acid-alkali digestion (AOAC 32-10), and crude protein by the Kjeldahl method using a nitrogen conversion factor of 6.25 (AOAC 46-30). Carbohydrate content was calculated by difference, and energy value was estimated using the Atwater system. Three replicates of each sample were examined.

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Determination of Total Phenolics Content

Folin-Ciocalteu method was used to determine the Total phenolic content according to procedure outlined by Okumu *et al*. [21] and with slight modifications. About 0.2 g of the samples (flours and biscuits) were put in a falcon tube with addition of 2ml petroleum ether and vortexed for 10 minutes at 3000g centrifugation for fat removal. The supernatant was discarded and the sample left dry. To extract phenolic compounds, a solvent mixture consisting of 2ml of 80% methanol, 2ml of 50% methanol, and 2ml of 70% acetone acidified with 1% concentrated Hydrochloric Acid was added to 1 g of finely ground biscuit sample and the volume adjusted to 10 ml with distilled water. This combination of solvents was used to maximize the extraction efficiency of both polar and non-polar phenolic compounds, as methanol effectively extracts hydrophilic phenols while acetone favors moderately hydrophobic phenols. The mixture was sonicated for 20 minutes at room temperature, then centrifuged at 4000 rpm for 10 minutes. The supernatant was filtered through Whatman No. 1 filter paper. A 3 ml aliquot of appropriately diluted extract was mixed with 1.5 ml of Folin-ciocalteu reagent (previously diluted tenfold with distilled water), followed by 1.2 ml of 75% aqueous sodium carbonate. The mixture was vortexed briefly and allowed to react at room temperature for 30 minutes in the dark, with tubes covered using parafilm to prevent oxidation and evaporation. After incubation, absorbance was read at 765 nm using a Hitachi 2900 UV/VIS spectrophotometer (Tokyo, Japan) against a blank containing distilled water [21]. A standard calibration curve was prepared using gallic acid (0.25-2.0 µg/ml), and results were expressed as mg gallic acid equivalents per 100 g dry weight (mg.GAE.g^{-1}). For each formulation, three independent extractions were performed, and each extract was analyzed in triplicate for total phenolic content.

Statistical analysis

Statistical analysis was performed using XLSTAT software version 2022.1. Data were expressed as mean ± standard deviation (n=3) and subjected to one-way analysis of variance (ANOVA) to determine significant differences among sample means. When significant differences were detected ($p < 0.05$), Turkey's Honest Significant Difference (HSD) post-hoc test was applied for mean separation.

RESULTS AND DISCUSSION

This section presents the effects of substituting wheat flour with wheat pollard and defatted soy flour on the sensory, physiochemical, and nutritional properties of the developed biscuits. Statistical analyses were performed to identify significant differences among formulations in terms of sensory acceptability, color attributes, proximate composition, and total phenolic content.

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Sensory Evaluation of Biscuits

The high protein content of defatted soybean flour and the fibrous characteristic of wheat pollard flour significantly ($P<0.001$) affected the color, flavor, texture, and general acceptance of the biscuit (Table 2). This was not the case for the crispness ($P=0.102$), flavor ($P=0.48$), and mouthfeel ($P=0.68$). The highest rating for appearance was observed in formulation 4 (5.93) followed by formulation 6 (5.63) and in last position for this parameter, formulation 1 (4.5). Regarding the color of the biscuits, again formulation 4 obtained the highest rating (6.1), followed by formulations 0 and 6 which both had a rating of 5.5, in last position formulation 1 which obtained a rating of 4.47. In terms of taste, formulation 4 had the highest rating (5.87) while formulation 5 (4.67) had the lowest. The texture of the biscuits in formulation 4 was the highest rated (6.13) while formulation 1 had the lowest rating in terms of texture (4.87). In terms of overall acceptability, formulation 4 was the most liked (6.1) followed by formulation 0 which is the control formulation (6.04), and formulation 1 was the least accepted in general (5.04).

