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Substituting wheat flour with okara flour in biscuit production

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Abstract:
Introduction. High fiber bakery products can be a healthy snack option for consumers. Our study focused on the effect of replacing wheat flour with okara flour on the physicochemical, nutritional, textural, and sensory attributes of biscuits.
Study objects and methods. We used 2, 4, 6, and 8% w/w okara flour to prepare biscuits. Refined wheat flour (control), mixed flour (okara and wheat flour), dough, and biscuits were assessed for physicochemical, textural, and nutritional properties, as well as sensory characteristics. The volume of particles was higher in 8% okara flour (145 μm) compared to refined wheat flour (91 μm).
Results and discussion. 2, 4, 6, and 8% w/w okara flour biscuits showed significantly ($P \leq 0.05$) lower spread ratio and weight loss than biscuits from wheat flour. Hardness, stickiness, and cohesiveness of 2, 4, 6, and 8% okara flour dough were significantly ($P \leq 0.05$) lower compared to the control, resulting in decreased cutting strength and increased hardness of okara flour biscuits. Moisture, protein, ash, fat, and crude fiber contents of 2, 4, 6, and 8% okara biscuits were significantly ($P \leq 0.05$) higher compared to the control biscuits. The sensory evaluation suggested that 4% okara biscuits had higher consumer acceptability and were superior to the control and other okara biscuits.
Conclusion. Mixed flour biscuits made from okara and wheat flours were superior in physicochemical, nutritional, textural, and sensory attributes, which allows considering them as an alternative healthy snack.

Keywords: Flour, dough, particle size, texture, biscuits, nutrient content, sensory evaluation

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INTRODUCTION

Biscuit is a popular, versatile bakery item consumed by all levels of society worldwide due to its taste, affordability, convenience, and an extended shelf life [1]. Biscuits, or cookies, are usually low in fiber, vitamins or minerals, and are highly calorific [2]. Thus, they cannot be added to the group of healthy foods. However, consumers are seriously concerned about their health issues. For this reason, bakery products with a high fiber content may be a choice for health-conscious people. Biscuits have good consumer acceptance, just as snacks do, and a long shelf life. Therefore, there is scope for nutritional development and fortification [3].

Okara is a pulpy, fiber-rich by-product of tofu and soy milk processing. Soy okara is a rich source of fiber [4]. It is composed of cellulose, hemicellulose, and lignin, as well as protein, lipids, vitamins, phytochemicals, and phytosterols [5, 6]. According to Grizotto *et al.*, one ton of processed soybeans could produce about two tons of okara following soymilk production [7]. As a result, every year enormous quantities of okara create disposal problems. To solve them, okara may be used as a dietary additive. It can further be processed to convenient and useful forms such as powders or extrudates [8]. It can be used directly in soups or salads. In addition, we can now find many online recipes where freshly produced okara is used as a raw ingredient.

However, it is hard to find an industrial product of soy okara because of its high moisture content (around 85 g) and poor textural quality that may cause rapid deterioration [5]. Some possible applications of okara might include baked goods, beef patties, and coconut cookies due to its high amount of fiber and protein [8, 9]. Dietary fiber is a significant component in bakery products, confectionery, meat, beverage, and dairy items [8]. However, supplementing baked products with dietary fiber may change the flavor, texture, and taste of final products [3].

A number of studies have shown the application of okara flour in tortillas, cookies, roti and parata, and even in breakfast cereals [8, 10–12]. The use of okara as a gluten free all-purpose flour may add further value to this agro waste and bring significant nutritional benefits.

Our study aimed to identify the effect of okara flour on the properties and nutritional composition of biscuits.

STUDY OBJECTS AND METHODS

Soybeans and refined wheat flour were collected from K-R Market (Mymensingh, Bangladesh). Sodium-bi-carbonate (food grade) was supplied by Mitali Scientific Co. Ltd., Bangladesh.

