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Quality evaluation of composite flours and snacks made from sweet potato, breadfruit and Tigernuts

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Abstract

The composite flour of sweet potato, Breadfruit, and Tigernuts were used to produce Cookies in the following proportion (100:0:0, 0:100:0, 65:30:5, 70:25:5, 75:20:5, 80:15:5), respectively. The proximate composition, functional and pasting properties of the flour were determined while proximate and sensory evaluation were carried out on the Cookies using standard method of analysis. Proximate composition of flour (%) Moisture (6.78-12.38), Crude fat (9.77-15.69), Crude Ash (3.99-7.17), Crude fibre (5.43-6.88), Crude protein (8.38-12.25), Carbohydrate (53.03-60.96). Functional properties of composite flours are Bulk density g/ml (0.63-0.71), Water absorption capacity % (1.76-4.02), Oil absorption capacity % (1.12-1.13), Swelling capacity g/g (4.01-5.89), Solubility index % (0.12-0.68), Dispersibility % (50.09-65.30). Result for color attributes shows L* (41.57-58.36), a* (-0.66-1.82), b*(12.75-14.82), ΔE* (19.91-32.52).

In conclusion, proximate composition, functional properties, and color attributes exhibited significant variations across the different formulations. These findings emphasize the influence of ingredient proportions on the resulting composite flours characteristics.

Keywords: Composite Flour; Proximate; Functional; Pasting; Cookies; Sensory Evaluation

1. Introduction

Sweet potato (Ipomoea batatas) is a root vegetable that is widely cultivated in tropical and subtropical regions around the world. It is a rich source of carbohydrates, dietary fiber, vitamins, and minerals. Sweet potato is a versatile crop that is grown in many parts of the world, especially in tropical and subtropical regions. It has been cultivated for thousands of years and is an important source of carbohydrates, fiber, and micronutrients in many countries. Sweet potato is known for its health benefits, including its antioxidant content, anti-inflammatory properties, and potential for reducing the risk of chronic diseases such as diabetes and heart disease. In addition to its nutritional value, sweet potato can be used in a wide range of food products, including baked goods, soups, stews, and snacks. (Mohanraj and Sivasankar, 2014)

Breadfruit, a fundamental starch crop deeply rooted in the culture of Oceania, specifically Melanesia, Micronesia, and Polynesia, has a remarkable historical background (Zerega et.al, 2004). Over countless generations, humans have

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deliberately cultivated and refined this crop, resulting in the selection of hundreds of unique cultivars. Notably, many of these cultivars are seedless and are propagated through vegetative means.

Tiger nut (Cyperus esculentus) is a tuber crop that has be en cultivated in different parts of the world for thousands of years. It is rich in starch, dietary fiber, and other essential nutrients. Tiger nut is a small, tuberous crop that is grown in many parts of the world, particularly in Africa, Spain, and the middle east. it has been used for food and medicine for thousands of years, and is a rich source of carbohydrates, dietary fiber, and minerals. Tiger nut is also known for its prebiotic properties, which can promote the growth of beneficial bacteria in the gut. In addition to its nutritional value, tiger nut can be used in a variety of food products, such as horchata (a traditional Spanish drink), porridges, and baked goods. (Abdullahi et al., 2022)

Overall, sweet potato, breadfruit, and tiger nut are all valuable sources of nutrition and have been used in traditional diets for centuries. The use of their flours in food products has the potential to increase the availability of nutrient-rich foods and contribute to sustainable food systems.

2. Materials and method

2.1. Materials

The materials utilized for the projects include sweet potato, breadfruit, and tigernuts. These ingredients were sourced from the renowned Kuto market in Abeokuta, Ogun State. Sweet potatoes, known for their vibrant color and natural sweetness, provide a versatile base for various culinary experiments. Breadfruit, with its starchy texture and mild flavor, adds an interesting twist to traditional recipes. Tigernuts, on the other hand, offer a unique nutty taste and are rich in nutrients. The Kuto market in Abeokuta, Ogun State, is celebrated for its diverse selection of fresh and high-quality produce, making it an ideal location to obtain these ingredients for the projects.

2.2. Methods

Sweet potato flour was produced by washing the sweet potatoes, peeling them, slicing them into thin rounds, and drying them in an oven or dehydrator until they became crisp and brittle. The dried sweet potato slices were then ground into a fine powder using a food processor.

For breadfruit flour, the seeds and skin were removed from the breadfruit, the flesh was cut into small pieces, and the pieces were dried in an oven or dehydrator until they became crisp and brittle. The dried breadfruit pieces were then ground into a fine powder using a food processor.