The gradual decline in consumer preference with increasing proportions of wheat pollard flour could be attributed to its high fiber content, which tends to impart a coarse texture and darker appearance to baked products, thereby reducing sensory appeal [22]. On the other hand, the moderate inclusion of defatted soybean flour improved sensory quality by enhancing color and flavor intensity while contributing to a softer texture, possibly due to its high protein and lipid-binding capacity [23,24]. This suggests that an optimal balance between soy flour and wheat pollard is essential to maximize both nutritional and sensory quality. The results imply that while partial substitution of wheat flour with defatted soybean and wheat pollard can enhance the nutritional profile of biscuits, excessive incorporation, particularly of wheat pollard may compromise consumer acceptability. Therefore, formulation F4 (90% wheat flour, 5% defatted soy flour, and 5% wheat pollard) represents a practical balance between nutrition and sensory acceptability, making it the most promising candidate for functional, protein-rich biscuit production.

Color evaluation of biscuits

The incorporation of defatted soya flour and wheat pollard flour significantly affected biscuit color parameters ($P < 0.05$) (Table 3). In terms of biscuit lightness (L^*), the control biscuits (F0) had a higher lightness than the other formulations (66.89), while formulation 1 (F1) containing 30% wheat pollard flour had the lowest lightness (56.85). As far as the a^* parameter is concerned, the addition of more wheat pollard flour than defatted soya flour significantly increased the redness of the biscuits (Table 2). The highest values of a^* were recorded by formulations F5, F2 and F1 with 13.74, 13.45 and 12.83, respectively. These formulations contained a higher proportions of wheat pollard flour, which contributed to the darker reddish-brown

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color observed. In contrast, the lowest values of a* were recorded in formulations F0, F4 and F7 with 8.23, 8.9 and 9.17 respectively, which had either no or minimal inclusion of wheat pollard. Yellowness (b*) was also influenced by the partial substitution of wheat flour with defatted soy flour and wheat pollard. Formulation F6 (70% wheat flour, 30% defatted soy flour) biscuits had the highest b* with a value of 27.17, followed by formulation F8 (85% wheat flour, 15% defatted soy flour) with 26.5, while formulation F3 (85% wheat flour, 15% wheat pollard) resulted in biscuits with the lowest yellowness value 22.88. The highest C* values were recorded in formulations 2 and 6 (F2, F6) with 29.41 and 29.22 respectively. The hue difference (Δh*) is an excellent indicator of color variation in the food matrix. Formulations 2 and 5 (F2, F5) showed the lowest variation in color, at 61.3 and 61.34 respectively. Formulations 0 and 4 (F0, F4) obtained the highest Δh* values, with 70.22 and 70.59 respectively. The results showed that wheat pollard flour significantly reduced the lightness (L*) and yellowness (b*) of the biscuits, while the redness (a*) was greatly increased. These results are corroborated by those of Ndala *et al*. [25] who observed similar color changes in fried dough products enriched with wheat bran flour. In their study, increasing wheat bran incorporation from 0 to 20% reduced lightness (L*) from 62.42 for the control to 47.2 and yellowness (b*) from 20.13 to 19.7, while redness (a*) increased from 1.94 to 8.98. Although their samples were fried rather than baked, the trend similarly indicates that the addition of fiber-rich cereal by-products such as wheat bran or pollard tends to darken the product and increase redness due to Maillard browning reactions during heat processing.

The impact of wheat pollard on color parameters is justified by the fact that wheat pollard is mainly made up of wheat aleurone, which is less rich in fiber than either wheat bran or wheat whole meal flour. The negative impact of defatted soy flour on biscuits lightness is mainly due to the increased protein content, which induces a more pronounced Maillard reaction during baking, leading to the darkening of the biscuits [26]. But in addition to this, the fiber in defatted soy flour would also be responsible for the reduction in L*. The increase in a* was an indicator of the decrease in L*.

