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The Effect of Okra Flour Addition on The Physicochemical Properties, Antioxidant Activity, and Sensory Quality of Mocaf-Based Snack Bars

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ABSTRACT: The research was conducted to determine the effect of okra flour addition on the physicochemical properties, antioxidant activity, and sensory quality of mocaf-based snack bars. A Completely Randomized Design (RAL) with five treatments (0%, 2.5%, 5%, 7.5%, and 10% w/w okra flour) and four replications was employed. Physicochemical properties evaluated included dietary fiber content, moisture content, water activity, bulk density, color, and texture, and antioxidant activity and sensory quality were also determined. Dietary fiber content and antioxidant activity were analyzed descriptively. Moisture content, water activity, bulk density, color, and texture were analyzed using Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test, whereas sensory quality was analyzed using the Kruskal–Wallis test followed by the Mann–Whitney test. The results showed that okra flour addition significantly affected ($p < 0.05$) the physicochemical properties, antioxidant activity, and sensory quality of mocaf-based snack bars, except for bulk density. Increasing okra flour concentration increased dietary fiber content, hardness, and gumminess, while decreasing L*, a*, and b* values, fracturability, and hedonic scores for color, aroma, texture, taste, and overall acceptance. Antioxidant activity increased up to the 5% okra flour addition and tended to stabilize at higher concentrations. The addition of 10% okra flour resulted in the highest dietary fiber content, whereas the addition of 2.5% okra flour produced the most favorable antioxidant activity and sensory quality

1. INTRODUCTION

Modern lifestyles have increased consumption of convenient ready-to-eat foods, often accompanied by inadequate intake of dietary fiber, fruits, and vegetables. Such dietary patterns may increase the risk of degenerative diseases due to the accumulation of free radicals in the body. Therefore, demand is growing for practical food products that not only provide convenience but also offer health benefits as functional foods. Snack bars are widely recognized as convenient, ready-to-eat foods with a compact, dense texture and are commonly consumed as practical sources of energy [1]. In addition, snack bars have a relatively long shelf life and can be formulated with various nutritious ingredients, making them a promising vehicle for developing functional foods [2].

In recent years, non-wheat flours derived from local resources have gained increasing attention in snack bar development. However, most commercial snack bars still use wheat flour, resulting in heavy dependence on imported wheat and limiting their suitability for individuals with gluten intolerance [3]. One promising alternative is Modified Cassava Flour (Mocaf), a fermented cassava flour with physicochemical and functional properties comparable to wheat flour, including a neutral aroma, bright color,

and desirable textural characteristics [4]. In addition, Mocaf contains higher dietary fiber than wheat flour, making it a potential local gluten-free ingredient for developing healthier snack bar products [5].

Dietary fiber plays an important role in maintaining digestive health, regulating blood glucose levels, and reducing the risk of chronic diseases [6]. However, dietary fiber intake in Indonesia remains below the recommended level, highlighting the need to develop fiber-enriched food products. Okra *(Abelmoschus esculentus* (L.) Moench) is a vegetable rich in dietary fiber, phenolic compounds, and bioactive substances with strong antioxidant activity [7]. Compared with fresh okra, okra flour contains higher concentrations of phenolic compounds and exhibits stronger antioxidant activity, making it a promising functional ingredient for food product development [8]. Incorporating okra flour has also been reported to improve the nutritional value and physicochemical properties of gluten-free bakery products while maintaining acceptable sensory characteristics [9].

Several studies have incorporated functional ingredients, such as tofu by-product flour, banana flour, rice bran, spinach powder, and okra flour, into snack bars to improve their nutritional quality [10]. In addition, okra flour in various food products has been reported to improve physicochemical properties, dietary fiber content, antioxidant activity, and sensory characteristics [11]. Nevertheless, studies on okra flour in Mocaf-based snack bars remain limited, particularly regarding its combined effects on physicochemical properties, antioxidant activity, and sensory quality. Therefore, this research aimed to determine the effect of okra flour addition on the physicochemical properties, antioxidant activity, and sensory quality of Mocaf-based snack bars. The findings are expected to provide scientific evidence supporting the use of Mocaf and okra flour as local functional ingredients for developing nutritious gluten-free snack bar products.

