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Utilization of broken rice and sweet potato flour to produce gluten-free snacks

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Abstract

The current investigation aimed to prepare gluten-free snacks using broken rice and sweet potato composite flour with ratio of 10, 20 and 30 % from broken rice flour. The prepared snacks were evaluated based on physicochemical properties as well as sensory evaluation. While, 30% substitution level exhibited the highest concentrations of fiber and ash contents, a significant reduction in caloric value was observed. The addition of sweet potato showed the most reduction in physical properties at level of 30% especially hardness. The color analysis revealed a pronounced decrease in L-value and an increase in a-value were found with increase of sweet potato ratio. The most acceptable sensory attributes (color and texture as well as overall acceptability) snacks were recorded in sweet potato samples compared with prepared from broken rice especially at 10 % level.

Keywords: Gluten-free, Snacks, Sweet potato, Broken rice, Physicochemical.

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1. Introduction

When particular wheat proteins and related proteins found in rye and barley are consumed, a state known as celiac disease (CD) develops. This syndrome is characterized by damage to the small intestine's mucosa [1]. Many goods, including breads, breakfast cereals, crackers, pastas, pretzels, and snacks, use wheat as their primary constituent. The largest problem for those with (CD) is definitely avoiding wheat [2]. A lifetime gluten-free diet is a necessary component of effective (CD) treatment. Therefore, it's crucial to offer a variety of wholesome and nutritional goods to (CD) sufferers. The Visco-elastic characteristics and cohesive dough formation of bakery items are however dependent on gluten, making their production difficult [3]. The bakery products are preferred by all age's consumers due to its low-price cost, long shelf-life, ready to use and variety of taste and flavor. Additionally, snacks could be used as a delivery system for vital nutrients to be given to (CD) patients who need more nutrients than what is recommended for them daily because of intestinal impairment [4-5]. During rice milling several by-products are generated such as broken rice and flour which considered as promising ingredients in different food products like snacks and ready-to-eat breakfast cereals. The loss of rice reaches to about 8.16-28.50% in Egypt and the breakage percentage increase with extended of storage. Additionally, the amount of moisture in the rice grain played a significant role in enhancing breakage [6-7].

Additionally, some rice products with little commercial value, like cracked and chalky grains, could have a considerable improvement if they could be used in the production of food. The main source of carbohydrates after rice is corn, cassava and the sweet potato (Ipomoea batatas L.) comes in the fourth stage. Although it is now thought that this crop has little commercial worth, it is very important socially. Although it is most frequently used as a snack food, many other countries utilize it as a staple diet or as a substitute for broken rice. Due to its quick maturity, adaptability to environmental and climacteric conditions and capacity to grow on less fertile soils, the sweet potato has a significant potential for use as food in poor countries with limited resources [8]. The flesh of a sweet potato might be creamy, creamy white, yellow, orange, or purple. The most popular colors to cultivate and consume are orange, white, and creamy [9]. While sweet potato characterized with high content of carbohydrates and the leaves are rich in fiber, antioxidant constituents, minerals such as sodium, potassium, zinc, iron etc., it had low concentrations of fat and protein [10]. The current study aimed to make gluten-free broken rice snacks by substituting with sweet potato flour and broken rice flour with levels of 10,20 and 30% and the prepared snacks were subjected to physicochemical analysis and sensory evaluation.

2. Materials and Methods

2.1. Materials

The broken rice was provided by Egyptian rice mill in Zagazig, Egypt during 2022-2023 and the baking ingredients as well as sweet potato were purchased from local market. All the chemicals and solvents used in the present study were of analytical grade.

2.2. Methods

2.2.1. Sweet potato and broken rice Preparation

Sweet potato samples, which have orange flesh, were cleaned and manually cut into thin slices using a knife. Slices were submerged in sodium meta-bisulphite (2000 ppm) and solution of citric acid (0.5%) for 1-2 minutes [11]. Slices of sweet potato were dried for 12 hours at 45–50 ˚C. The dried pieces were ground into flour and powdered using sieving. After that, the flour was placed in polyethylene bags and maintained at -20 ˚C for additional testing. After soaking, dried broken rice grains were used to make broken rice flour (*Oryza sativa L)* using the dry milling method [12]. The rice grains were repeatedly washed, soaked in water for one hour, and then dried at 45 to 50ºC for six hours in a tray dryer until a crack appeared in the grains. A flour mill (Saral Systems, Ahmedabad) was used for milling. To obtain finer flour, the resulting flour was sieved. It was then placed in polyethylene bags and stored at -20 °C for additional analysis.