Proximate composition of the five most appreciated Biscuits

The incorporation of defatted soy and wheat pollard flour has significantly affected the proximate values of biscuits (Table 5). The moisture content of different flours ranged from 5.15g/100g for defatted soybean flour to 14.66g/100g for wheat pollard flour, indicating a significant difference (P<0.05) (Table 3). This is of course in perfect agreement with the results of Naik and Sekhon [27], which found that the moisture content of defatted soybean meal ranged from 5.38 to 7.75. Other researchers have found quite different results, reporting a fat content ranging from 1.64% to 2.81% depending on the method of defatting, either by organic solvent or by using

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supercritical carbon dioxide [28]. The fat content significantly varied (P<0.05) from 1.7g/100g wheat flour to 6.11g/100g defatted soybean flour (Table 3). The protein composition of flours was significantly different (P<0.05). Protein content ranged between 12.35g/100g for wheat pollard flour and 45.22g/100g for defatted soya flour. Xing *et al.* [29] found results close to ours in their study aimed at increasing the protein concentration in soybean meal by defatting it via two methods, which are respectively defatting by organic solvent and defatting by press, and they obtained, for the two methods, the following residual fat contents 7.4% and 9.3%, respectively.

The crude fiber content showed substantial differences (P<0.05). Wheat flour had the lowest fiber content (0.76g/100g), and wheat pollard flour had the highest crude fiber level (7.09g/100g). There was a significant variation (P<0.05) in the ash concentration amongst flours. Defatted soybean flour had the highest ash content (6.15g/100g), whereas wheat flour had the least (0.79g/100g). Carbohydrate content varied significantly (P<0.05), with wheat flour having the highest carbohydrate content (67.89g/100g) and defatted soybean flour having the lowest (32.37g/100g). There were no significant variations (P>0.05) in the energy content of different flours.

The proximate values of the most popular biscuits presented showed that all proximate parameters varied significantly (*P*<0.05) in comparison with the control formulation except for the ash content (P=0.05) whose values were not statistically different from each other (Table 5). The moisture content of the biscuits showed significantly different values (*P*<0.05). The lowest moisture content was obtained by formulation 8 (2.98%), followed by formulation 6 (3.05%). Although the rest of the biscuits obtained statistically similar moisture contents, it nevertheless shows that the highest moisture content was recorded with formulation 2 (4.35%). The presence of wheat pollard flour induced a sharp increase in moisture content. These results are in contrast to those of Ayoub *et al.* [30] who reported that wheat bran induced a reduction in the moisture content of the biscuits. The discrepancy may arise from differences in the nature of the by-products used, as wheat pollard contains fine endosperm fragments and aleurone-rich particles, whose cell walls include hydrophilic polysaccharides such as arabinoxylans, which may have enhanced the water retention within the biscuit matrix [31]. It has also been reported that the partial incorporation of defatted soy flour into the biscuit formulation proportionally increased the water absorption capacity of the biscuits resulting in a higher moisture content of the biscuits [32]. The fat and protein content of the biscuits showed significant difference (P<0.05). The lowest values of fat and protein content were found in the control biscuits with the following values for fat and protein content respectively: 19.93g/100g and 10.25g/100g. The highest fat content was found in the biscuits from formulation 8 (24.31g/100g), while for protein content the highest value was recorded in the biscuits from formulation 6 (17.04g/100g). The protein content increased sharply with the increase in defatted soy flour. Similar trends have been reported by Roger *et al.* [24]. In terms of ash content, the highest value was obtained with formulation 6 (1.86g/100g) while the lowest value was obtained in control formulation. Wheat pollard flour as well as defatted soybean flour significantly affected the ash content of the biscuits. Ash content is an important indicator of the minerals in a food [26]. Oke *et al.* [33] reported that the outer layers of cereals are important reserves of minerals. This explains the great involvement of wheat pollard flour. However, legumes have also been reported to be important sources of minerals [34]. A clear statistical difference was observed in terms of crude fiber content (P<0.05). For this parameter of crude fiber content, the biscuits of formulation 7 stood out with the highest crude fiber content (1.63g/100g) while the biscuits of the control formulation had the lowest crude fiber content (1.02g/100g). Wheat pollard flour and defatted soybean flour are both very high in fiber. Gamal *et al.* [35] report results with similar trends by attributing the high fiber content of biscuits to wheat bran flour. Zaker *et al.* [23] reported that defatted soybean flour significantly increased the fiber content of the biscuits; however, the values obtained in their study remained relatively low (0.12-0.8g/100g).