Whole soybeans were soaked in a 0.5% $NaHCO_3$ solution (1:2) at 60°C for four hours in a water bath (Schufzart, Membart GmBH+ Co., Büchenbach, Germany). The water was discarded and the soaked beans were dehulled before grinding to remove unwanted substances using a dehuller. The hydrated soybeans were blanched at 90 ± 2°C for 10 min with the addition of 0.5% $NaHCO_3$ (w/v), and the solution was drained well. The beans were washed with potable water for three times [13]. The blanched beans were ground with the addition of hot water (100°C) [bean to water ratio = 1:4] using a super mass collider (Masuko Sangyo Co. Ltd., Kawaguchi, Japan).

Soy okara was collected after soy milk extraction by filtering through double layers of cheese cloth. Soy okara was dried in a cabinet drier (Dayton Electric MFG. Co. Ltd., USA) at 60°C for 24 h and ground using a grinder. The ground okara was sieved (420-micron mesh size) and kept in a desiccator to reduce the moisture content by up to 5% [11]. The powder was finally placed in a sealed polyethylene-laminated aluminum foil bag and kept at –20°C before analysis and further processing.

Moisture, protein, ash, and fat contents of soy okara flour, refined wheat flour, and biscuits were determined according to the AOAC method [14]. Genistein was determined by the HPLC method as modified by [15].

Particle size was measured according to [16]. Average particle sizes (d3,2 – surface-weighted mean diameter, Sauter mean diameter and d4,3 – volume-weighted mean diameter, De Brouckere mean diameter) of refined wheat flour, as well as 2, 4, 6 and 8% soy okara flour were determined using a particle size analyzer (Malvern Zetasizer Nano ZS, UK) with the attachment of dry feed.

Refined wheat flour (RWF), okara flour, and other ingredients were weighed according to Table 1 and mixed together. Fat was mixed with the ingredients and water was added to the mixer to form dough. The dough was kneaded, rolled to uniform thickness (5 mm) and cut in round shape biscuits of 4 cm in diameter. They were baked at 220°C for 10 min and cooled at room temperature. The biscuits were packed in HDPE and kept in desiccators for further analysis.

The spread ratio, an essential quality parameter of biscuits, was determined as follows:

$$\text{Spread ratio} = D / T$$

where D is the average diameter and T is the average thickness of biscuits after baking, cm.

Weight loss (WL) of biscuits during baking was calculated by the following formula [17]:

$$WL = (W_{dough} - W_{biscuit}) / W_{dough} \times 100$$

where W_{dough} is the weight before baking and $W_{biscuit}$ is the weight after baking five samples, g.

The doughs made from different amounts of soy okara flour (2, 4, 6, and 8%) and only refined wheat flour (control) were tested for firmness by a penetration test. The dough was placed in a concentric cylinder (30 mm in diameter) under a cylindrical probe (5 mm) (Stable Micro Systems, UK). The test conditions included 2 mm/s pretest speed, 3 mm/s test speed, 10 mm/s post-test speed, 50 kg load, and 60% strain. When the probe penetrated 60% of the dough, it was found to gain its original position. The absolute peak force of the force-time curve was taken as dough firmness [18]. Each dough was tested three times.

Dough strength, adhesion, and stickiness tests were carried out using an SMS/Chen-Hosney Stickiness Cell and Prespex cylinder probe (25 mm) (Stable Micro Systems, UK). The test conditions included 2 mm/s pretest speed, 2 mm/s test speed, 10 mm/s post-test speed, 40 g trigger force, 3 mm return distance, and 10 s contact time [19–21]. The positive peak constraint from the curve was considered as stickiness force. The area falling under this force-distance curve indicates the work of adhesion. The distance of sample extension

Table 1 Basic formulation for preparation of biscuits (on 100 g flour basis)

Ingredients, g	Samples				
	Control (wheat flour)	Experimental (with okara flour)			
Wheat flour	100	98	96	94	92
Okara flour	–	2	4	6	8
Sugar	50	50	50	50	50
Oil	40	40	40	40	40
Baking powder	1.5	1.5	1.5	1.5	1.5
Milk powder	5	5	5	5	5
Salt	0.5	0.5	0.5	0.5	0.5
Egg	45	45	45	45	45
Ammonium bicarbonate	0.5	0.5	0.5	0.5	0.5

during prove return was considered as dough strength or cohesiveness [18].