2. MATERIALS AND METHODS

2.1 Snack Bar Samples

Snack bars were prepared using Modified Cassava Flour (MOCAF) (Ladang Lima), okra flour (produced from fresh okra through drying and milling), granulated sugar (Gulaku), margarine (Blue Band), eggs, milk powder, honey, and vanilla (Koepo-Koepo). The formulation was based on Zaddana et al. [12], with modifications. Five treatments were prepared based on different concentrations of okra flour, including T0 (0%), T1 (2.5%), T2 (5%), T3 (7.5%), and T4 (10%) (w/w

2.2 Preparation of Okra Flour

Okra flour was prepared according to Nugroho and Hariono [13] with modifications. Fresh okra pods were sorted, washed, and sliced into approximately 1 cm thickness. The slices were soaked in a 0.5% citric acid solution for 5 min to prevent browning. The samples were then dried in a cabinet dryer at 70°C for 10 h. The dried okra was then ground and sieved using a Tyler sieve to obtain okra flour.

2.3 Determination of Dietary Fiber

Total dietary fiber was determined using the enzymatic-gravimetric method (AOAC, 1995). The sample was sequentially treated with α-amylase, protease, and amyloglucosidase to remove starch and protein components. The residue was then precipitated using ethanol, filtered, and dried to a constant weight. The final residue was corrected for protein and ash content to obtain total dietary fiber.

2.4 Determination of Total Moisture Content

The moisture content was determined using the oven-drying method according to AOAC (2000). Approximately 2 g of sample was placed in a pre-dried container and dried at 105°C until reaching a constant weight. Moisture content was determined based on the difference between the sample weight before and after drying.

2.5 Determination of Water Activity (a_w)

The water activity (a_w) was measured using a calibrated a_w meter following AOAC (2005). Place approximately 4 g of homogenized sample in the measurement chamber and record the value once it reaches equilibrium.

2.6 Determination of Bulk Density

Bulk density was determined based on the ratio of mass to volume [14]. The dimensions of the snack bar (length, width, and height) were measured using a caliper, and the volume was calculated. Bulk density was expressed as g/cm^3.

2.7 Determination of Color

Color intensity of the snack bar samples was determined according to Widiyani et al. [15], using a Chroma Meter (Konica Minolta CR-400, Japan). We calibrated the instrument with a standard white calibration plate before measurement. We placed each sample on the measurement platform and positioned the sensor perpendicular to the sample surface. We measured color in triplicate at three points on the sample surface to obtain average values for lightness (L*), redness-greenness (a*), and yellowness-blueness (b*).

2.8 Determination of Texture

Texture analysis was performed using a Texture Analyzer (Brookfield CT3) according to the method described by Kidnem et al. [16]. Texture Profile Analysis (TPA) was conducted using a trigger force of 30.0 g, a deformation distance of 8.0 mm, and a test speed of 1.00 mm/s. The hardness of the snack bar samples was recorded and expressed as gram-force (gf).

2.9 Determination of Bulk Density

Bulk density was determined based on the ratio of mass to volume [14]. The dimensions of the snack bar (length, width, and height) were measured using a caliper, and the volume was calculated. Bulk density was expressed as g/cm^3.

2.10 Determination of Antioxidant Activity

Antioxidant activity was determined using the DPPH free radical scavenging method, following Wattanakul et al. [17], with slight modifications. Snack bar samples were extracted using methanol (p.a.). The DPPH solution was prepared by dissolving 2,2-diphenyl-1-picrylhydrazyl (DPPH) reagent in methanol (p.a.), while ascorbic acid (vitamin C) was used as the standard. The sample extract and standard solution were mixed with the DPPH solution in aluminum foil-wrapped vials and incubated in the dark for 30 min. The absorbance was measured using a UV–Vis spectrophotometer at 517 nm, with methanol (p.a.) as the blank.

2.11 Hedonic Test

The hedonic test was conducted with 30 semi-trained panelists following a modified method of Sirajuddin et al. [18]. The panelists evaluated the color, aroma, taste, texture, and overall acceptability of the snack bar samples coded with random three-digit numbers. Consumer preference was assessed using a four-point hedonic scale ranging from 1 – 4.

2.12 Organoleptic Evaluation

Organoleptic evaluation used a scoring test with 30 untrained panelists to assess the color, aroma, texture, and taste of five snack bar samples corresponding to different treatments. Before evaluation, panelists received instructions on the evaluation procedures and scoring methods. Each sample was presented with reference samples to help standardize panelists perceptions during evaluation. Panelists evaluated each attribute using a four-point scale. The scale ranged from 1 to 4, representing increasing intensity levels: color (from not brownish-green to very brownish-green), aroma (from not langu to very langu), texture (from not hard to very hard), and taste (from not sweet to very sweet).