For the parameters of carbohydrate and energy content, there were indeed significant differences (P<0.05) between the control biscuits and the biscuits from other formulations. The highest carbohydrate content was recorded by the control formulation biscuits (64.66g/100g), while the lowest carbohydrate content was recorded in the formulation 7 biscuits (54.g/100g). Regarding energy content, the highest energy content was recorded in the biscuits from formulation 8 (498.48 Kcal/100g), while the lowest energy content was recorded in the control biscuits (478.66 Kcal/100g). The high protein content of the defatted soya flour and the high fiber and mineral content of the wheat pollard led to a sharp reduction in the carbon hydrate content. These claims are supported by Zaker *et al*. [23] and Lebert *et al.* [31]. Despite the nutritional improvements, biscuits with higher levels of wheat pollard showed lower sensory acceptability. This reduction may result from the presence of aleurone and bran particles, which increase the fiber content of biscuits and reduce the lightness (L*), giving them a darker, less appealing color. The higher fiber content may also have interfered with gluten formation and gas retention during baking, leading to a denser texture [36]. These color and texture changes explain the decline in sensory scores with increasing pollard substitution, highlighting the need to balance nutritional enhancement with consumer preference in composite flour formulations.

Total phenolic compounds of flour and most appreciated biscuits

Phenolic compounds and their antioxidant potential are increasingly interested in reducing the risk of chronic diseases [37]. The results of the analysis of variance on the total phenolic content of flours are significantly different (P<0.05). The results showed that wheat pollard flour was the flour with the highest phenolic compound content (339.4 mg GAE/100g), followed by wheat flour with a phenolic compound content of 273.05 mg GAE/100g and, lastly, defatted soy flour with a value of 224.39 mg GAE/100g (Table 5). Abozed *et al*. [38] reported that the outer layers of cereals are important reserves of phenolic compounds. The analysis of variance showed a significant difference (P<0.05) in the total phenolic content of the biscuits. Indeed, formulation 7 obtained the highest value in total phenolic compounds (298.9 mg GAE/100g), followed by formulation 4 (277.75 mg GAE/100g). The lowest level of total phenolic compounds was recorded for control formulation, with only 181.6 mg GAE/100g. Similar results reporting a strongly positive correlation between the total phenolic compound content of the biscuits and the increase in soybean flour from 243.78 to 448.22mg GAE/g [39]. Saleh and Aly [40] claimed a sharp increase in total phenolic compounds in biscuits (223.48-350.46mg GAE/100g) with the incorporation of whole meal barley and oat flours.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

This study successfully developed high protein-energy biscuits through partial substitution of wheat flour with defatted soy flour and wheat pollard. Among the formulations, biscuits containing 90% wheat flour, 5% wheat pollard, and 5% defatted soy flour (F4) were the most acceptable and nutritionally superior to the control. The incorporation of defatted soy flour significantly increased protein content (up to 17.04 g/100 g), while wheat pollard enhanced fiber, ash (up to 1.86 g/100 g), and total phenolic content (up to 298.9 mg GAE/100 g), indicating improved antioxidant potential. This formulation demonstrates a viable approach for valorizing wheat pollard, an underutilized milling by-product into nutrient dense, affordable food products that align with the World Food Program’s nutritional recommendations. The antioxidant capacity associated with the elevated phenolic content may also contribute to reducing the risk of chronic diseases linked to oxidative stress.

Future studies should investigate the bioavailability of key nutrients and the impact of anti-nutrient factors such as phytates on mineral absorption. In addition, studies on the in-vitro antioxidant potential, long-term shelf-life stability, and consumer acceptance under different storage conditions are recommended.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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Table 1: Composition of wheat flour, wheat pollard, and defatted soy flour in the ten biscuits formulations (F0-F9)