2.2. Preparation of gluten free blends different composite flour

Samples were prepared by partially substituting of broken rice flour (BRF) by different ratios (10, 20 and 30%) of sweet potato flour to prepare different blend samples which used in preparation of gluten free snacks samples.

2.3. Preparation of snacks using broken rice and sweet potato flour

With a few minor tweaks, snacks were made using Jan et al., (2016) technique [13]. A mixer (5K5SS Kitchen Aid, USA) was used to whip up the butter (64 g) and icing sugar (40 g) until they were frothy. Different mixes of broken rice flour, sweet potato flour, salt, and CMC (1%), along with water, were combined for three minutes. After being worked, the dough was sheeted to a consistent thickness of 0.5 cm and then cut into a circle with a 6 cm diameter. For 10 minutes, snacks were baked at 180˚C. Before further analysis, the snacks were allowed to cool for two hours at room temperature.

2.4. Proximate analysis of investigated flours

Broken rice and sweet potato flour were analyzed for moisture, protein, and ash, fat as well as crude fiber according to the methods of AOAC (2012) [14]. Total carbohydrate was calculated by difference.

2.5. Physical characteristics of prepared snacks

Quality of gluten-free baking weight (g), thickness (cm), diameter (cm), volume (cm^3), specific volume (cm^3/g), and spread ratio of snacks were measured according to Gaines (1991) guidelines [15]. For the evaluation, three snacks were placed edge to edge, and the average was recorded. A Vernier Calliper was used to measure the diameter and thickness. The following calculation was used to get the spread ratio from the diameter to thickness ratio: Spread ratio is calculated as diameter divided by thickness.

2.6. Functional properties of broken rice and sweet potato flours

By employing the techniques recommended by Beuchat (1977), the water holding capacity and oil holding capacity of the samples were determined [16]. In a pre-weighed centrifuge tube, the flour or mix (1 g) were vortexed for 30 minutes with distilled water (10 mL). The sample were centrifuged for 25 min. at 3000 xg after 30 min. of standing at room temperature. After the supernatant had been completely removed, the sediments were weighed. The flour/blend (0.5 g) were homogenised with canola oil (5 mL) in a pre-weighed centrifuge tube and preceded as outlined for WHC in order to determine OHC. WHC and OHC calculated as follows:

$$\textbf{WHC or OHC (\%)} = W_2 - W_1 * 100 / W_0$$

Where;
W_0 is the weight of the sample.
W_1 is the weight of centrifuge tube plus sample.
W_2 is the weight of the centrifuge tube plus sediments.

2.7. Texture profile analysis of snacks

The hardness (N) of the samples was measured using a texture analyzer (Brookfield CT3 Texture Analyzer Operating Instructions Manual No. M08-372-C0113, Stable Micro Systems, USA) to determine the texture profile of sweet snacks Compression test conditions include the following: target of 5.0mm, hold time of 0s, trigger load of 5.00 N, test speed of 2.00mm/s, return speed of 2mm/s, number of cycles: 1, pretest speed of 2mm/s, probe TA-PFS-C, fixture TA-RT-KIT, and load cell 10000g.The experiments were carried out in natural settings.

2.8. Chemical analysis of snacks

Moisture, protein, ash, crude fat and crude fiber content were determined according to the method described in AOAC (2012) [14]. Available carbohydrates content of the sample was calculated by the difference as mentioned by Fraser and Holumes (1959) [17].

% Available carbohydrates (on wet basis) = 100 – (%Moisture, %Ash + %Fat +%Protein + %Fiber)

The approximate energy of snacks was calculated according to the (FAO/WHO, 1974) as follows:

Total energy (K. Cal/100g) = 4 (%carbohydrate +% protein) +9 (%fat)

2.8.1. Minerals contents

Minerals quantification of snacks was carried out by Atomic Absorption Spectrophotometer (type A Analyst 400, Perkin–Elmer, Waltham, MA, USA) after sample digestion with HCl as described by Gupta et al., (2011) [18].