2.13 Statistical Analysis

We performed statistical analysis using IBM SPSS Statistics version 26.0. The experiment followed a Completely Randomized Design (RAL) with five treatments and four replications. We analyzed moisture content, water activity, bulk density, color, and texture data using one-way analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) at the 5% significance level. Dietary fiber content and antioxidant activity were analyzed descriptively. Sensory evaluation data were analyzed using the Kruskal–Wallis test, followed by the Mann–Whitney test when significant differences were observed.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Characteristics of Snack Bars

The physicochemical characteristics of mocaf-based snack bars with different levels of okra flour addition were evaluated, including dietary fiber content, moisture content, water activity, and bulk density. The results are presented in Table 1.

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Table 1. Physicochemical of Snack Bars (Dietary Fiber, Moisture Content, Water Activity, and Bulk Density) with the addition of Okra Flour

Parameter	T0 (0%)	T1 (2,5%)	T2 (5%)	T3 (7,5%)	T4 (10%)
Dietary Fiber Content	3,35 ± 0,03	4,48 ± 0,03	5,32 ± 0,00	5,89 ± 0,01	6,76 ± 0,12
Moisture Content	14,22 ± 1,58^{c}	11,59 ± 2,79^{b}	8,71 ± 0,61^{a}	8,80 ± 0,37^{a}	8,68 ± 0,83^{a}
Water Activity (a_w)	0,59 ± 0,01^{b}	0,56 ± 0,04^{b}	0,48 ± 0,02^{a}	0,46 ± 0,01^{a}	0,46 ± 0,02^{a}
Bulk Density (ns)	0,72 ± 0,10	0,79 ± 0,15	0,58 ± 0,01	0,61 ± 0,12	0,75 ± 0,10

Note: Data are presented as mean ± standard deviation. Values with different superscript lowercase letters in the same column indicate significant differences ($p < 0.05$). ns = not significant. T0, T1, T2, T3, and T4 represent snack bars with okra flour concentrations of 0%, 2.5%, 5%, 7.5%, and 10%, respectively.

Dietary Fiber

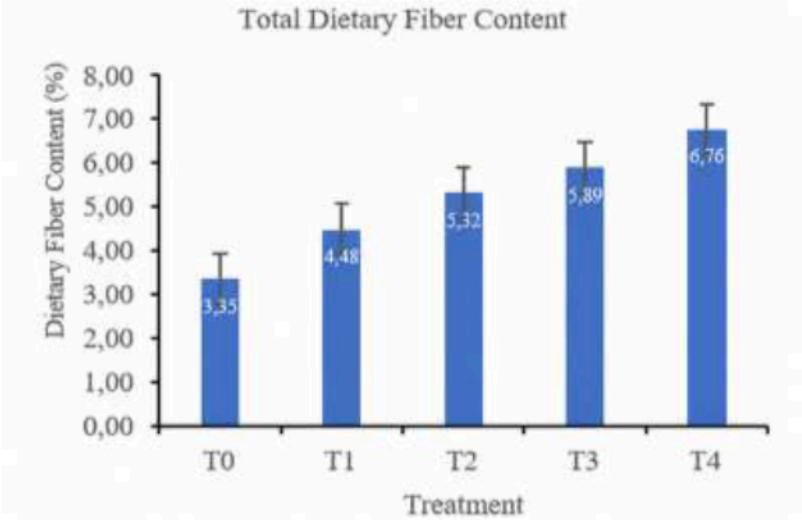


Figure 1. Dietary fiber content in snack bars with the addition of Okra flour

Dietary fiber content represents the total amount of indigestible components, including both soluble and insoluble fiber fractions in food products. Figure 1 and Table 1 present the dietary fiber analysis results for mocaf-based snack bars with added okra flour. The results showed a consistent increase in dietary fiber content as okra flour levels increased, ranging from 3.35% (T0) to 6.76% (T4). The control sample (T0) had the lowest value, while T4 (10% okra flour) had the highest. This indicates a proportional relationship between okra flour concentration and total dietary fiber content. The increase in dietary fiber content is attributed to okra flour's high fiber content, which includes soluble fiber such as pectin and mucilage, as well as insoluble fiber such as cellulose and hemicellulose. Okra flour has been reported to contain higher fiber levels than fresh okra because drying reduces moisture [19]. Mocaf also contributes to dietary fiber content, although in lower amounts, as it is derived from fermented cassava [20]. Furthermore, okra polysaccharides, particularly mucilage, are hydrophilic hydrocolloids that interact with water molecules and help form a more complex food matrix [21]. This characteristic supports the retention and increase of dietary fiber in the final product.