To make tiger nut flour, the tiger nuts were soaked in water for several hours to soften them, drained of the water, spread on a baking sheet, and dried in an oven or dehydrator until they became hard and dry. The dried tiger nuts were then ground into a fine powder using a food processor.

2.3. Formulation of Flour from Sweet Potato, Breadfruit, and Tigernuts

The blends of sweet potato flour, breadfruit flour, and tigernuts flour were mixed. About 100g of each blend (Sweet potato, Breadfruit, and Tigernuts) were mixed in various proportions of A- 100:0:0, B-0:100:0, C- 65:30:5, D- 70:25:5, E- 75:20:5, F- 80:15:5 (Table 1).

Table 1 Formulation of the composite flours

SAMPLES	SWEET POTATO %	BREADFRUIT %	TIGERNUTS %
A	100	0	0
B	0	100	0
C	65	30	5
D	70	25	5
E	75	20	5
F	80	15	5

2.4. Chemical Analysis

The analysis of composite flours involved proximate analysis (AOAC, 2012) to determine moisture, fiber, fat, protein, ash, and carbohydrate content, along with functional property evaluations including water and oil absorption capacity (Sosulski, 1962), bulk density (Narayana and Narasinga-Rao, 1984), swelling power (Leach et al., 1959), solubility index, and dispersibility. Color properties were assessed using the CIE method. These analyses provide crucial insights into the nutritional composition, functional properties, and color attributes of the composite flours, guiding their culinary applications and product development.

2.5. Statistical Analysis

The data obtained from the chemical analysis were subjected to statistical analysis of ANOVA, and the mean was separated using Duncan (2020). The analysis of variance (ANOVA) and separation of the mean values (using Duncan's Multiple Range Test at p (<0.05) were calculated using Statistical Package for Social Scientists (SPSS) software (window 13).

3. Results and discussion

3.1. Proximate Composition of Flours Produced from Sweet Potato, Breadfruit, and Tigernuts

The proximate composition of the composite flours is as shown in Table 2. There were significant differences (p≤0.05) in moisture content, crude protein, crude fat, ash content, crude fiber, and total carbohydrate of the flours. The mean values of moisture content ranges from 6.78%-12.38%. Sample 100:0:0, exhibits the highest moisture content of 12.38%. This outcome is consistent with the natural characteristics of sweet potatoes, known for their relatively high-water content. Generally, the permissible upper limit for moisture content within flour is set at 14%. According to (Nasir et al., 2003) flour having 9% moisture content to 10% moisture content are suitable for extended shelf life. In contrast, sample 0:100:0 demonstrates a lower moisture content of 9.33%, reflecting the drier nature of breadfruit. A decreased moisture content in flour indicates favorable microbial stability and can also aid in mitigating the likelihood of baked food products becoming stale (Chukwu and Abdullahi, 2015). As the proportion of sweet potato decreases and breadfruit and tiger nut are introduced, the moisture content of the composite flours gradually decreases. Higher percentages of drier components (breadfruit and tiger nut) contribute to reduced moisture content. Elevated moisture levels facilitate the proliferation of microorganisms, therefore impacting both the flour's shelf life and its nutritional properties. Maintaining a reduced moisture content proves vital for extended food preservation, reduced humidity levels within food items lead to heightened nutrient concentration. (Marina et al., 2019).

The crude fat content of the samples exhibits a range from 9.77% to 15.69%, which underscores the influence of sweet potato, breadfruit, and tiger nut compositions within the samples. Sample 80:15:5 has the highest fat content (15.69%), highlighting its notable fat-based nutritional value. This distinction can be attributed to its composition, where larger portions of high-fat ingredients like tiger nut are present. As ingredient ratios shift towards lower fat content constituents, crude fat content declines. The breadfruit's low-fat content implies its potential value in weight management programs (Ariyo et al.). The varying levels of crude fat content have implications for both the nutritional value and sensory characteristics of the composite flours. Foods possessing high fat content plays a significant role in fulfilling the energy needs of both humans and animals (Sunday et al., 2021)