2.8.2. Color measurement of snacks

Objective evaluation of snacks sample colors was measured by Hunter L*, a*, and b* parameters using a spectro-colorimeter (Tristim-ulus Color Machine) in accordance with Nabil et al., (2020) [19].

2.9. Sensory evaluation of snacks

Samples were assessed organoleptically for their sensory qualities. The ten panellists received water to rinse their hands in between sampling of snacks, which were placed on white, smell-free, disposable plates. Using Larmond' (1982) technique, samples were graded on their flavor, color, taste, texture, crispiness, and overall acceptability [20].

2.10. Statistical analysis

The obtained results were evaluated statistically using analysis of variance as reported by Mc-Clave and Benson (1991) [21].

3. Results and Discussion

3.1. Proximate chemical analysis of broken rice and sweet potato flours

Table 1 showed the proximate chemical analysis of broken rice and sweet potato flours which used in the preparation of gluten-free snacks in the present study. Ash, fat, and fiber concentrations were the highest in sweet potato flour (3.43, 1.84, and 8.76%) respectively. The amount of fat matched that of reported by Srivastava et al., (2012) [22]. Broken rice flour had the least amount of fat and fiber (0.43 and 0.11%), but the largest percentage of carbohydrates (90.91%). Our findings for broken rice flour were somewhat consistent with those of Dahab (2006) who mentioned that broken rice flour contains protein, crude fiber, ash and carbohydrates with concentrations of 7.68%, 0.27%, 0.36% and 90.81% respectively [23]. The flour generated from milled broken rice had 27% amylose as recorded by Cameron and Wang (2005) [24]. Sweet potato flour has a protein value of 3.87% and the sweet potato flour's carbohydrate content (91.90%) was comparable to Singh et al., (2008) and Ahmed et al., (2010) findings [25-26]. According to Taher-Maddah et al., (2012), the extent of foreign materials, impurities, varieties, different processing and measuring methods, and differences in cultivars and growing conditions (such as geographic, seasonal variations in climate and soil characteristics) may all contribute to the variation in chemical composition of flour Abd-Elmoneem et al., *(*2021) [27- 28]. The water and oil holding capacity are shown in Table 1, and it is obvious that sweet potato flour had the highest values with 173.09% WHC and 115.28% OHC, followed by broken rice flour with 168.13% WHC and 139.20% OHC, respectively. Eleazu and Ironua (2013) indicated that the range of the water holding capacity they had observed was from 149 to 471% [29]. According to Uthumporn et al., (2015), the high water-holding capacity of flour can be attributed to the hydroxyl groups of cellulose in fiber, which can form hydrogen bonds with free water molecules to increase their capacity to hold water [30]. Both red and white sweet potato flours had limited oil absorption capabilities, according to Osundahunsi et al., (2003) [31]. According to Omran and Hussien (2015), the physical trapping of oil and the binding of fat to the polar chain of protein are the key factors contributing to the mechanism of fat absorption [3].

3.2. Chemical composition of snacks

Initially, replacing broken rice flour with sweet potato flour reduced the contents of total protein and fat in the resulting snacks and decreased these contents by increasing the replacement percentage. The results of this study agree with those observed by Omran and Hussien (2015), Motawei et al., (2022) and Kumar *et al.*, (2023), when they replacing wheat flour with broken rice flour in baking products to produce gluten-free baking products [3,32-33]. Table 2 displays the findings of the nutritional analysis of prepared snacks from broken rice flour and sweet potato with different ratios. Because sweet potatoes have a high water-binding capacity and retain more moisture in their final products, the moisture content of snacks increased linearly as sweet potato concentration increased. The results for snacks moisture contents matched those from Singh et al., (2008) and Srivastava et al., (2012) [22,25]. The high fiber content was cited by Uthumporn et al., (2015) as the cause of the variance in moisture content between samples [30]. Due to the high ash concentration of sweet potatoes, the prepared snacks had significant ash content as the ratio sweet potato flour had increased. Our research supports the findings of Uthumporn et al., (2015) [30]. Based on the findings in Table 2, sweet potato-substituted snacks had significantly lower protein levels than control snacks (made entirely of broken rice flour). Our research results are in agreement with Uthumporn et al., (2015) [30]. Additionally, when sweet potato flour incorporation increased, the fat content somewhat decreased. The results of the proximate composition of snacks made with sweet potatoes are comparable to those of Srivastava et al., (2012) [22]. The higher fiber content of sweet potato flour caused significant increase in fiber dramatically as the ratio increased. According to Srivastava et al., (2012), fiber produces a feeling of fullness (having an appetite entirely fulfilled) since it absorbs a lot of water [22]. As the amount of sweet potato increased, there was a modest rise in carbohydrates. It has been discovered that adding sweet potato flour to snacks lowers their protein and fat levels. As the amount of sweet potato flour substituted increased, the ash contents also increased [34]. Energy of the snacks decreased as the percentage of sweet potato flour increases [35].