Incorporating fiber-rich ingredients has been widely reported to increase dietary fiber content in snack products [22,23]. According to BPOM Regulation No. 1 [24], products containing ≥3 g/100 g of fiber are classified as fiber sources, while those containing ≥6 g/100 g are categorized as high-fiber products. Based on these criteria, all treatments qualify as fiber sources, and T4 meets the requirement for a high-fiber product.

Moisture Content

Moisture content is a key physicochemical parameter affecting food stability, texture, and shelf life. Table 1 showed that adding okra flour significantly affected the moisture content of mocaf-based snack bars ($p < 0.05$), as determined by ANOVA. The moisture content decreased from 14.22% (T0) to 8.68% (T4), with intermediate values of 11.59% (T1), 8.71% (T2), and 8.80%

(T3). Further analysis using Duncan's Multiple Range Test (DMRT) showed that treatments T0–T2 differed significantly, while T2–T4 did not. The control sample (T0) exhibited the highest moisture content and exceeded the standard limit, whereas the other treatments met the acceptable range for commercial snack bar products [25].

The higher moisture content in T0 is associated with the dominance of mocaf as a starch-based ingredient, which retains water during gelatinization. In contrast, adding okra flour, which is rich in dietary fiber, reduces measurable moisture content by decreasing free water. This is attributed to the hydrophilic nature of dietary fiber, which contains hydroxyl groups that bind water through hydrogen bonding and limit water mobility [26]. As a result, less free water is available for evaporation, lowering measured moisture content.

In addition, okra mucilage, a hydrocolloid polysaccharide, contributes to water retention and stabilizes water distribution within the food matrix, forming a more structured system [21]. Similar findings were reported by Owheruo et al. [27], where increasing okra flour concentration resulted in decreased moisture content due to fiber–water interactions. The absence of significant differences among treatments T2–T4 suggests that at higher concentrations (≥5%), the system reaches a relatively stable condition in water binding, where available binding sites for water molecules become saturated, supported by the ability of soluble fiber to form viscous solutions or gels that stabilize water distribution in food systems [3] From a practical perspective, lower moisture content is advantageous as it enhances product stability and shelf life by reducing microbial growth and physicochemical deterioration [14].

Water Activity (a_w)

Water activity (aw) reflects the availability of free water for microbial growth and chemical reactions. The results showed that adding okra flour significantly affected ($p<0.05$) the snack bars' aw values. The results are presented in Table 1. The aw values decreased from 0.587 (T0) to 0.461 (T4), indicating reduced free water availability as okra flour concentration increased. All treatments exhibited water activity (aw) values below 0.60, indicating that the products were relatively stable against microbial growth. Water activity is a critical parameter related to the availability of free water for microbial growth and chemical reactions in food systems [28]. Lower aw values are generally associated with improved product stability and extended shelf life [29].

According to Negara et al. [30], most microorganisms require aw values above 0.80 to grow; thus, the low aw values obtained in this study suggest good microbial stability and shelf-life potential. The observed decrease in aw with increasing okra flour addition is strongly associated with dietary fiber and mucilage, which are hydrophilic and form hydrogen bonds with water molecules, reducing water mobility and availability [31]. Furthermore, okra's hydrocolloid nature contributes to water binding and stabilization of the food matrix [21]. At higher concentrations (T2–T4), no significant differences were observed, indicating that the system had reached a relatively stable condition or equilibrium in water binding, where water distribution within the matrix becomes more uniform. This finding is consistent with Tastan [32], who reported that fiber fortification in fruit snack products leads to more controlled water distribution without significant changes at certain concentrations.

Bulk Density

Bulk density is a physical parameter that describes a product's compactness, defined as the ratio of mass to volume, and reflects particle arrangement and void spaces within the matrix [33]. Table 1 showed that adding okra flour did not significantly affect bulk density ($p>0.05$). The bulk density values ranged from 0.58 to 0.79 g/cm³. This range remains relatively low and stable for food products, as bulk density values around 0.5–1.0 g/cm³ are generally categorized as low to moderate compactness [34]. These findings suggest that adding okra flour up to 10% was not sufficient to significantly alter the product's structural compactness. The observed fluctuations in bulk density can be explained by dietary fiber's dual role in the product matrix. Increased fiber content enhances water-binding capacity, and during baking, evaporation of bound water may form pores within the structure, potentially reducing bulk density. This phenomenon is consistent with findings by Nuraisyah et al. [35], who reported that water absorbed by fiber and subsequently evaporated can increase product porosity. Conversely, higher fiber content may limit structural expansion by interfering with starch interactions and reducing matrix elasticity, resulting in a more compact structure and potentially higher density [36]. These opposing mechanisms occur simultaneously, leading to fluctuating bulk density values without significant differences among treatments.

