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Improving the Nutritional Value of Biscuits by Adding Wheat Germ and Sugar Beetroot Pulp

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Abstract

In this study, locally nutrient-dense sources like wheat germ (WG) and sugar beetroot pulp powder (SBP) were used to produce highly nutritive biscuits. Chemical composition and minerals analysis of wheat flour (WF), WG, and SBP were carried out. WF biscuits were prepared by incorporating different percentages of (10, 20, and 25%) WG and (3, 6, and 9%) SBP. The chemical composition, physical parameters, sensory evaluation, color, and texture profile of the prepared biscuits were determined. Physicochemical analysis showed that 25% WG biscuits were significantly ($P \leq 0.05$)higher in protein (11.93%), fat (16.82%) and ash (2.08%) contents, whereas 9% SBP biscuits were higher in fiber (2.53%) content and had a lower calorific value than the control sample. Results indicated that as the concentration of WG or SBP in the blend increased, the biscuits became darker in color with a significant ($P \leq 0.05$) increase in their spread factor. The texture profile analysis of the biscuits showed that the 9% SBP biscuits had the highest hardness value of 37.16 (N). Sensory panellists rated biscuits containing 10% WG as highly acceptable in relation to their overall acceptability scores and were closest to the control biscuits. It can be concluded that WG and SBP can be tools to produce biscuits with good nutritional and physical characteristics with substitution percentages up to 25% and 6%, respectively.

*Keywords:*Wheat germ; Sugar beetroot pulp; Wheat flour; Fortification; Bakery products; Sensory properties; Fiber

1. Introduction

It is reported that there are a large number of by-products in the food industry; if not used in feed production, these are considered waste that greatly pollutes the environment [1]. Large quantities of waste, besides the large loss of valuable materials, cause serious economic and ecological problems. High nutritive ingredients that can be found in food by-products (fiber, protein, antioxidants and minerals) may increase the nutritional value of food products if incorporated or used for fortification purposes and thus reducing the overall waste. Therefore, the use of these by-products in the food industry has become a growing trend [2]. In recent years, there have been a lot of studies that investigated the influence of food industry by-products on the nutritional characteristics of different food products [3]. Jozinović et al. [4] concluded that the addition of apple pomace, brewer's spent grain and SBP increased the antioxidant activity, total phenolic content and dietary fiber of corn grits-based products. The biscuit's nutritional characteristics were improved by the addition of flour obtained from bergamot by-products [5], grape by-products [6], red beetroot and carrot pomace powder [7], sugar beetroot fiber [8–10], whole wheat germ and defatted wheat germ [11–14].

The wheat grain consists of bran, endosperm, and WG. WG accounts for about 2 or 3% of the wheat grain, which is a highly available and underutilized resource as it is separated as a by-product during the production of wheat flour [15]. Utilization of WG in food products is encouraged as it is considered a precious nutritional capsule. WG is an inexpensive source of high protein quantity and quality, vitamins E and B, minerals, dietary fiber and significant

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quantities of bioactive compounds, as well as a high unsaturated oil fraction [16]. Although the WG protein is a plant protein, it is reported to be comparable to animal proteins (egg and milk proteins) [17]. This unique protein is rich in essential amino acids, in particular methionine, lysine and threonine, which are deficient in many cereal grains. Therefore, deficiencies in essential amino acids in cereal foods can be compensated by adding WG [18]. WG is characterized by a palatable taste due to its high sugar and fat content [19]. Also, it has an important impact on human health as it contains stronger antioxidant activities than those of vitamin E, vitamin C, and synthetic antioxidants. Also, it has the potential for the therapy and prevention of carcinogenesis [20, 21].

In recent years, increasing efforts have been made to valorize milling wastes, thereby turning WG from a waste into a highly valuable by-product. New strategies were developed to provide healthy and low-cost ingredients for food-making.Flour blends made from raw or processed WG received great interest from both a nutritional and technological perspective. However, the quality of the end product strongly depended on the supplementation level as well as the type and severity of separation and stabilization techniques that WG went through [15]. Cereal-based foods have been enriched with WG or its derivatives, i.e., biscuits and cookies [12, 22, 13, 20] Pasta and noodles [23–25] and bread [26, 27].