The three-point bending test was carried out employing a 3-point bending rig (Stable Micro Systems, UK) connected to a texture analyzer. The test conditions included 10 mm/s pretest speed, 1 mm/s test speed, 10 mm/s post-test speed, 10 mm distance, and 50 kg load cell; descending development was continued till the biscuits broke. The most extreme constraint was recorded as the "hardness" of the biscuits [22].

The cutting strength of biscuits was measured using an HDP/BS blade-type texture analyzer (Stable Micro Systems, UK). The biscuits were set on the platform, and the blade was connected to the crosshead of the instruments. The test conditions included 2 mm/s pretest speed, 2 mm/s test speed, 10 mm/s post-test speed, and 5 mm distance. The outright peak force of the curve was recognized as the cutting strength of the biscuits [18, 21]. Textural properties of the dough and biscuits were determined by a TA-XT plus texture analyzer (Stable Micro Systems, UK) with Texture ExpertTM software.

The color of biscuits was analyzed by a colorimeter (Chroma Meter CR400, Konica Minolta, Japan) under illuminant: *C, D65 and space: LAB. It was determined in *L**, *a** and *b** system, where *L** is lightness (100: white, 0: black), *a** is redness (+)/greenness (–), and *b** indicates yellowness (+)/blueness (–). All analyses were performed in triplicate.

The sensory evaluation of the control and experimental samples included color, texture, flavor, and overall acceptability by ten semi-trained panelists on a 9-point hedonic scale (9 = like extremely, 8 = like very much, 7= like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much and 1 = dislike extremely). The results were evaluated by analyses of variance (ANOVA) and Duncan's new multiple range test (DMRT) of the Statistical Analysis System (SAS).

The physicochemical, nutritional, and textural properties were determined in replicate and statistically analyzed by a two-way ANOVA using the Microsoft Excell-2010.

Table 2 Chemical composition of okara and refined wheat flour (RWF)

Components	Okara flour	Refined wheat flour
Moisture, %	13.75[a] ± 1.25	12.65[a] ± 1.50
Protein, %	35.14[a] ± 2.00	13.00[b] ± 1.90
Fat, %	10.78[a] ± 1.40	1.80[b] ± 1.00
Ash, %	3.95[a] ± 0.50	1.47[b] ± 0.25
Crude fiber, %	30.01[a] ± 2.25	3.23[b] ± 0.50
Genistein, mg/100 g of okara flour	5.05 ± 0.50	nd

Mean ± SD represents the average of three replicates for each analysis
Different letters in the same row show significant differences ($P < 0.05$)
nd = not determined

RESULTS AND DISCUSSION

Table 2 shows the nutritional composition of okara and refined wheat flour (RWF). Okara flour had significantly higher contents of protein, fat, ash, and crude fiber compared to wheat flour. However, when making biscuits, it is important to add wheat flour as it contains gluten, which makes the dough adhesive and cohesive. Yet, gluten is also responsible for celiac diseases [23]. In our study, we substituted 2, 4, 6, and 8% of wheat flour with the same quantities of gluten-free okara flour.

Figure 1 illustrates the distribution of particle sizes in the mixed flour (2, 4, 6, and 8% okara flour mixed with wheat flour) and control flour (RWF). We identified two distinct peaks for all mixed flour samples, whereas the first peak in the control was not as distinct, showing that the particle size distribution of all flours was bimodal. The results were in agreement with [16] and [24]. We also found the maximum particle size to be ~ 100 μm, indicating a higher volume. The particle sizes for both the experimental and control samples ranged from 0.1 to 100 μm, but the volume of particles was the highest at ~ 145 μm and 91 μm, respectively. The results indicated that refined wheat flour had lower protein and fiber contents [25]. Hard dough prepared with finer particle-size flour has higher density, resulting in less developed biscuits during baking [26]. Thus, coarser, mixed or composite, flour is most desirable for preparing hard dough biscuits.