3.2 Color Characteristics

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Color is an important quality attribute of food products because it influences consumer perception and acceptance. Incorporating okra flour may affect the visual characteristics of snack bars because of natural pigments such as chlorophyll. The color characteristics of snack bars are shown in Table 2.

Table 2. Color characteristics of snack bars with the addition of Okra flour

Parameter	L*	a*	b*	Appearance
T0 (0%)	60,68 ± 2,97^{a}	5,70 ± 1,08^{a}	40,17 ± 0,21^{a}	
T1 (2,5%)	54,80 ± 0,39^{b}	2,85 ± 0,92^{b}	34,42 ± 0,98^{b}	
T2 (5%)	48,86 ± 1,86^{c}	6,60 ± 0,81^{b}	32,34 ± 0,51^{c}	
T3 (7,5%)	45,98 ± 1.52^{d}	5,97 ± 0,87^{b}	29,76 ± 0,80^{d}	
T4 (10%)	41,55 ± 0,51^{e}	4,83 ± 0,75^{b}	26,47 ± 0,36^{e}	

Note: Data are presented as mean ± standard deviation. Values with different superscript lowercase letters in the same column indicate significant differences ($p < 0.05$). T0, T1, T2, T3, and T4 represent snack bars with okra flour concentrations of 0%, 2.5%, 5%, 7.5%, and 10%, respectively.

Table 2 showed that adding okra flour significantly affected ($p < 0.05$) all color parameters of the snack bars. The lightness (L*) value decreased progressively with increasing okra flour concentration, from 60.68 in the control treatment (0%) to 54.80, 48.86, 45.98, and 41.55 at 2.5%, 5%, 7.5%, and 10% okra flour, respectively. This indicates that higher okra flour concentrations resulted in darker snack bars. The decrease in lightness likely resulted from chlorophyll degradation during heating and Maillard reactions, which promote the formation of brown pigments such as melanoidins. This finding is consistent with Ning et al. [37], who reported that brown pigment formation during heating can reduce the lightness of food products.

The redness (a*) value decreased from the control to the 2.5% treatment and subsequently fluctuated at higher concentrations. Nevertheless, all okra flour treatments showed lower a* values than the control. The decrease in a* values indicates that chlorophyll pigments from okra contributed to the snack bars' greenish coloration [38]. The fluctuations at higher concentrations may have resulted from browning reactions during baking that partially masked the green color of chlorophyll. The yellowness (b*) value also decreased as okra flour concentration increased. This indicates reduced yellow coloration, suggesting that chlorophyll pigments from the okra flour increasingly masked the original yellow color of the Mocaf-based dough. This finding is supported by Wattanakul et al. [17], who reported that ingredients with high chlorophyll content can reduce b* values because green coloration predominates in food products.

3.3 Texture Characteristics

Texture is an important quality attribute of snack bar products because it influences product structure, mouthfeel, and consumer acceptance. Adding fiber-rich ingredients such as okra flour may affect snack bar texture by changing water distribution and matrix structure. Table 3 presents the texture characteristics of snack bars.

Table 3. Texture characteristics of snack bars with the addition of Okra flour

Parameter	Hardness	Fracturability	Gummines
T0 (0%)	382.24 ± 12.45^{a}	560.35 ± 93.11^{a}	83.25 ± 8.91^{a}
T1 (2,5%)	437.85 ± 16.28^{a}	399.05 ± 12.33^{b}	127.50 ± 4.38^{b}
T2 (5%)	542.08 ± 27.79^{b}	374.10 ± 7.93^{b}	148.73 ± 12.20^{c}
T3 (7,5%)	1091.90 ± 60.67^{c}	296.05 ± 36.63^{c}	184.10 ± 7.74^{d}
T4 (10%)	1565.71 ± 60.76^{d}	164.00 ± 24.61^{d}	208.33 ± 15.38^{e}

Note: Data are presented as mean ± standard deviation. Values with different superscript lowercase letters in the same column indicate significant differences ($p < 0.05$). T0, T1, T2, T3, and T4 represent snack bars with okra flour concentrations of 0%, 2.5%, 5%, 7.5%, and 10%, respectively.