N	WF(g)	DSF(g)	WPF(g)	Sugar(g)	Shortening (Palm fat) (g)	Backing Powder(g)	SAPP(g)	NH_4HCO_3 (g)	Lecithin (g)
F0	100	0	0	28.5	43	2	1	0.2	1.5
F1	70	0	30	28.5	43	2	1	0.2	1.5
F2	70	15	15	28.5	43	2	1	0.2	1.5
F3	85	0	15	28.5	43	2	1	0.2	1.5
F4	90	5	5	28.5	43	2	1	0.2	1.5
F5	75	5	20	28.5	43	2	1	0.2	1.5
F6	70	30	0	28.5	43	2	1	0.2	1.5
F7	75	20	5	28.5	43	2	1	0.2	1.5
F8	85	15	0	28.5	43	2	1	0.2	1.5
F9	80	10	10	28.5	43	2	1	0.2	1.5

WF: Wheat Flour; DSF: Defatted soy flour; WPF: Wheat Pollard Flour; SAPP: Sodium Acid Pyrophosphate; NH_4HCO_3: Ammonium Bicarbonate

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Table 2: Sensory Evaluation of Biscuits

Formulations	Appearance	Color	Smell	Crunchiness	Taste	Flavor	Texture	Mouth feel	Overall acceptability
F0	5.46 ± 1.3 ab	5.5 ± 1.2 ab	5.3± 1.1 ab	5.8± 1.15 a	5.57± 1.5 ab	5.77± 1.3 a	5.87± 1.1 b	5.63± 1.5 a	6.04± 0.97 b
F1	4.5 ±1.7 a	4.47 ± 1.5 a	5.2 ± 1.2 ab	5.3± 1.4 a	4.8± 1.3 a	5.1± 1.2 a	4.87± 1.4 a	5± 1.3 a	5.04± 1.2 a
F2	5.46 ± 1.1 ab	5.47 ± 1.04 ab	5.23± 0.9 ab	5.83± 1.08 a	5.5± 0.9 ab	5.3± 1.11 a	5.53± 1 ab	5± 1.2 a	5.64± 0.7 ab
F3	4.63 ± 1.5 a	4.9 ± 1.4 a	4.9± 1.2 ab	5.3± 1.2 a	5.27± 1.2 ab	5.03± 1.2 a	5.27± 1.3 ab	5.07± 1.4 a	5.2± 1.1 ab
F4	5.93 ± 1.3 b	6.1 ± 1.02 b	5.8± 0.88 b	5.97± 0.9 a	5.87± 1.1 b	5.67± 1.2 a	6.13± 0.93 b	5.8± 1.1 a	6.1± 0.85 b
F5	4.93 ± 1.2 ab	4.93 ± 1.3 a	4.8± 1.1 a	5.47± 1.2 a	4.67± 1.3 a	5± 0.74 a	5.27± 0.8 ab	5.1± 1.02 a	5.08± 0.91 a
F6	5.63 ± 1.3 ab	5.5 ± 1.4 ab	5.3± 1.3 ab	6± 1.16 a	5.37± 0.9 ab	5.5± 0.86 a	5.83± 0.94 b	5.53± 1.04 a	5.84± 0.94 ab
F7	5.27 ± 1.3 ab	5.47 ± 1.3 ab	5.3± 1.08 ab	5.47± 1.3 a	5.27± 1.2 a	5.2± 1.1 a	5.67± 0.9 ab	5.2± 1.4 a	5.24± 1.2 ab
F8	5.37 ± 1.5 ab	5.37 ± 1.4 ab	5.47± 0.9 ab	5.93± 0.9 a	5.8± 0.92 b	5.53± 1.2 a	5.67± 0.8 ab	5.6± 1.2 a	5.76± 1.1 ab
F9	4.6 ± 1.5 a	4.87 ± 1.4 a	5.4± 1.3 ab	5.37± 1.6 a	4.77± 1.3 a	5.03± 1.1 a	5.43± 1.1 ab	5.47± 0.8 a	5.2± 0.76 ab
P-Value	<0.001***	<0.001***	.049	.102	<0.001****	.048	<0.001****	.068	<0.001****