3.3. Minerals content of snacks

The data in Table 2 showed that there is increase in sodium content with the increase of sweet potato flour ratio which reached to 205.43 mg/100 g for snacks T_3 compared to T_0 which had 141.13 mg only. The obtained results confirmed by Ariyo et al., (2022) and Roger et al., (2022), who mentioned that all minerals had increased in the prepared cookies using sweet potato flour [36-37]. The maximum content of calcium was noticed in the snacks substituted with 30% of sweet potato flour and recorded 160.36mg/100g in comparison with T_0 (control) snacks which recorded 127.75 mg/100g. The prepared snacks had concentrations of 160.36mg/100 g and 33.12 mg/100g for phosphorus and manganese, respectively at the substitution level of 30% from sweet potato flour compared to 228.06 mg/100g and 11.34 mg/100g for the aforementioned minerals respectively (Table 2). The prepared snacks in the present study with high concentration of manganese was recommended for consumption.

This is due to the creation of sex hormones and the proper operation of the neurological system which correlated with high concentration of manganese. Magnesium plays a domestic role in body's metabolic processes, including those that preserve muscle, enhance neuronal function, keep the heart rate constant, and control blood sugar as mentioned by Dent and Selvaratnam (2022) [38]. The prepared snacks using sweet potato flour at ratio of 30% had magnesium concentration of 147.43mg/100g compared to control 137.0 mg/100g. The increase in potassium which considered as important mineral in reduce the blood pressure at level of 30% sweet potato flour (439.63 mg/100 g) may be due to its high content of potassium as reported by Badila et al., (2009) [39]. The consumption of snacks T_3 (30% SPF) would be a good source of copper with an intake of 0.98 mg/100g. Numerous enzymes and chemical processes involve copper in their operation. It is crucial for the myocardium's (the heart muscle's) correct operation and is involved in the oxidation of glucose. By influencing mood, sleep, memory, and attention, copper affects the quality of cartilage, the mineralization of bones, and the modulation of neurotransmitters. Additionally, iron metabolism and the immune system are also impacted by copper [40]. With an intake of 0.81 mg/100g, snacks T_3 (30% SPF) would be a decent source of copper.

3.4. Snacks prepared from broken rice and sweet potato flours color

Table 2 provides color measurements for samples of snacks made using broken rice and sweet potato flours. The L* value of the snacks drastically dropped from 67.77 to 48.20 as the amount of sweet potato flour was increased. The high ratio of sweet potato flour caused increase in the b* value which measures how yellow snacks are rose noticeably from 13.12 to 24.01. Our findings concur with those of Singh et al., (2008), and Saeed et al., (2012), who noted a similar pattern in color changes in the making of cookies incorporating sweet potato flour in varying quantities [25,41]. The carotenoid pigments in sweet potato snacks which impact the red-green chromaticity, are what give them their yellow-orange color [42]. Given that cooked sweet potatoes had a lower L value, it was expected that the snacks made with them would be darker. It is clear that control snacks had a substantially higher L* value than other snacks made with sweet potato. According to Uthumporn et al., (2015), the increase in the substitution level of fiber into the formulation was seen as the lightness of cookies decreased [30].