Table 3 showed that adding okra flour significantly affected ($p < 0.05$) snack bar hardness. Hardness increased with increasing okra flour concentration, from 382.24 in the control treatment (0%) to 437.85, 542.08, 1091.90, and 1565.71 at 2.5%, 5%, 7.5%, and 10% okra flour, respectively. The increase became significant at the 5% treatment, while the 2.5% treatment did not differ significantly from the control. The increase in hardness was likely related to okra's polysaccharide fiber content, which can bind water and reduce water availability in the dough. In addition, fine particles of okra flour may fill spaces within the product matrix, resulting in a denser, firmer structure. This finding is consistent with Adhiwono et al. [39], who reported that water binding by fiber can reduce product moisture and interfere with gelatinization. These compact particle structures can contribute to significant hardening during heating [40].

In contrast, fracturability decreased as okra flour concentration increased. The control showed the highest fracturability (560.35), followed by 399.05, 374.10, 296.05, and 164.00 at 2.5%, 5%, 7.5%, and 10% okra flour, respectively. The decrease in fracturability indicates that the snack bars became less brittle and more resistant to fracture. This may be attributed to okra's fiber and hydrocolloid components, which can retain moisture and promote a denser, more cohesive product structure. This finding agrees with Aussanasuwannakul et al. [41], who reported that fiber and hydrocolloids can increase matrix density and reduce the brittleness of food products. Gumminess also increased significantly with increasing okra flour concentration, from 83.25 in the control to 127.50, 148.73, 184.10, and 208.33 at 2.5%, 5%, 7.5%, and 10% okra flour, respectively. The increase in gumminess indicates that greater chewing energy was required before swallowing. This result may be linked to increased snack-bar hardness, as gumminess is influenced by product hardness [42]. Sahan and Capraz [43], reported a similar finding, finding that okra addition increased hardness and gumminess in gluten-free food products.

3.4 Antioxidant Activity

Antioxidant activity is an important parameter for evaluating the functional properties of food products, as bioactive compounds in plant-based ingredients may contribute to free radical scavenging activity. Okra flour contains several antioxidant compounds, including phenolic compounds, flavonoids, and chlorophyll pigments, which may enhance the antioxidant potential of snack bars. Figure 2 presents the antioxidant activity of mocaf-based snack bars with different levels of okra flour addition.

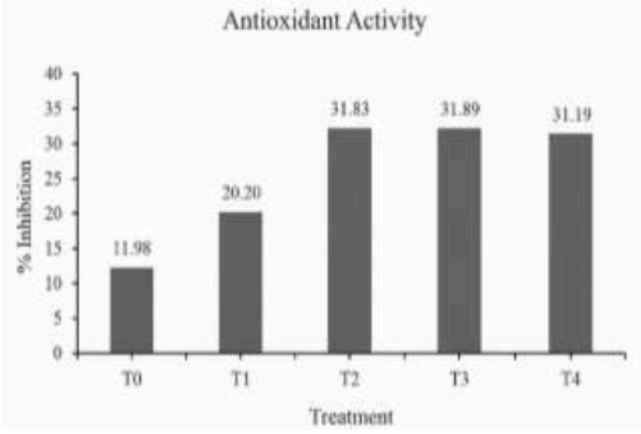


Figure 2. Antioxidant Activity in snack bars with the Addition of Okra Flour

Figure 2 shows that adding okra flour increased the antioxidant activity of the Mocaf-based snack bars. The control treatment (0%) showed the lowest antioxidant activity (11.98%), which increased to 20.20% at 2.5% and peaked at 31.83% with 5% okra flour. At higher concentrations, antioxidant activity remained stable, at 31.89% and 31.19% at 7.5% and 10%, respectively. The increase in antioxidant activity likely resulted from phenolic compounds, quercetin, and vitamin C in okra, which act as free-radical scavengers. Chlorophyll compounds may also contribute to the product's antioxidant activity. This finding is consistent with Fauza et al. [8], who reported that okra flour exhibits high antioxidant activity due to its phenolic and flavonoid contents. The relatively stable antioxidant activity at 7.5% and 10% okra flour may be attributed to the degradation of antioxidant compounds during baking. Thermolabile phenolic compounds can degrade at high temperatures, so antioxidant activity does not increase further despite higher okra flour concentrations [44].