The mean volume diameter and the surface mean diameter of refined wheat flour (70.05 and 27.5 μm, respectively) were significantly ($P < 0.05$) smaller than those of all mixed flour samples (83.7 and 32.8 μm, respectively). There was no significant difference among 2, 4, 6, and 8% okara flour samples ($P > 0.05$). The flour particle size often affects the biscuits' water absorption capacity, density, and spread ratio. When fine particle-

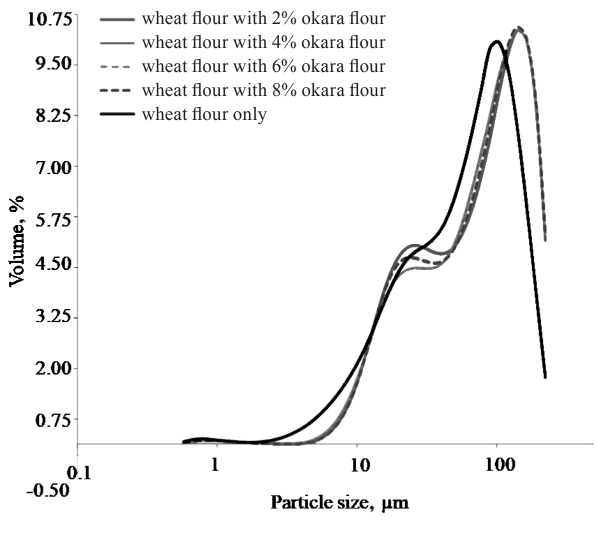

Figure 1 Particle size of refined wheat flour and wheat flour mixed with okara flour

Table 3 Effect of okara flour on physical properties of biscuits

Biscuits	Weight, g	Diameter (D), cm	Thickness (T), cm	Spread ratio (D/T)	Weight loss, %
Control (refined wheat flour)	4.95^b ± 0.40	4.62^a ± 0.32	0.62^e ± 0.06	7.45^a ± 0.80	11.46^a ± 0.35
2% okara flour	5.94^a ± 0.50	4.58^b ± 0.50	0.63^d ± 0.05	7.27^b ± 0.70	10.01^b ± 0.55
4% okara flour	5.95^a ± 0.35	4.56^c ± 0.42	0.64^c ± 0.02	7.13^c ± 0.50	10.03^b ± 0.50
6% okara flour	5.94^a ± 0.70	4.55^c ± 0.45	0.65^b ± 0.01	7.00^d ± 0.90	10.01^b ± 0.65
8% okara flour	5.93^a ± 0.55	4.53^d ± 0.60	0.66^a ± 0.01	6.86^e ± 0.80	10.09^b ± 0.75

Mean ± SD represents the average of five replicates for each analysis
Different letters in the same column indicate significant difference ($P < 0.05$)

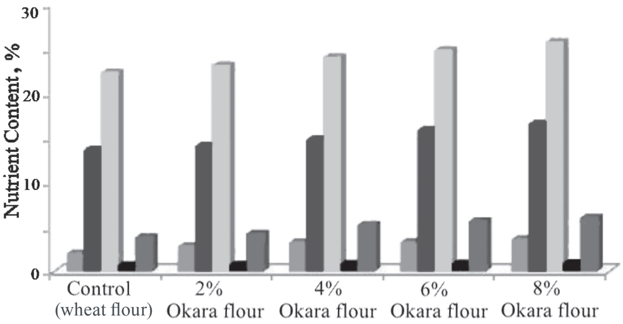

Figure 2 Nutritional components of biscuits from wheat flour and okara flour-enriched biscuits

size flour is used for hard dough biscuits, it usually results in higher density and less effective baking properties [26]. Therefore, coarser composite flour is more desirable.

The weight of okara flour biscuits was higher than that of biscuits prepared with only refined wheat flour (control). The biscuits prepared with coarser 2, 4, 6, and 8% okara flour mixes had a significantly ($P < 0.05$) higher thickness and a smaller diameter than the control (RWF) biscuits (Table 3) due to higher development during baking [26]. As a result, they had a reduced spread ratio compared to the control. The spread ratio correlates with texture, grain fineness, bite, and overall mouth feel of the biscuits [27]. Additionally, using flour high in protein and fiber in place of wheat flour provides a reduced spread ratio [28].