In the agricultural sector, the processing of sugar crops for the production of sugar generates a wide variety of by-products. Their reuse represents a prime opportunity for value capture and for the sugar processing industry to be at the forefront of sustainability while possibly realizing additional profits. Sugar beetroot includes a rich sugar fraction in addition to fiber [28]. Sugar beetroot pulp is a by-product of the sugar extraction processes that remains after water extraction of sugar from the sliced beet tuber and is not usable as livestock feed [9]. Nutritional data show that sugar beetroot fiber contains around 8% protein and 67% carbohydrates, such as cellulose (19%), hemicellulose (28%) and pectin (18%) [29]. Dietary fiber available for human digestion is generally more than 20%. Physical and chemical properties suggest the possibility of its utilization as dietary fiber in human diets [1]. Sugar beetroot pulp dietary fiber has protective physiological effects due to its ability to bind bile and cholesterol and inhibit their resorption. Also, dietary fibers prolong the feeling of satiety, prevent constipation and reduce the risk of cancer and heart disease. Dietary fibers have been widely recommended in bakery products, snacks, pastries and meat products. The incorporation of sugar beetroot dietary fiber in bakery products changes the main characteristics of their quality and prolongs their freshness for a long time [9]. Therefore, the objectives of this investigation were to produce biscuits enriched with WG and SBP as natural sources of minerals and fibers and study the physicochemical, texture profile properties, color parameters and sensory characteristics of the prepared biscuits.

2. Materials and methods

2.1. Materials

Sugar beetroot pulp was collected from Fayoum Company for sugar production inFayoum Governorate, Egypt. The ready-to-consume WG was procured from one of the Egyptian Ministry of Agriculture outlets. WF (72%) was obtained from the North Cairo Flour Mills Company, Egypt. Other materials like butter, sugar, baking powder, salt (sodium chloride), whole milk and vanilla used for biscuit making were purchased from the Dokki local market, Egypt.

2.2. Methods

2.2.1. WG and SBP preparation

WG has been milled to a fine powder using a local milling machine (coffee grinder-w Moulinex, France) and kept in plastic sachets. SBP was prepared as presented in chart (1).

Sugar beetroot pulp

↓

Drying (50° C/48 hours)

↓

Grinding

↓

Sieving

↓

Packing in an airtight polypropylene jar and stored in a cool and dry place

Chart. 1.A flow chart for the preparation of SBP

2.2.2. Blends preparation

WF of 72% extraction was well blended with WG at different levels (10, 20 and 25%) and SBP at different levels (3, 6 and 9%) to produce individual mixtures. All samples were stored in airtight containers and kept at 3-5°C until use.

2.2.3. Preparation of biscuits

Biscuit samples were prepared according to the method of the AACC [30], with some modifications to the recipe. The biscuits were prepared by mixing 100 g of WF and their blends containing WG or SBP. The biscuit formula was as follows: 100 g flour, 40 g sucrose, 32 ml whole milk, 28 g butter, 1.11 g baking powder, 1 g vanilla and 0.5 g salt. Biscuit preparation: butter and ground sugar were mixed until fluffy. Whole milk was added while mixing and then it was mixed for a total of about 30 minutes. Flour, vanilla, baking powder and salt were mixed thoroughly and added to the cream mixture, where they were all mixed together to form a dough. The dough was rolled and cut into shapes. The baking was carried out at180°C for 20 minutes (SHEL LAB 1370FX, USA). Biscuit samples were cooled and stored in polyethylene bags until needed.

2.2.4. Gross chemical composition of raw materials and biscuits

WF, WG, SBP and biscuit samples have been analyzed for the following constituents: moisture, protein, fat, crude fiber and ash according to A.O.A.C. methods [31]. The percentage of crude protein has been calculated by multiplying the total nitrogen content by the conversion factor (WF and biscuits (N) × 6.25), (WG (N) × 5.36) and (SBP (N) × 5.7). The analyses have been done in triplicate. Carbohydrates were calculated by the difference as follows:

Carbohydrates (%) = 100 - [moisture% + ash% + proteins% + fat% + crude fiber%].

2.2.5. Calorific value

The total calories of the samples were calculated according to James [32] as follows:

Total calories (Kcal/100 g) = (Fat × 9 Kcal) + (Protein × 4 Kcal) + (Carbohydrate × 4 Kcal)

2.2.6. Mineral composition of raw materials

Macro- and microelements were determined by the dry ashing method, according to Jones et al. [33]. Calcium (Ca) and magnesium (Mg) were determined by the versenate (EDTA) method according to Cheng and Bray [34]. Phosphorus (P) was determined by the ascorbic acid method [35]. Potassium (K) and sodium (Na) were determined by the flame photometric technique [36]. Manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), and nickel (Ni) were determined by inductively coupled plasma (ICP) emission spectroscopy [37].