3.5 Hedonic Test

Sensory evaluation is an important aspect of food product development because consumer acceptance determines the product's potential application. A hedonic test was conducted to evaluate panelists' preferences toward snack bars with different levels of okra flour addition. The evaluated attributes included color, aroma, texture, taste, and overall acceptability. Table 4 presents the hedonic test results.

Table 4. Hedonic test of snack bar with the addition of Okra flour

Parameter	T0 (0%)	T1 (2,5%)	T2 (5%)	T3 (7,5%)	T4 (10%)
Color	$2,73 \pm 0,87^{ab}$	$3,13 \pm 0,86^{a}$	$2,70 \pm 0,70^{b}$	$1,77 \pm 0,68^{c}$	$1,37 \pm 0,81^{d}$
Aroma	$3,03 \pm 0,81^{a}$	$3,03 \pm 0,67^{a}$	$2,77 \pm 0,73^{a}$	$1,97 \pm 0,81^{b}$	$1,53 \pm 0,82^{c}$
Texture	$2,73 \pm 1,01^{ab}$	$2,90 \pm 0,84^{a}$	$2,67 \pm 0,61^{ab}$	$2,37 \pm 0,85^{b}$	$1,93 \pm 0,58^{c}$
Taste	$2,60 \pm 0,97^{a}$	$3,13 \pm 0,82^{b}$	$2,67 \pm 0,76^{a}$	$1,63 \pm 0,72^{c}$	$1,37 \pm 0,61^{c}$
Overall	$2,83 \pm 0,91^{ab}$	$3,20 \pm 0,71^{a}$	$2,73 \pm 0,74^{b}$	$1,87 \pm 0,68^{c}$	$1,30 \pm 0,53^{d}$

Note: Data are presented as mean ± standard deviation. Values with different superscript lowercase letters in the same column indicate significant differences ($p < 0.05$). T0, T1, T2, T3, and T4 represent snack bars with okra flour concentrations of 0%, 2.5%, 5%, 7.5%, and 10%, respectively.

Table 4 showed that adding okra flour significantly affected ($p < 0.05$) panelists' preferences for color, aroma, taste, texture, and overall acceptability of the snack bars. Overall, the 2.5% okra flour treatment received the highest acceptance for most attributes, while higher concentrations produced lower hedonic scores. The decrease in color preference was presumably associated with the darker color of the snack bars caused by browning reactions during baking, which reduced their visual appeal. For aroma, increasing okra flour concentrations produced a stronger characteristic raw or grassy odor that may have masked the typical aroma of Mocaf. This undesirable odor may be associated with volatile compounds formed through lipoxygenase activity and lipid oxidation [45]. Meanwhile, lower taste acceptance may have resulted from bitter taste and aftertaste associated with compounds such as saponins and tannins in okra [38].

Decreased texture preference was linked to the increasingly dense and hard structure of the snack bars as okra flour concentration increased. Okra fiber can absorb water and contribute to a firmer structure [46]. The absence of gluten in Mocaf and okra may also contribute to the dense texture after baking. The combination of darker color, undesirable aroma, bitter taste, and harder texture contributed to the lower overall acceptance at higher okra flour concentrations. Overall, the 2.5% okra flour treatment showed the highest panelist acceptance.

3.6 Organoleptic Evaluation

The Kruskal–Wallis analysis indicated that adding okra flour to mocaf-based snack bars significantly affected all sensory attributes ($p<0.05$), including color, aroma, texture, and taste. Therefore, we conducted further analysis using the Mann–Whitney test to determine differences between treatments. The mean sensory scores presented in Table 5 showed significant differences among treatments for all evaluated attributes.

Table 5. Organoleptic of snack bar with the addition of Okra flour

Attribute	T0 (0%)	T1 (2,5%)	T2 (5%)	T3 (7,5%)	T4 (10%)
Brownish-green color	$1,03 \pm 0,183^{a}$	$2,40 \pm 0,563^{b}$	$2,50 \pm 0,572^{bc}$	$2,73 \pm 0,907^{c}$	$3,10 \pm 1,242^{d}$
Langu (vegetative) aroma	$1,13 \pm 0,434^{a}$	$1,37 \pm 0,556^{b}$	$1,70 \pm 0,651^{c}$	$2,10 \pm 0,885^{c}$	$2,90 \pm 1,029^{d}$
Hardness	$1,23 \pm 0,504^{a}$	$1,30 \pm 0,535^{a}$	$2,23 \pm 0,626^{b}$	$2,63 \pm 0,765^{c}$	$2,63 \pm 0,850^{c}$
Sweetness	$2,63 \pm 0,718^{a}$	$2,43 \pm 0,504^{ab}$	$2,20 \pm 0,664^{b}$	$1,73 \pm 0,691^{c}$	$1,43 \pm 0,568^{c}$