3.5. Physical analysis of snacks prepared from broken rice and sweet potato flours

The physical properties of bakery products analysis such as width, diameters, thickness *etc.*, is critical from view of both manufacturers and consumers. According to Table 3 findings, the width of snacks was significantly impacted by the amount of sweet potatoes flour used. With rising levels of sweet potato flour, a diminishing tendency was seen. Snacks with 30% sweet potato had a minimum diameter of 57.0 mm, whereas the control had a maximum diameter of 67.0 mm. It is evident that adding more sweet potato flour greatly reduced the diameter of the snacks. This may be explained by the fact that adding more sweet potato flour, which is a great source of dietary fiber, increased the amount of fiber in the cookies. The findings concur with those of Singh et al., (2008), and Saeed et al., (2012) [25,41]. With increasing percentages of sweet potato flour, the thickness of snacks dropped significantly from 5.80 to 6.25mm among treatments. Evidently, the thickness of snacks was greatly reduced when the amount of sweet potato flour was increased. These findings corroborate those of Singh et al. (2008), Srivastava et al., (2012), and Saeed et al. (2012), who noted that the thickness of cookies decreased with an increase in the percentage of sweet potato flour [22,25,41]. As the ratio of sweet potato flour was increased, the spread ratio of snacks decreased from 9.57 (treated) to 11.07 (control). These findings are consistent with those of Srivastava et al., (2012), Saeed et al., (2012), and Singh et al., (2008) [22,25,41]. The ability of flour to absorb water has been shown to have a substantial correlation with cookie spread [43]. Since sweet potato flour has a greater capacity to hold water than broken rice flour does, it is assumed that sweet potato flour will partition free water more quickly than wheat flour. Thus, it can be said that the use of sweet potato flour restricts the spreading of cookies. Table 3 demonstrates how the Specific volume of snacks reduced as the amount of sweet potatoes flour increased. The findings concur with those of Singh et al., (2008), who noted that the Specific volume of the sweet potato snacks decreased gradually and significantly [25]. Sweet potato's great ability to bind water made the snacks dough appear "dryer" than dough made just of broken rice flour. Due to the dough's inability to spread properly, the snacks were dense and undersized.

3.6. Texture profile of snacks

Due to its tight relationship with how people perceive freshness, hardness is the textural characteristic that receives the most attention when evaluating baked items [44]. More people are becoming aware of how important snacks texture is to consumer approval. The impact of SPF on the textural characteristics of gluten-free snacks made with broken rice flour is depicted in Table 4. Generally speaking, the softer the snacks, the lesser the hardness and chewiness. Potato snacks were much less hard and chewy than wheat and broken rice snacks ($P \leq 0.05$), although they were significantly more resilient ($P \leq 0.05$). The elasticity did not differ significantly. This outcome is in line with a prior study [45]. The mix of flour has a significant impact on how hard snacks are. Snacks made with sweet potato may have lost some of its hardness because the flour is possibly hydrophilic, which allowed it to absorb too much moisture and impair the hardness. The findings are consistent with those of Uysal et al., (2007), Toma et al., (2009), and Qaisrani et al., (2014), who shown that adding fiber to cookies makes them softer [46-48]. Rather than a protein/starch structure, starch gelatinization and super-cooled sugar are principally responsible for the texture of baked cookies [49]. This might be the cause of the snacks decreasing firmness as the sweet potato flour content rises. According to Seyhun et al., (2003), the re-crystallization of amylose and amylopectin, the development of complexes between starch and proteins, the redistribution of water among the product's constituent parts, as well as other possible occurrences in this baked good during storage, are all possible causes of the increased hardness [50].

Table 1: Proximate chemical analysis of broken rice and sweet potato flours.

	Broken rice flour (BRF)	Sweet potato flour (SPF)
Moisture	10.53±0.65[* b]	5.68±0.44 [c]
Crude protein	7.40±0.22 [b]	3.87±0.38 [c]
Crude lipids	0.43±0.04[c]	1.84±0.06 [a]
Total ash	0.55±0.05[b]	3.43±0.54 [a]
Crude fiber	0.11±0.01 [c]	8.76±0.96 [a]
Carbohydrates	90.51±1.86 [a]	82.10±2.04 [c]
WHC (%)	168.13±2.94 [b]	173.09±1.85 [a]
OHC (%)	139.21±3.14 [b]	115.28±3.42 [c]

*: Values are expressed as (mean ± SD).
WHC: water holding capacity; OHC: oil holding capacity.