Among the experimental biscuits, 8% okara samples had a smaller diameter and a lower spread ratio compared to the others (Table 3). This might be due to comparatively higher protein and fiber contents in 8% okara biscuits. Further, mixed flour biscuits showed a significant ($P < 0.05$) reduction in weight loss compared to biscuits from wheat flour (Table 3). However, there was no significant difference ($P > 0.05$) in weight loss among 2, 4, 6, and 8% okara flour biscuits. The lower weight loss in the experimental biscuits might be due to better water absorption by the flour components due to protein hydration, with less water evaporated during baking [17].

Moisture, ash, protein, and fat contents in the biscuits prepared with okara flour were higher than those in the biscuits from control flour (RWF) (Fig. 2). Among mixed flours, 8% okara flour provided significantly ($P \leq 0.05$) higher nutrient contents compared to the others. The biscuits made with 8% okara flour had a higher moisture content than the control or the other mixed-flour samples due to a greater volume of water required at the time of dough making for its high fiber and protein contents.

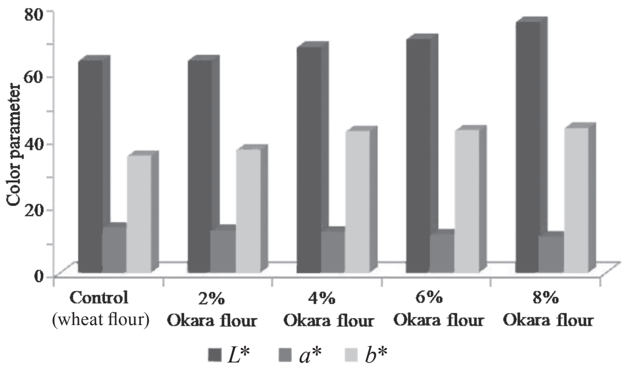

Figure 3 Color parameters of biscuits from wheat flour and okara flour-enriched biscuits

Table 4 Textural properties of dough and biscuits from refined wheat flour and okara flour

Samples	Dough				Biscuits	
	Firmness, N	Stickiness, N	Work of adhesion (N-S)×10^{-3}	Dough strength, mm	Cutting strength, N	Hardness, N
Control (refined wheat flour)	4.45^a ± 0.05	0.28^a ± 0.05	5.20^a ± 0.5	0.65^a ± 0.10	64.94^a ± 2.00	15.20^c ± 19.05
2% okara flour	3.90^b ± 0.09	0.21^b ± 0.07	4.75^b ± 0.3	0.54^b ± 0.09	55.75^b ± 1.75	17.55^b ± 1.55
4% okara flour	3.79^c ± 0.07	0.18^b ± 0.05	4.50^c ± 0.4	0.50^b ± 0.01	52.55^b ± 1.55	18.10^b ± 1.25
6% okara flour	3.66^{cd} ± 0.05	0.16^b ± 0.03	4.25^c ± 0.1	0.40^c ± 0.03	43.90^c ± 2.50	18.76^a ± 2.00
8% okara flour	3.45^d ± 0.04	0.14^b ± 0.05	3.50^d ± 0.7	0.35^c ± 0.05	40.35^{cd} ± 2.75	19.05^a ± 2.05

Mean ± SD represents the average of five replicates for each analysis
Different letters in the same column indicate significant difference ($P < 0.05$)

Table 5 Sensory characteristics of biscuits from refined wheat flour and okara-enriched biscuits

Biscuits	Sensory parameters			
	Color	Flavor	Texture	Overall acceptability
Control (refined wheat flour)	$6.93^{b} \pm 0.50$	$6.73^{b} \pm 0.65$	$6.47^{b} \pm 0.85$	$6.60^{b} \pm 0.80$
2% okara flour	$6.33^{b} \pm 0.43$	$6.20^{c} \pm 0.50$	$5.94^{bc} \pm 0.69$	$6.47^{b} \pm 0.45$
4% okara flour	$7.20^{a} \pm 0.72$	$7.20^{a} \pm 0.75$	$6.93^{a} \pm 0.95$	$7.33^{a} \pm 0.75$
6% okara flour	$6.00^{b} \pm 0.660$	$6.53^{bc} \pm 0.95$	$5.73^{c} \pm 0.99$	$6.33^{b} \pm 0.95$
8% okara flour	$6.00^{b} \pm 0.85$	$6.27^{c} \pm 0.55$	$5.67^{c} \pm 0.45$	$6.13^{b} \pm 1.20$
LSD	0.577	0.447	0.566	0.574