Note: Data are presented as mean ± standard deviation. Values with different superscript lowercase letters in the same column indicate significant differences ($p < 0.05$). T0, T1, T2, T3, and T4 indicate okra flour concentrations of 0%, 2.5%, 5%, 7.5%, and 10%, respectively. The sensory score was based on a 1–4 scale, where score 1 indicates "not brownish-green color," "not langu aroma," "not hard," and "not sweet"; score 2 indicates "slightly brownish-green color," "slightly langu aroma," "slightly hard," and "slightly sweet"; score 3 indicates "brownish-green color," "langu aroma," "hard," and "sweet"; and score 4 indicates "very brownish-green color," "very langu aroma," "very hard," and "very sweet."

The perception of brownish-green color increased with higher okra flour concentration, resulting in a more pronounced brownish-green appearance across treatments. The control sample (T0) exhibited the lowest color intensity, while higher substitution levels produced a deeper brownish-green tone. This phenomenon is primarily attributed to chlorophyll pigments

in okra, which contribute to the product's green coloration [47]. In addition, thermal processing during baking promotes non-enzymatic browning reactions, particularly the Maillard reaction, leading to the formation of brown pigments [48]. These interactions produce the characteristic brownish-green color observed in the snack bars. Aroma intensity became increasingly "langu" with higher levels of okra flour addition. The control treatment exhibited a relatively neutral aroma, while higher substitution levels produced a more noticeable characteristic odor. This change is associated with volatile compounds present in okra, which may originate from enzymatic activity and lipid oxidation processes [49]. These volatile compounds, including carbonyl compounds, can influence sensory perception and contribute to the characteristic vegetative aroma of okra [45]. As okra flour concentration increases, these compounds become more dominant, leading to a stronger "langu" aroma.

Texture became progressively harder as okra flour concentration increased. The control sample and lower substitution levels showed a softer texture, while higher concentrations produced a firmer, denser structure. This change is closely related to the increased dietary fiber content from okra flour, which reduces free water availability and increases the solid fraction within the product matrix [50]. In addition, the absence of gluten-forming proteins in mocaf and okra flour may contribute to a less flexible structure, resulting in a denser and harder texture after baking [51]. Lower moisture content further supports a more compact, rigid structure. Taste showed a gradual decrease in sweetness as okra flour concentration increased. The control sample had the highest sweetness intensity, while higher substitution levels resulted in a less sweet taste profile. This reduction in perceived sweetness is associated with bitter compounds in okra, such as saponins (diosgenin), which contribute to a characteristic bitter aftertaste [38]. Furthermore, thermal processing may promote the formation of undesirable flavor compounds, which can influence taste perception [23]. As the proportion of okra flour increases, the bitter aftertaste becomes more pronounced and masks the product's sweetness. Sensory attributes, particularly taste, play a crucial role in determining overall product acceptability.

4. CONCLUSION

Adding okra flour to Mocaf-based snack bars affected the products' physicochemical characteristics, antioxidant activity, and sensory quality. Increasing okra flour concentration increased dietary fiber content, hardness, and gumminess, while decreasing moisture content, water activity, lightness (L*), and yellowness (b*). Bulk density was not significantly affected by okra flour addition. Antioxidant activity increased with okra flour addition up to 5% and remained relatively stable at higher concentrations. Increasing okra flour concentration influenced sensory characteristics, changing color, aroma, texture, and taste attributes, with higher concentrations generally reducing overall acceptance. Among the treatments, 2.5% okra flour showed the highest sensory acceptance and provided a suitable formulation for developing Mocaf-based snack bars. Further studies are recommended to improve sensory acceptance, particularly aroma and taste, and to evaluate nutritional composition and shelf-life stability.

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AUTHOR CONTRIBUTIONS

ESP, NLFZ, and DFA: Conceptualization, methodology, investigation, writing original draft preparation. UA, HBPP, and AML: Supervision, review and editing. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICS STATEMENT

This study did not involve human or animal experiments requiring ethical approval. The sensory evaluation followed appropriate procedures, and all panelists provided informed consent before participating.

DATA AVAILABILITY STATEMENT

The data supporting this study's findings are available from the corresponding author upon reasonable request.

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