Means with the same superscripts within the same column are not significantly different (P>0.05) b>a. F0=Wheat flour (100); F1=Wheat flour + Wheat pollard (70 :30); F2=Wheat flour + Wheat pollard+ Defatted Soy flour (70:15:15); F3=Wheat flour +Wheat pollard (85:15); F4=Wheat flour + Wheat pollard+ Defatted Soy flour (90:5:5); F5=Wheat flour +Defatted soy flour + Wheat pollard (75 : 5 : 20); F6=Wheat flour + Defatted Soy flour (70:30); F7=Wheat flour + Defatted Soy flour + Wheat pollard (75:20 : 5); F8=Wheat flour + Defatted Soy flour (85: 15); F9=Wheat flour + Defatted Soy flour + Wheat pollard (80:10:10)

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Table 3: Color changes of biscuits

Formulations	L*	a*	b*	c*	h°
F0	66.89±1.02[a]	9.48±0.37 [bc]	26.36±0.27 [ab]	28.02±0.36 [ab]	70.22±0.57 [a]
F1	56.85±0.99 [e]	12.83±0.94 [ab]	23.41±0.7 [bc]	26.71±1.02 [ab]	61.3±1.21 [c]
F2	60.07±1.8 [cde]	13.45±1.1[a]	26.14±1.91 [abc]	29.41±2.06 [a]	62.77±1.56 [bc]
F3	62.44±1.24 [bcd]	8.9±1.9 [c]	22.88±1.31 [c]	24.59±1.82 [b]	68.91±3.56 [a]
F4	62.71±3.23 [bcd]	8.23±0.97 [c]	23.37±0.72 [bc]	24.79±0.78 [b]	70.59±2.13 [a]
F5	59.33±0.75 [cde]	13.74±1.8 [a]	25.04±1.61 [abc]	28.57±2.25 [ab]	61.34±1.62 [c]
F6	62.46±0.77 [bcd]	10.69±2.18 [abc]	27.17±1.79 [a]	29.22±2.46 [a]	68.68±2.77 [a]
F7	63.72±0.6 [abc]	9.17±0.59 [c]	25.18±0.16 [abc]	26.8±0.32 [ab]	69.98±1.13 [a]
F8	64.19±2.4 [ab]	9.81±2.27 [bc]	26.5±2.44 [ab]	28.09±3.04 [ab]	69.79±2.96 [a]
F9	63.5±1.61 [abc]	10.56±1.47 [abc]	25.56±0.82 [abc]	27.68±0.61 [ab]	67.54±3.23 [ab]
P-value	<0.001	< 0.001	0.001	0.003	<0.001

Means with the same superscripts within the same column are not significantly different (P>0.05) [a>b]. F0=Wheat flour (100); F1=Wheat flour + Wheat pollard (70:30); F2=Wheat flour + Wheat pollard+ Defatted Soy flour (70:15:15); F3=Wheat flour +Wheat pollard (85:15); F4=Wheat flour + Wheat pollard+ Defatted Soy flour (90 5:5), F5=Wheat flour +Defatted soy flour + Wheat pollard (75 : 5 : 20); F6=Wheat flour + Defatted Soy flour (70:30); F7=Wheat flour + Defatted Soy flour + Wheat pollard (75:20 : 5); F8=Wheat flour + Defatted Soy flour (85: 15); F9=Wheat flour + Defatted Soy flour + Wheat pollard (80:10:10)

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Table 4: Comparative Proximate composition of main flour

	Moisture (g/100g)	Fat (g/100g)	Protein (g/100g)	Crude (g/100g)	fiberAsh (g/100g)	Carbo-hydrates (g/100g)	Energy (Kcal/100g)
WP	10.82 ±0.1^{ab}	4.94 ±0.2^{b}	12.35 ±0.1^{c}	7.09 ±0.3^{a}	3.33 ±0.1^{b}	61.45 ±0.3^{a}	339.72 ±0.2^{a}
WF	14.66 ±3.4^{a}	1.7 ±0.1^{c}	14.19 ±0.2^{b}	0.76 ±0.3^{b}	0.79 ±0.2^{c}	67.89 ±2.7^{a}	343.66 ±12.6^{a}
DSF	5.15 ±0.0^{b}	6.11 ±0.1^{a}	45.22 ±0.4^{a}	4.97 ±0.8^{a}	6.15 ±0.2^{a}	32.37 ±1.3^{b}	365.39 ±4.8^{a}
p-value	0.04	<0.001	<0.001	0.003	<0.001	0.001	0.085