Mean ± SD represents the average of five replicates for each analysis
Different letters in the same column indicate significant difference ($P < 0.05$)

Flours rich in protein require much water to make machinable dough as protein is not sufficiently hydrated to form a network [29].

Dough firmness, strength (cohesiveness), and stickiness were significantly lower in 2, 4, 6, and 8% okara flour samples compared to the control (wheat flour only) (Table 4). Decreased dough firmness is usually related to a high fat content in formulations. This disrupts the development of a gluten network by lubricating the complete matrix and making it hydrated [17, 30]. Okara flour is gluten-free, which also accounted for lower firmness in mixed flour dough compared to dough made from wheat flour only. Stickiness is a significant parameter of dough quality as it affects the handling convenience and may damage the apparatus [31]. Okara flour dough showed lower stickiness compared to the control, owing to a higher water absorption ability. Lower stickiness and adhesion of okara dough correlate with a greater water absorption capacity, a comparatively low gluten content, and a higher fat content [16].

The three-point bending test showed significantly lower ($P \leq 0.05$) hardness for 2, 4, 6, and 8% okara flour biscuits compared to wheat biscuits (Table 4). This was due to a high protein content and a better water absorption capacity in the mixed flour. 8% okara flour biscuits seemed harder than those with 2, 4, and 6% okara flour due to a lower gluten content compared to the control and the other mixed flours.

There was a significant ($P < 0.05$) difference for all five types of biscuits in terms of color (Fig. 3). The L^* value of all composite flour biscuits was lower than that in the refined wheat flour biscuits due to the presence of natural anti-browning substance such as genistein in okara flour [32]. In particular, its genistein content was 5.05 ± 0.5 mg/100 g of okara flour (Table 2). 8% okara flour had the highest L^* value, indicating less brown pigment formation. The result suggested that okara flour could reduce brown pigments. We observed high positive a^* values (redness) for 2, 4, 6 and 8% okara flour biscuits. Positive b^* values (yellowness) were significantly ($P < 0.05$) higher in mixed flour biscuits compared to the control due to the presence of phytochemicals and crude fiber in okara flour [11].

The results of sensory evaluation of biscuits enriched with okara flour and control biscuits are shown in Table 5. The sample with 4% okara flour showed the finest sensory characteristics in terms of color, texture, flavor, and overall acceptability. However, the other samples were also found acceptable. A DMRT analysis revealed that 4% okara biscuits were significantly better in color, texture, flavor, and overall acceptability than other biscuits containing 2, 6, and 8% okara flour. However, increasing the amount of okara flour decreased the level of overall acceptability.

CONCLUSION

Biscuits prepared from mixed okara (2, 4, 6, and 8%) and refined wheat flour were found to outperform refined wheat flour biscuits in physicochemical, nutritional, textural, and sensory attributes. Okara flour biscuits had an inferior spread ratio, but higher fiber and protein contents. We also found them to have poor cutting strength and greater hardness. Okara flour biscuits had better color due to the presence of genistein. 4% okara biscuits had higher consumer acceptability on a 9-point hedonic scale. Decreased dough hardness due to okara flour diminished the cutting strength and increased hardness in the corresponding biscuits. Thus, we can conclude that biscuits prepared from okara flour can be considered as a healthy snack option.

CONTRIBUTIONS

Md. A. R. Mazumder and Thottiam V. Ranganathan conceptualized and supervised the work. Anjuman A. Begum and Md. F. Jubayer were involved in manuscript writing and data analysis. Md. A. Momin and Asmaul H. Nupur performed laboratory experiments and data collection.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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