Table 2: Snacks prepared from broken rice and sweet potato flours chemical composition and energy.

Sample	Moisture	Protein	Ash	Crude fiber	Fat	Total Carb.	Energy Kcal/100 g
T_0	2.95±0.09[c]	6.56±0.14[b]	0.89±0.02[d]	0.41±0.02[d]	24.89±0.14[b]	64.32±0.14[c]	507.49±0.24[a]
T_1	3.14±0.12[bc]	5.15±0.06[c]	0.94±0.07[c]	0.650.07±[c]	24.74±0.19±[bc]	65.40±0.12[a]	504.80±0.19[bc]
T_2	3.250.05±[b]	4.91±0.16[d]	1.02±0.09[b]	0.97±0.05[b]	24.69±0.14[c]	65.17±0.24[ab]	502.51±0.17[c]
T_3	3.56±0.17[ab]	4.50±0.08[e]	1.13±0.03[a]	1.14±0.06[a]	24.66±0.13[c]	65.03±0.13[b]	500.00±0.13[d]
LSD at 0.05	**0.226**	**0.272**	**0.061**	**0.141**	**0.179**	**0.424**	**1.504**
Minerals content (mg/100g)							
	Na	**Ca**	**P**	**K**	**Cu**	**Mn**	**Mg**
T_0	141.13±0.05[e]	127.75±0.08[e]	228.06±0.09[d]	190.44±0.09[d]	0.62±0.04[b]	11.34±0.04[d]	137.00±0.07[c]
T_1	162.74±0.07[c]	133.23±0.06[c]	239.09±0.12[c]	116.32±0.12[e]	0.50±0.03[c]	17.87±0.03[c]	139.54±0.02[c]
T_2	184.39±0.09[b]	145.28±0.03[b]	249.60±0.06[b]	226.18±0.17[c]	0.62±0.02[b]	23.54±0.06[b]	141.57±0.08[b]
T_3	205.43±0.04[a]	160.36±0.05[a]	261.47±0.07[a]	357.16±0.25[b]	0.85±0.07[ab]	33.12±0.07[a]	147.43±0.04[a]
LSD at 0.05	**7.524**	**4.235**	**3.856**	**12.25**	**0.092**	**2.124**	**2.458**
Color analysis							
	L		a		b		
T_0	67.77±0.12[a]		13.86±0.12[e]		13.12±0.14[e]		
T_1	57.73±0.24[c]		16.83±0.18[c]		17.80±0.17[c]		
T_2	51.56±0.19[d]		19.02±0.22[b]		19.50±0.12[b]		
T_3	48.20±0.16[e]		22.21±0.34[a]		24.01±0.15[a]		
LSD at 0.05	**2.901**		**1.860**		**1.897**		

T_0: snacks manufacture with 100 % broken rice flour.
T_1: snacks manufacture with 90 % broken rice flour + 10% sweet potato flour.
T_2: snacks manufacture with 80 % broken rice flour + 20% sweet potato flour.
T_3: snacks manufacture with70 % broken rice flour + 30% sweet potato flour.

Table 3: Physical analysis of snacks made from broken rice and sweet potato composite flours.

Sample	Weight(g)	Volume(cm^3)	Specific volume (cm^3.g)	Diameter(cm)	Thickness(cm)	Spread ratio
T_0	45.80±0.25^c	102±0.14^b	2.23±0.14^c	67.00±0.17^a	6.05±0.12^{ab}	11.07±0.12^a
T_1	46.25±0.19^c	125±0.37^a	2.71±0.12^b	65.00±0.26^a	6.02±0.17^{ab}	10.79±0.16^a
T_2	50.60±0.34^b	129±0.28^a	2.55±0.09^b	57.00±0.31^b	5.90±0.08^b	9.75±0.13^{bc}
T_3	57.65±.27^a	123±0.16^a	2.13±0.08^c	55.00±0.18^b	5.80±0.06^b	9.57±0.15^c
LSD at 0.05	**2.701**	**10.551**	**0.202**	**4.718**	**0.315**	**0.510**

T_0: snacks manufacture with 100 % broken rice flour.
T_1: snacks manufacture with 90 % broken rice flour + 10% sweet potato flour.
T_2: snacks manufacture with 80 % broken rice flour + 20% sweet potato flour.
T_3: snacks manufacture with70 % broken rice flour + 30% sweet potato flour.