2.2.7. Baking quality of biscuits

Diameter (mm), thickness (mm), weight (gram), Volume (ml), specific volume (ml/gram) and spread ratio were determined as described in AACC [30] methods. The spread factor of biscuits was recorded according to Youssef et al. [38] by the following equation:

Spread factor = (Spread ratio of the sample / Spread ratio of the control sample) × 100

2.2.8. Color determinations

Color parameters of biscuit samples were determined using Hunter Lab (UltraScan PRO Spectrophotometer, USA). The instrument was calibrated each time using a white tile. Color values were expressed as L* (lightness or brightness/darkness), a* (redness/greenness) and b* (yellowness/blueness) and were measured according to the device formula. Hue and Chroma were calculated according to Palou et al. [39] method. ΔE (total color difference) was calculated according to Marpalle et al. [40] as follows:

$\text{Hue} = \tan^{-1} [b^*/a^*]$

$\text{Chroma} = 1/2 \text{ square root of } [a^{*2} + b^{*2}]$

$\Delta E = (L^{*2} + a^{*2} + b^{*2})1/2$

Where (a*=a*-a*0), (b*=b*-b*0) and (L*=L*-L*0). Subscript “O” indicates the color of the control.

2.2.9. Sensory properties of biscuits

According to Linda et al. [41], sensory evaluation of prepared biscuit samples was conducted by twenty semi-trained panellists from the food technology and nutrition institute staff at the National Research Centre, Egypt. Sensory evaluations for the color, taste, odor, appearance, texture and overall acceptability were done in order to determine consumer acceptability. A numerical hedonic scale ranging from 1 to 20 (where 1 is the most disliked and 20 is the most liked) was used for sensory evaluation.

2.2.10. Texture analysis

The texture of the baked biscuit samples was measured by a texturometer (Brookfield, CT3-10 kg, USA) equipped with a cylinder probe (TA.AACC36). Texture profile analysis (TPA) was conducted to determine hardness, adhesiveness, cohesiveness, gumminess and resilience. The analyzer was set to perform two cycle measurements to give a two bite texture profile curve. Trigger load and test speed were 9.00 Ng and 2 mm/s, respectively.

2.2.11. Statistical analyses

Standard deviation (SD) calculations have been done by using the software Excel 2010. Statistical analysis was conducted with the CoState program using a one-way analysis of variance (ANOVA). The statistical analysis of the obtained results was done with triplicate replications, except for the sensory evaluation data, which had 20 replicates [42]. Data were represented as means followed by ± (SD).

3. Results and discussion

3.1. Gross chemical composition ofraw materials

The gross chemical composition of WF, WG and SBP is reported in Table (1). The moisture and carbohydrate contents of WF (12.24% and 75.88%) were higher than those of WG (8.07% and 51.26%) and SBP (8.28% and 59.32%), respectively. WG was characterized by its higher protein, fat and ash contents (24.80%, 9.77% and 4.22%, respectively), while SBP had a higher fiber content (20.50%) than WF.Protein values correlated well with the earlier reported values of 9.12% in WF [43] and 9% in SBP [44]. WG protein content has been reported to vary from 18.3 to 36.7% [45] and from 18.8 to 26.2% [18].Khattab et al. [9] found that the fat content of SBP was 0.53%. Farrel et al. [46]reported that the fat content of milled WG ranged from 6.5% to 10.6%, while it ranged between 5.2% and 11.6% as stated by Jadhav and Vali [18]. These variations may be due to lipid purity or genetic factors.

The ash content of WG, SBP and WF was 4.22%, 2.98% and 0.39%, respectively. These findings were in close agreement with previously reported values of 3.6 to 5% in WG [18], 2.50% in SBP [47] and 0.47 to 1.14% in WF [48]. WF showed the lowest percentage of ash, maybe due to the high extraction rates. The crude fiber content in WG, SBP and WF was found to be 1.86%, 20.50% and 0.31%, respectively. Youssef [12] and Essa and Mostafa [49] reported that the crude fiber content of SBP and WG was 21.89% and 2%, respectively. Salehifar and Shahedi [50] found the crude fiber content of WF within the range of 0.12 to 1.89%. Basman and Koksel [51] and Persson [52] reported that SBP is considered a valuable and important source of dietary fiber. Thus, it is used to produce concentrated dietary fiber for the food industry. The results presented in Table (1) showed that the gross chemical composition of WG and SBP contained more nutrients compared to WF. Man et al. [43] and Mamat and Hill [53] pointed out that the chemical composition of valuable high nutritive sources and low gluten, along with the high carbohydrate content, especially starch, of WF, leads to composite flours with good characteristics for biscuit manufacturing.