Table 2 Proximate Composition of Composite Flour

Samples (%)	Moisture (%)	Crude Fat (%)	Crude Ash (%)	Crude Fibre (%)	Crude Protein (%)	Carbohydrate (%)
100:0:0	12.38±067^{a}	10.88±037^{b}	3.99±0.13^{a}	6.78±0.23^{b}	10.03±0.54^{b}	55.97±0.12^{b}
0:100:0	9.33±0.51^{b}	9.77±0.34^{ab}	7.17±0.25^{d}	5.78±0.20^{a}	8.38±0.45^{a}	59.58±0.16^{d}
65:30:5	7.84±0.42^{a}	10.44±0.36^{a}	4.74±0.16^{b}	5.43±0.18^{a}	10.60±0.58^{bc}	60.96±0.17^{e}
70:25:5	7.52±0.41^{a}	13.00±0.45^{c}	4.81±0.16^{b}	6.50±0.23^{b}	11.26±0.62^{bcd}	56.93±0.26^{c}
75:20:5	6.98±0.38^{a}	14.12±0.49^{d}	4.98±0.17^{bc}	6.71±0.23^{b}	11.71±0.64^{cd}	55.51±0.34^{b}
80:15:5	6.78±0.37^{a}	15.69±0.54^{e}	5.38±0.18^{c}	6.88±0.24^{b}	12.25±0.66^{d}	53.03±0.42^{a}

Values are mean ± standard deviation. Data with different superscripts in the same row are significantly different at P≤ 0.05

The crude ash content analysis reveals substantial variations among the composite flour samples, spanning from 3.99% to 7.17%. Sample 0:100:0 prominently stands out with the highest crude ash content at 7.17%. Higher crude ash content, as seen in Sample 0:100:0, indicates a greater presence of minerals such as calcium, magnesium, and potassium (Ndife et al., 2013). These minerals play a role in disease prevention and promoting overall well-being (Malomo, 2011).

The variation in crude fiber content across the samples ranges from 5.43% to 6.88%, highlighting compositional differences. Notably, the elevated crude fiber content in Sample 100:0:0 indicates a richer fiber profile, carrying potential nutritional benefits. Crude fiber's positive impact on human health is well-known, as it aids digestion, cleanses the intestines by eliminating waste, and contributes to the regulation of bowel movements (Sobota et al., 2010).

The crude protein content varies significantly across the samples, spanning from 8.38% to 12.25%, reflecting diverse compositions. Among the samples, Sample 80:15:5 stands out with the highest crude protein content of 12.25%, representing the most protein-rich composition. In contrast, Sample 0:100:0 displays the lowest crude protein content at 8.38%. Interestingly, the outcomes contrast with the results reported by (Hasmadi et al., 2021).

The carbohydrate content ranges from 53.03% to 60.96%, indicating differences in the compositions of the samples. Sample 65:30:5 demonstrates the highest carbohydrate content at 60.96%, marking it as the most carbohydrate-rich sample.

3.2. Functional Properties of Flours Produced from Sweet Potato, Breadfruit, and Tigernuts

Table 3 displays the inherent physical and chemical characteristics of the flours, known as functional properties. These properties offer insights into the intricate interplays among factors like protein composition, structural arrangement, conformation, and the physical and chemical attributes of other components present in the food. These interactions are assessed within the specific conditions and surroundings in which they are observed and measured. Bulk density, indicating the mass of composite flour per unit volume, varies from 0.63% to 0.71% in this dataset. Sample 0:100:0 has the lowest bulk density at 0.63%, significantly differing from other samples except for Sample 100:0:0, which has the highest bulk density at 0.70%. Lower bulk density is advantageous when producing complementary foods for children as it increases unique composition of composite flours, where ingredient densities contribute to overall differences nutrient and calorie concentration per serving (Awolu et al., 2016).

Table 3 Functional Properties of Composite Flour

Samples (%)	Bulk Density (%)	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Swelling Capacity (%)	Solubility Index (%)	Dispersibility (%)
100:0:0	0.70±-0.00 [e]	1.76±0.01[a]	1.13±0.01 [a]	4.01±0.28 [a]	0.68±0.01[f]	65.30±0.28[f]
0:100:0	0.63±0.00 [a]	4.02±2.14 [a]	1.37±0.02 [d]	4.81±0.28 [b]	0.44±0.01[e]	50.09±0.04 [a]
65:30:5	0.66±0.00 [b]	1.98±0.01 [a]	1.26±0.02 [c]	5.89±0.03[f]	0.12±0.01[a]	58.60±0.14 [b]
70:25:5	0.67±0.00 [c]	2.10±0.01 [a]	1.20±0.01 [b]	5.81±0.03[e]	0.15±0.01[b]	59.91±0.06 [c]
75:20:5	0.69±0.00 [d]	2.15±0.01 [a]	1.16±0.01 [ab]	5.22±0.04 [d]	0.20±0.02[c]	60.97±0.04 [d]
80:15:5	0.71±0.00 [f]	2.20±0.01 [a]	1.12±0.01 [a]	5.08±0.04 [c]	0.24±0.01[d]	61.50±0.13[e]

Mean values followed by different alphabet within a column are significantly different (p≤0.05); Key Words: SP- Sweet potato; BF- Breadfruit; TN-Tigernuts

Variations in bulk density are due to the unique composition of composite flours, where ingredient densities contribute to overall differences. Bulk density significantly affects processing, preparation, and food applications, with lower density enhancing flow characteristics and higher density impacting texture and volume in baking (Suresh and Samsher, 2013). These differences provide insights into composite flour's physical properties and their suitability for various culinary uses.