Table 4: Texture profile of snacks made from broken rice and sweet potato composite flours.

Sample	Hardness (N)	Adhesiveness (g·cm)	Resilience	Springiness (mm)	Chewiness (g·cm)	Gumminess (N)
T_0	1.90±0.06^e	0.00^d	0.01±0.002^b	0.63±0.01^d	0.00^e	0.02±0.01^d
T_1	8.28±0.03^c	2.00±0.01^b	0.02±0.001^b	1.96±0.02^a	38.00±0.02^a	1.88±0.06^b
T_2	12.59±0.05^b	3.00±0.02^a	0.08±0.001^a	1.42±0.01^c	36.00±0.03^b	2.51±0.05^a
T_3	3.70±0.07^d	1.00±0.01^c	0.02±0.001^b	0.31±0.01^e	1.00±0.04^d	0.28±0.02^d
LSD at 0.05	1.04	0.04	0.03	0.09	1.014	0.62

T_0: snacks manufacture with 100 % broken rice flour.
T_1: snacks manufacture with 90 % broken rice flour + 10% sweet potato flour,
T_2: snacks manufacture with 80 % broken rice flour + 20% sweet potato flour.
T_3: snacks manufacture with70 % broken rice flour + 30% sweet potato flour.

Table 5: Sensory evaluation of snacks prepared from broken rice and sweet potato flours

Sample	Color (20)	Taste (20)	Texture (20)	Crispiness (20)	Flavor (20)	OAA (100)
T_0	16.30±0.13b^c	17.20±0.17^b	17.21±0.15^b	18.33±0.19^{ab}	18.66±0.14^a	87.70±0.24^b
T_1	18.66±0.19^a	18.60±0.28^a	18.50±0.12^{ab}	19.00±0.24^{ab}	18.90±0.19^a	93.66±0.19^a
T_2	17.65±0.34^{ab}	18.13±0.13^{ab}	16.20±0.17^c	17.00±0.36^{bc}	18.30±0.24^a	87.28±0.16^b
T_3	15.70±0.16^c	17.29±0.31^b	16.00±0.11^c	16.00±0.12^c	17.40±0.31^a	82.39±0.18^b
LSD at 0.05	**1.560**	**1.964**	**2.100**	**2.303**	**2.234**	**6.626**

T_0: snacks manufacture with 100 % broken rice flour.
T_1: snacks manufacture with 90 % broken rice flour + 10% sweet potato flour,
T_2: snacks manufacture with 80 % broken rice flour + 20% sweet potato flour.
T_3: snacks manufacture with70 % broken rice flour + 30% sweet potato flour
OAA: Overall acceptability

3.7. Sensory evaluation of snacks prepared from broken rice and sweet potato flours

In order to evaluate consumer products, the field of sensory evaluation applies techniques from statistical analysis as well as experimental design to human senses [51-55]. The sensory evaluation of snacks made with various amounts of sweet potato flour was compared to control snacks made with 100% broken rice flour (Table 5). Sweet potato snacks produced with broken rice flour had a softer, more tolerable texture than those made exclusively with broken rice flour only. According to the sensory score, sweet potatoes at a 10% replacement are the most palatable option in terms of overall acceptability, color, and texture. In sweet potato snacks, the flavor (taste and odor) score greatly improved. This might be due to common flavorings and the caramelization of free sugar during baking in sweet potato flour. These findings concur with those of Singh et al., (2008) and Srivastava et al., (2012), who used sweet potatoes to make cookies [22,25]. Additionally, the substitution of more sweet potato flour resulted in substantial changes in color, texture, flavor, and overall acceptance. However, it was discovered that the 40% optimum substitute level was the level at which consumers would find the product less acceptable [35].

4. Conclusion

The obtained results in the present investigation emphasize the importance of substituting broken rice flour with sweet potato flour during preparation ready-to eat snacks to improve the physicochemical properties as well as the sensory attributes especially at level of 10%. The higher level of substitution (20 and 30%) showed a remarkable effect on some physicochemical properties of freshly prepared snacks especially texture and color parameters. Therefore, the study will extend to evaluate these changes during storage under various conditions.

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