Table 1
Gross chemical composition (%) of WF, WG and SBP

Sample	WF	WG	SBP	LSD at 5%
Moisture	12.24^{a} ±0.02	8.07^{c} ±0.03	8.28^{b} ±0.01	0.045
Protein	9.82^{b} ±0.02	24.80^{a} ±0.01	8.58^{c} ±0.01	0.038
Fat	1.34^{b} ±0.02	9.77^{a} ±0.02	0.31^{c} ±0.01	0.039
Ash	0.39^{c} ±0.01	4.22^{a} ±0.02	2.98^{b} ±0.01	0.036
Fiber	0.31^{c} ±0.01	1.86^{b} ±0.02	20.50^{a} ±0.01	0.038
Carbohydrate	75.88 ^{a}±0.03	51.26^{c} ±0.04	59.32^{b} ±0.03	0.067

Where: Wheat flour: WF, wheat germ: WG and sugar beetroot pulp powder: SBP. Means ± (SD) followed by different superscripts within rows significantly different (P ≤ 0.05).

3.2. Mineral content of raw materials

The evaluation of the macro- and microelement composition of WF, WG and SBP is displayed in Table (2) as mg/100 g sample. WG was found to be a good source of Ca (1499.89 mg/100 g), Mg (321.40 mg/100 g) and Na (233.98 mg/100 g) compared to SBP and WF. SBP had the highest content of P (619.00 mg/100 g), K (882.78 mg/100 g), Mn (7.74 mg/100 g), Zn (6.74 mg/100 g) and Ni (0.13 mg/100 g) compared to WG and WF.

The obtained result about WG Mn content was similar to that obtained by Nurgazezova et al. [54]. Levent and Bilgiçli [55] showed that WG is rich in Ca, Cu, Fe, Mn, P, K, Zn and Mg. It is reported that products made from SBP were rich in Fe, Mg, Cu, Zn and Mn [56]. WG and SBP powder can be recommended as sources of essential elements. Hence, the nutritive value and mineral content of both of them can play a considerable role in developing bakery products.

Table 2
Mineral content (macro- and microelement) of WF, WG and SBP as mg/100 gram sample

Minerals	WF	WG	SBP
P	80.2	234.00	619.00
K	187.3	575.53	882.78
Ca	39.30	1499.89	1140.25
Mg	55.2	321.40	136.83
Na	55.6	233.98	210.71
Fe	1.01	0.29	0.34
Mn	5.18	7.38	7.74
Zn	0.55	6.59	6.74
Cu	0.07	2.17	2.09
Ni	0.07	0.09	0.13

Where: Wheat flour: WF, wheat germ: WG and sugar beetroot pulp powder: SBP

3.3. Gross chemical composition of control biscuits and biscuits containing WGorSBP

Table (3) showed the gross chemical composition of biscuit samples supplemented with WG or SBP at different levels compared to the control biscuits. The moisture content of biscuit samples was found to range from a maximum of 6.26% in the control sample to a minimum of 5.44% in the 25% WG biscuits. The protein content was found in the range of 8.20% to 11.93%. The ash content of biscuits varied from 1.63 to 2.08 %. However, a drastic difference was observed in the fat content of the biscuit samples, ranging from 15.20% for the control biscuits to 16.82% for the 25% WG biscuits. Fiber and carbohydrate contents in biscuits were gradually decreased in all samples as the substitution proportion of WG or SBP increased, which might be related to the initial low fiber and carbohydrate contents of the raw materials used in the mixtures. These results agree with El-Zainy et al. [57].

In comparison to the control biscuits, 25% WG biscuits were characterized by higher protein, fat and mineral content, while 9% SBP biscuits were characterized by higher total fiber content. Further, all biscuits obtained in this study can be labeled as bakery products with high fiber content if compared to control biscuits. Such data are in good accordance with Al-Marazeeq and Angor [13] who reported that fortification of biscuits with 20% WG significantly ($P \leq 0.05$) increased protein and total mineral content. Similar patterns were previously noticed by Simić et al. [1] who stated that the addition of extruded SBP significantly increased the amount of total dietary fiber and minerals in cookies. It was observed that the energy values of WG biscuits increased, whereas the energy values of SBP biscuits decreased with the increase in substitution percent compared to the energy values of control biscuits. The increase was higher in the case of the 25% WG biscuits, which contained the highest fat content. Khattab et al. [9] showed that energy decreased with increasing SBP levels in bread.

Table 3
Gross chemical composition of biscuits fortified with WG or SBP at different levels compared to the control sample