Water Absorption Capacity (WAC) denotes a material's capacity to soak up water. In this dataset, the WAC values demonstrate variability among the samples, spanning from 1.76% to 4.02%.

Remarkably, all samples have no statistically significant differences in WAC exist among them. As stated by Adejuyitan et al. (2009), the water absorption capacity of flours is primarily influenced by proteins and carbohydrates, representing significant contributing factors. While this superscript implies statistical similarity, the actual values reveal disparities. Notably, Sample 0:100:0, primarily composed of breadfruit, boasts the highest WAC value at 4.02%. Intriguingly, this finding aligns with observations from (Ajatta et al., 2016). Elevated WAC values, such as those witnessed in Sample 0:100:0, underline the water-absorption enhancing attributes of breadfruit. This characteristic can potentially influence the behavior of composite flours in applications necessitating water incorporation, like doughs and batters.

Oil Absorption Capacity (OAC) measures how well a substance can soak up oil. In this dataset, OAC values range from 1.12% to 1.37%. OAC values varies significantly across all samples, signifying significant differences in their oil absorption capabilities. These variations suggest that the ingredients in these samples interact differently with oil, resulting in diverse oil absorption capacities. As explained by (Yadav et al. 2012), a high oil absorption capacity is linked to the presence of a substantial hydrophobic group relative to the hydrophilic group on the protein molecule's surface. This capacity to absorb oil is significant because it contributes to a more pronounced taste experience in the mouth. In essence, the oil serves as a reservoir for retaining flavor in food, as noted by (Masri et al. 2012).

Swelling Power (SW) refers to the ability of a substance to increase in volume when immersed in a liquid. In the dataset, SW values vary across the samples, with values ranging from 4.01% to 5.89%. Each of these samples has a statistically significant differences in their swelling power. Higher SW values suggest that the composite flour has a greater tendency to swell or absorb water when immersed in a liquid. (Nuwamanya et al. 2011) described that flours with high amylose content tend to obtain high swelling capacity. This property can be relevant in applications like thickening sauces, soups, or puddings, where the flour's ability to absorb and hold liquid is important for achieving desired textures.

Solubility Index (SI) indicates the ability of a substance to dissolve in a liquid. In this dataset, SI values vary across the samples, with values ranging from 0.12% to 0.68%. Each of these samples has a statistically significant differences in their solubility indices. When solubility values are low, it signifies a limited degree of starch breakdown, whereas elevated solubility values indicate a substantial extent of starch degradation occurring during the processing of flour blends (Banu et.al, 2012). Lipids in flours, can decrease water absorption capacity, potentially resulting in decreased swelling capacity and, consequently, reduced solubility (Opong et al., 2015). High solubility in food can indicate better digestibility, making it suitable for uses like infant formula and baby food (Kate et al., 2019).

Dispersibility (DISP) measures the ability of a substance to disperse and dissolve in a liquid medium. In the dataset, DISP values vary across the samples, ranging from 50.09% to 65.30%. Higher DISP values suggest that the composite flour has a greater ability to disperse and dissolve in a liquid. This property is valuable in applications where quick and uniform dissolution is desired, such as instant beverage mixes or sauces. The variations in DISP values can be attributed to the composition and physical properties of the composite flours. The significant dispersibility values observed in the flour blend suggest that these blends will improve the ability to reconstitute and the textural qualities of dough when created from composite flour during the mixing process, consistent with findings reported by (Babajide and Olowe, 2013). The ingredients may interact differently with the liquid medium, affecting their dispersibility.

3.3. Color Attributes of Flours Produced from Sweet Potato, Breadfruit and Tigernuts

The color analysis data provides intricate insights into the color characteristics of the composite flours derived from different formulations of sweet potato, breadfruit, and tiger nuts. The color parameters L* (lightness), a* (redness-greenness), b* (yellowness-blueness), and ΔE* (total color difference) were employed to decipher the color profiles of these samples.

This is displayed in Table 4. The L* values ranged from 41.66 to 58.36, indicating a significant variance in lightness among the samples. Notably, 100:0:0, consisting of 100% sweet potato, and Sample 80:15:5, exhibited lower L* values, implying a darker appearance. Conversely, Sample 0:100:0, composed of pure breadfruit, displayed the highest L* value, implying a relatively lighter appearance.