Means with the same superscripts within the same column are not significantly different (P>0.05) $^{a>b}$. Mean ± standard deviation; Wheat Pollard (WP); Wheat Flour (WF); Defatted Soy Flour (DSF)

Table 5: Proximate composition of 5 most appreciated biscuits

	Moisture (g/100g)	Fat (g/100g)	Protein (g/100g)	Crude fiber (g/100g)	Ash (g/100g)	Carbo-hydrates (g/100g)	Energy (Kcal)
F0	3.44±0.04^{b}	19.93 ±0.25^{c}	10.25 ±0.11^{e}	1.02 ±0.02^{b}	0.7 ±0.04^{b}	64.66 ±0.04^{a}	478.99±1.7^{c}
F2	4.35 ±0.08^{a}	23.26 ±0.42^{b}	14.87 ±0.15^{bc}	1.51 ±0.06^{a}	1.01 ±0.07^{b}	55.01 ±0.22^{bc}	488.83 ± 2.3^{b}
F4	4.19 ± 0.12^{a}	23.83 ±0.09^{ab}	14.01 ±0.01^{d}	1.13 ±0.1^{b}	0.93 ±0.13^{b}	55.89 ±0.03^{b}	494.09 ± 0.79^{ab}
F6	3.05 ± 0.24^{c}	24.14 ± 0.15^{a}	17.04 ± 0.28^{a}	1.48 ± 0.06^{a}	1.86 ± 0.05^{a}	52.41 ± 0.09^{d}	495.1 ± 2.1^{ab}
F7	4.17 ±0.07^{a}	24.02 ±0.14^{ab}	15.29 ±0.62^{b}	1.63. ±0.02^{a}	1.03 ±0.69^{b}	54.09 ±1.2^{c}	493.74 ± 3.7^{ab}
F8	2.98 ± 0.06^{c}	24.31 ± 0.43^{a}	14.41 ± 0.18^{cd}	1.58 ± 0.06^{a}	1.14 ± 0.08^{ab}	55.57 ± 0.41^{bc}	498.68 ± 2.9^{a}
p-value	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	<0.001
CV%	3.3	1.2	2.1	4.2	17.4	1.03	0.5

Means with the same superscripts within the same column are not significantly different ($P>0.05$)$^{a>b}$. F0= Wheat flour (100) ; F2 = Wheat flour + Wheat pollard+ Defatted Soy flour (70 =15 =15); F4 = Wheat flour + Wheat pollard+ Defatted Soy flour (90 =5 =5) ; F6 = Wheat flour + Defatted Soy flour (70 =30) ; F7 = Wheat flour + Defatted Soy flour + Wheat pollard (75 =20 =5); F8 = Wheat flour + Defatted Soy flour (85=15)

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Table 6: Total phenolics compound of flour and most appreciated biscuits

Flour	**Total Phenolics (mg GAE/100g)**
WF	273.05 ± 2.5[b]
WP	339.44 ± 1.0[a]
DSF	224.39 ± 2.1[c]
p-Value	**<.001**
CV%	**0.7**
Biscuits Formulations	**Total Phenolics (mg GAE/100g)**
F0	181.6± 1.3[c]
F2	226.7± 2.7[b]
F4	277.75± 4.3[a]
F6	191.5± 8.3[bc]
F7	298.9± 1[a]
F8	231.1± 3.4[b]
p-Value	**<.001**
CV%	**7.7**

Means with the same superscripts within the same column are not significantly different (P>0.05)[a>b]. Mean ±Standard deviation; WF: Wheat Flour, WP: Wheat pollard, DSF: Defatted Soy Flour; F0 : Wheat flour (100) ; F2 : Wheat flour + Wheat pollard+ Defatted Soy flour (70 :15 :15); F4 : Wheat flour + Wheat pollard+ Defatted Soy flour (90 :5 :5) ; F6 : Wheat flour + Defatted Soy flour (70 :30) ; F7 : Wheat flour + Defatted Soy flour + Wheat pollard (75 :20 :5); F8 : Wheat flour + Defatted Soy flour (85:15)

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