Samples	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate	Caloric value (Kcal)
	%						
Control	6.26^{a}±0.04	8.20^{d}±0.08	15.20^{d}±0.14	1.63^{d}±0.02	0.71^{g}±0.02	67.97^{a}±0.22	441.56^{c}±0.46
WG10%	5.53^{e}±0.05	11.33^{c}±0.04	16.13^{c}±0.15	1.88^{bc}±0.02	0.81^{f}±0.02	64.29^{b}±0.06	447.73^{b}±1.04
WG20%	5.51^{ef}±0.2	11.69^{b}±0.06	16.44^{b}±0.05	1.98^{ab}±0.02	0.95^{e}±0.02	63.42^{c}±0.08	448.45^{ab}±0.36
WG25%	5.44^{f}±0.03	11.93^{a}±0.08	16.82^{a}±0.14	2.08^{a}±0.12	1.09^{d}±0.09	62.61^{d}±0.19	449.64^{a}±1.07
SBP 3%	6.16^{b}±0.06	7.91^{e}±0.07	15.03^{de}±0.10	1.68^{d}±0.09	1.31^{c}±0.03	67.89^{a}±0.18	438.55^{d}±0.44
SBP 6%	6.03^{c}±0.05	7.60^{f}±0.05	14.80^{ef}±0.17	1.71^{d}±0.10	1.91^{b}±0.02	67.93^{a}±0.20	435.39^{e}±1.00
SBP 9%	5.91^{d}±0.02	7.38^{g}±0.07	14.63^{f}±0.14	1.74^{cd}±.13	2.53^{a}±0.06	67.79^{a}±0.20	432.41^{f}±0.90
LSD at 5%	0.078	0.121	0.240	0.157	0.083	0.307	1.421

Means ± (SD) followed by different superscripts within columns significantly different ($P \leq 0.05$)

3.4. Physical properties of biscuit samples

The physical properties of biscuit samples prepared by substituting different levels of WF with WG or SBP compared to the control samples (Photo1) were measured and tabulated in Table (4). Results indicated that there were significant differences ($P \leq 0.05$) between the control sample and other biscuit samples. The increase in WG and SBP levels in blends led to a significant increase in biscuit diameter. The diameter of the control sample was 63 mm and it increased to the highest diameter value of 64.33 mm in the 25% WG biscuits. The thickness of the biscuits decreased markedly with the higher addition of WG. The same trends in thickness were also described in the study of cookies incorporated with various levels of defatted WG flour [58]. As the SBP level increased, the thickness and diameter of the biscuits slightly increased.

WG and SBP incorporation in biscuits increased the spread ratio and spread factor of the biscuits. 25% WG biscuits recorded the highest value of the spread ratio (8.31). These results were in agreement with the findings of Sudha et al. [59]. A similar increase in spread ratio was also reported in a previous study on biscuits fortified with 15% and 20% of WG [12]. Kuchtová et al. [19] stated that the addition of WG and corn germ in crackers at a level of 15% significantly increased the spread ratio. This can be attributed to a lower amount of hydrophilic spots in the blends, which bind low free water in dough; this then leads to a decrease in dough viscosity and an increase in biscuit spread and vice versa; or it may be attributed to the dilution of gluten by increasing substitution levels of WF with WG or SBP in biscuit manufacture [60].

The data regarding biscuit weight showed that the addition of WG slightly reduced the weight and volume of biscuits, whereas the addition of SBP increased the weight and volume as substitution levels were increased. This might be due to the different flour quality and fiber. Incorporation of WG in biscuit blends reduced specific volume, whereas SBP addition increased specific volume. These results agree with Meriles et al. [16] and Kuchtová et .

al. [19]. Specific volume has great importance in determining biscuit quality, as it is generally influenced by the quality of the ingredients used in the formulation of biscuits [19].

A higher spread factor, a higher diameter and a lower height are considered positive biscuit characteristics [61]. Also, the spread ratio is an indicator of biscuit quality, so high-quality biscuits should have a high spread ratio [62]. As a result, the incorporation of WG and SBP could lead to composite flours with good characteristics for biscuit manufacturing

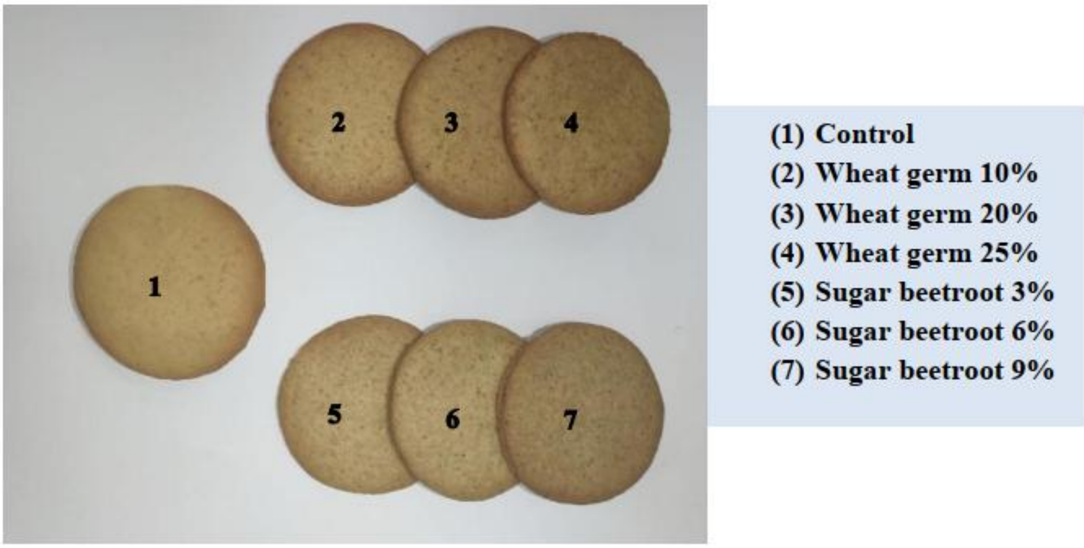

Photo.1.Biscuits supplemented with different levels of WGorSBP

Table 4
Baking quality of biscuits supplemented with different levels of WG or SBP

Samples	Diameter (mm)	Thickness (mm)	Spread ratio	Spread factor (%)	Weight (gram)	Volume (ml)	Specific volume (ml/g)
Control	63.00^{c}±0.10	8.06^{ab}±0.11	7.81^{c}±0.12	100.00^{d}±0.00	11.97^{bc}±0.01	32.00^{b}±0.00	2.67^{b}±0.01
WG10%	63.03^{c}±0.05	7.96^{b}±0.05	7.91^{c}±0.05	101.31^{c}±0.69	11.92^{bc}±0.01	31.66^{b}±0.57	2.65^{b}±0.05
WG20%	63.73^{b}±0.46	7.83^{c}±0.05	8.13^{b}±0.05	104.17^{b}±0.76	11.90^{c}±0.01	31.66^{b}±0.58	2.65^{b}±0.04
WG25%	64.33^{a}±0.28	7.73^{c}±0.05	8.31^{a}±0.05	106.51^{a}±0.69	11.85^{c}±0.01	31.33^{b}±0.57	2.64^{b}±0.04
SBP 3%	63.16^{c}±0.05	8.06^{ab}±0.05	7.83^{c}±0.04	100.26^{cd}±0.62	11.97^{bc}±0.01	33.00^{a}±0.00	2.75^{a}±0.01
SBP 6%	63.36^{bc}±0.11	8.06^{ab}±0.05	7.85^{c}±0.05	100.58^{cd}±0.65	12.09^{ab}±0.17	33.33^{a}±0.58	2.75^{a} ±0.01
SBP 9%	63.66^{b}±0.05	8.10^{a}±0.00	7.86^{c}±0.01	100.64^{de}±0.09	12.19^{a}±0.18	33.66^{a}±0.57	2.76^{a} ±0.03
LSD at 5%	0.380	0.114	0.113	1.019	0.171	0.854	0.059

Means ± (SD) followed by different superscripts within columns significantly different ($P \leq 0.05$)

3.5. Color parameters of biscuits

Biscuit color plays a major role in consumers' perception and acceptability. The color parameters (L∗), (a∗), (b∗), Hue angle and Chroma for the biscuits were represented in Table (5). It was observed that there was a significant increase ($P \leq 0.05$) in the biscuits' darkness with the increase in WG and SBP levels. Hence, all biscuit samples were darker than the control, as indicated by lower (L∗) values. There were no significant ($P \leq 0.05$)

differences among all biscuits in redness (a∗) values. A slight decrease in the biscuits' yellowness (b∗) value was observed as the WG and SBP levels increased. The hue angle value slightly decreased with the increase of WG in biscuits, indicating that these biscuits had a slightly browner color compared to other biscuits. Chroma represents the color intensity of the top surface of the biscuits. Chroma value decreased with the higher additions of WG and SBP compared to the control sample.

Bansal and Sudha [11] stated that above 20% WG in biscuit formulation caused a pale yellow color due to the decrease in brightness and increased redness compared to the control biscuits. The dark color of the biscuits is possibly due to millard reactions, the caramelization reaction, the high protein content or changes in pH [63, 59].

Table 5
Color parameters of biscuits supplemented with different levels of WG or SBP

Samples		Color parameters					
		L*	***a****	***b****	**Chroma**	**Hue**	**ΔE**
Control		65.65a ±0.37	10.86a±1.74	38.87a±1.40	40.37a±1.80	74.44a±1.90	-
WG	**10%**	64.61a ±0.63	11.93a±0.06	35.37b ±2.18	37.33b±2.08	71.32b±1.02	4.28b±2.09
	20%	62.26b ±1.25	12.10a±1.15	34.46b ±0.29	36.53b±0.55	70.66b±1.67	6.07ab±0.40
	25%	60.90b ±1.43	12.15a±0.05	33.19b ±1.34	35.35b±1.27	69.87b±0.74	7.81a±1.27
LSD at 5%		1.925	1.967	2.767	2.902	2.657	2.859
Control		65.65a±0.37	10.86a±1.74	38.87a±1.40	40.37a±1.80	74.44a±1.90	-
SBP	**3%**	64.21a±1.88	9.90a±1.20	34.18b±1.08	35.60b±1.16	73.84a±1.82	5.34b±0.92
	6%	61.25b±0.12	9.82a±2.60	32.51bc±2.41	34.00b±3.02	73.37a±3.22	8.07ab±2.48
	9%	59.65b±0.05	9.52 a±0.72	29.79c±2.78	31.27b±2.86	72.25a±0.58	11.05a±2.31
LSD at 5%		1.809	3.227	3.845	4.405	3.948	4.0540

Means ± (SD) followed by different superscripts within columns significantly different ($P \leq 0.05$).

3.6. Sensory characteristics of biscuits

Sensory evaluation values of biscuits prepared from different flour mixes are presented in Table (6) and figure (1). A gradual decrease in appearance and color values was observed in WG biscuits and SBP biscuits. This was due to the less smooth surface of the WG biscuits and the darker color of the SBP biscuits at higher levels. This can be explained by the fact that the panellists were able to visually distinguish the samples based only on their color and the degree of irregularities that could be seen on the surface of the biscuit. The decrease in the appearance values may be due to the gradual decrease in the amount of moisture and carbohydrates in the biscuit samples, as shown in Table (3); this caused a decrease in the surface appearance value of the biscuit and a darker color during baking. There is a positive correlation between appearance, moisture, and total carbohydrates. In contrast, appearance is negatively correlated with ash, fat and crude fiber [43]. Bansal and Sudha [11] showed that the incorporation of more than 20% steamed WG into the biscuit composition resulted in a pale yellow color and a less smooth surface.

Texture plays a key role in assessing consumers' acceptance of products. Unconsciously, most of the time, the consumer’s preference toward a product is often due to the texture. The complex changes in texture during the process of eating (mouth behavior) can influence the acceptance or rejection of the product [44]. Substitution levels did not negatively affect biscuit texture. WG biscuits obtained higher scores in taste compared to SBP biscuits due to the unique nutty flavor of WG. The sensory panellists rated the control sample with the highest score for all attributes. This was closely followed by the blend containing 10% WG. The highest overall acceptability scores of 96% and 95% were for the control sample and 10% WG. After this level of substitution, a decrease in acceptability scores was observed. There were no significant differences in overall acceptability between 20 and 25% WG biscuits and 3% SBP biscuits. Biscuits prepared from 9% SBP were given the lowest score for overall acceptability. It is reported that the taste and aroma of the biscuit are positively correlated with its content of protein, ash, fat and crude fiber and negatively correlated with moisture and total carbohydrate [43].

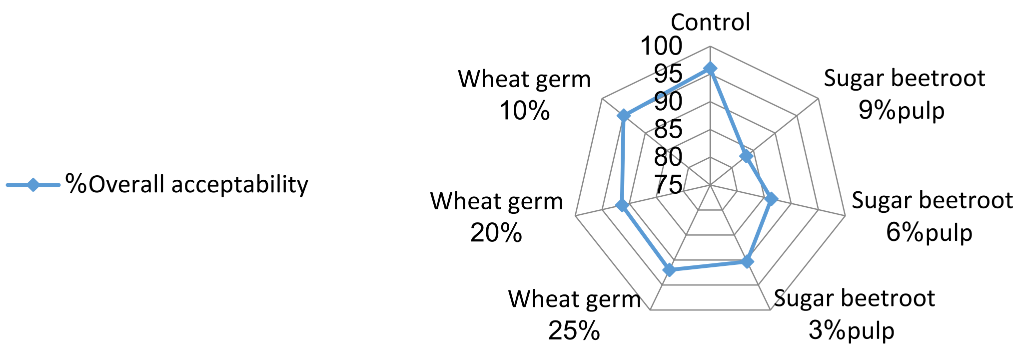

Fig.1: Overall acceptability% of biscuits

Table 6
Mean values of sensory characteristics of biscuits supplemented with different levels of WG or SBP

Biscuits	Color (20)	Taste (20)	Odor (20)	Appearance (20)	Texture (20)	Overall acceptability%
Control	19.33a	19.00a	19.66a	19.33a	18.66a	96.00a
WG10%	18.33b	19.00a	19.66a	19.00ab	19.00a	95.00a
WG20%	17.00d	18.33ab	19.33ab	18.33abc	18.33a	91.33b
WG25%	18.00bc	18.66ab	19.00ab	18.00bcd	18.33a	92.00b
SBP 3%	17.33cd	17.66bc	18.66bc	18.66cd	18.00ab	90.33b
SBP 6%	16.00e	16.66cd	18.00cd	17.66d	18.00ab	86.33c
SBP 9%	16.00e	16.33d	17.66d	16.33e	17.00b	83.33d
LSD at 5%	0.936	1.080	0.854	0.854	1.146	2.675

Means followed by different superscripts within columns significantly different ($P \leq 0.05$)

3.7. Texture profile analysis (TPA) of biscuits

Texture profile analysis is an important parameter of biscuit quality. The texture of the biscuits was determined by the application of breakage force. It was measured the day after baking. Hardness (N), adhesiveness (g.cm), cohesiveness, gumminess (N) and resilience slightly differed among samples as presented in Table (7). Hardness decreased as the amount of WG increased, while it increased as the level of SBP increased in biscuits. The results of the increased hardness of SBP biscuits compared to WF biscuits are in accordance with Gujral et al. [64] and the same as those of Sudha et al. [59] noticed the increase in breaking strength with the addition of fibers to wheat. Arshad et al. [58] and Meriles et al. [16] observed lower hardness in cookies than in control samples with the addition of defatted WG. The diluting effect of gluten caused by substituting flour with other components can result in a weaker gluten network and a less rigid structure [11].

Adhesiveness is defined as the negative force area for the first bite and represents the work required to overcome the attractive forces between the surface of food and the surface of other materials with which the food comes into contact [65]. From table (8), it can be seen that the adhesiveness showed slight differences among all biscuit samples. The highest value of adhesiveness was 2.66 g.cm for 10% WG biscuits and the lowest value was 0.33 g.cm for 3% SBP biscuits.

Cohesiveness (consistency) indicates the strength of internal bonds making up the food body and the degree to which it can deform before breaking; it is measured as the rate at which the material is disintegrated under mechanical action [66]. The cohesiveness values of the biscuit samples were in the range of 0.080 to 0.033. The highest value obtained was for control biscuits, and the lowest value obtained was for 10% WG biscuits and 6% SBP biscuits.

Gumminess is defined as the hardness and cohesiveness of the product. From the TPA table, it can be seen that the control sample had a higher gumminess value of 2.42 (N), and biscuits with 10% WG had the lowest value of 1.18 (N). Resilience is a measurement of how the sample recovers from deformation both in terms of speed and force [67]. In simple terms, it is the elastic recovery of the sample. A higher value for resilience was obtained for 10% WG biscuits, being 0.07.

Table 7
Texture profile analysis of biscuits supplemented with different levels of WG or SBP

Sample	Hardness (N)	Adhesiveness (g.cm)	Cohesiveness	Gumminess (N)	Resilience
Control	32.54b±1.37	1.66ab±0.57	0.080a±0.02	2.42a±0.68	0.05ab±0.02
WG 10%	32.44b±1.76	2.66a±2.08	0.033c±0.01	1.18b±0.42	0.07a±0.04
WG 20%	31.39b±1.09	2.33a±0.57	0.036bc±0.01	1.47ab±0.37	0.01ab±0.00
WG 25%	30.92b±2.07	2.33a±1.52	0.063ab±0.02	2.25ab±1.37	0.01b±0.01
SBP 3%	34.05ab±0.77	0.33b±0.58	0.036bc±0.01	1.19b±0.52	0.04ab±0.04
SBP 6%	36.30a±2.95	1.66ab±0.57	0.033c±0.01	1.29ab±0.29	0.02b±0.00
SBP 9%	37.16a±3.37	2.00ab±0.00	0.046bc±0.01	1.67ab±0.23	0.02b±0.00
LSD at 5%	3.698	1.872	0.029	1.165	0.046

Means ± (SD) followed by different superscripts within columns significantly different ($P \leq 0.05$)

4. Conclusion

The present study was undertaken to see the potential of WG and SBP in enhancing the nutritional and physical characteristics of biscuits. The results revealed that WG exhibited significantly higher protein, fat, ash and fiber contents, whereas SBP was found to be high in mineral and fiber contents compared to WF. As a result, WG and SBP biscuits contained more nutrients compared to the control biscuit. The increased level of WG and SBP in the blends led to a darker color and negatively affected the appearance of the biscuits. On the other hand, the physical properties of the biscuits were enhanced with the increase in the spread factor. WF substitution with WG and SBP in the biscuit formulation proposed in this study can be an example of successful collaboration between research and confectionery product trends. Therefore, 25% WG and 6% SBP are highly recommended to be incorporated into the WF biscuit formulation. Thus, these biscuits offer more nutritious and healthy alternatives to consumers with reasonable acceptance. It might be beneficial to further study how the storage duration and conditions will affect the quality characteristics of WG and SBP fortified biscuits or a related bakery product.

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