Exploring the a* values (redness-greenness), Sample 0:100:0 stood out with the lowest a* value of -0.66, signifying a shift towards the green end of the spectrum. In contrast, Sample 100:0:0 showcased the highest a* value of 1.82, indicating a tendency towards redness. This agrees with the findings from (Hasmadi et al., 2021). The b* values (yellowness-blueness) ranged from 12.75 to 14.82, with Sample 100:0:0 again exhibiting the highest value, suggesting more pronounced yellowness. This may be attributed to the existence of carotenoid pigments and anthocyanins present in the flour samples (Hasmadi et al., 2021).

Total color differences (ΔE*) ranged from 19.91 to 32.52, with Sample 0:100:0 showing the greatest ΔE* value, indicative of significant color differentiation. Interestingly, Sample 100:0:0 recorded the lowest ΔE* value, implying minimal color disparity. These variations underscore the intricate interplay of sweet potato, breadfruit, and tiger nut proportions in influencing the overall color of the composite flours.

Table 4 Color Attributes of Composite Flour

Samples	l*	a*	b*	ΔE*
100:0:0	41.66±0.02^{a}	1.82±0.01^{e}	14.82±0.00^{d}	20.42±0.02^{a}
0:100:0	58.36±0.01^{e}	-0.66±0.01^{a}	12.75±0.01^{a}	32.52±0.21^{e}
65:30:5	46.45±0.15^{d}	1.44±0.01^{b}	14.59±0.04^{cd}	23.52±0.14^{d}
70:25:5	43.61±0.28^{b}	1.47±0.03^{b}	13.83±0.34^{b}	21.08±0.25^{b}
75:20:5	44.71±0.38^{c}	1.57±0.03^{c}	14.54±0.10^{cd}	22.23±0.35^{c}
80:15:5	41.57±0.43^{a}	1.67±0.03^{d}	14.25±0.13^{c}	19.91±0.37^{a}

Values are mean ± standard deviation of duplicate determinations. Mean values along the same column with different superscripts are significantly different (p≤0.05); L* (lightness), a* (redness-greenness), b* (yellowness-blueness), and ΔE* (total color difference)

The use of different superscripts (a, b, c, d, e) in the data indicates statistically significant color differences among the samples. Such distinctions have pivotal implications for product development, culinary applications, and consumer acceptance. The color of food products plays a crucial role in influencing consumer perceptions and preferences.

The adjustments in ingredient proportions can be employed to target specific color outcomes based on the desired appearance of the final product.

The L* value represents lightness, with higher values indicating lighter colors, while the a* and b* values represent color shifts along the red-green and yellow-blue axes, respectively. The ΔE* value quantifies the overall color difference between two samples.

3.4. Proximate Analysis of Cookies

The proximate composition of cookies made from different ingredients, including SP, BF, and TN, was shown in Table 5. Significant differences (P<0.05) were observed in various components, including moisture content, crude fat, crude ash, crude fiber, crude protein, and total carbohydrate.

Moisture content ranged from 10.42% to 13.82%, with sample BF 100 having the highest moisture value at 13.82%. The variation in moisture content was influenced by the addition of BF, and SP's high water-binding capacity also played a role Adegunwa et al., (2014). Soft cookies should ideally have a moisture content of 10% to 12% to maintain their texture before expiration. Cookies with moisture values of 12.89%, 10.42%, 11.70%, and 10.70%

Table 5 Proximate Compositions of Cookies

Samples (SP:BF:TN)	Moisture (%)	Crude Fat (%)	Crude Ash (%)	Crude Fiber (%)	Crude Protein (%)	Carbohydrate (%)
SP 100	12.89±0.70^{bc}	15.77±0.96^{ab}	6.72±0.28^{cd}	6.88±0.28^{bc}	9.72±0.71^{a}	48.04±0.46^{c}
BF 100	13.82±0.75^{c}	17.78±1.08^{bc}	5.51±0.23^{a}	3.39±0.14^{a}	12.34±0.91^{b}	47.17±0.66^{c}
SP65:BF30:TN5	10.42±0.57^{a}	14.56±0.79^{a}	6.22±0.25^{bc}	6.83±0.28^{bc}	8.86±0.65^{a}	53.11±0.40^{e}
SP70:BF25:TN5	13.58±0.74^{c}	15.58±0.95^{ab}	5.62±0.23^{ab}	6.33±0.26^{b}	8.84±0.62^{a}	50.48±0.38^{d}
SP75:BF20:TN5	11.70±0.64^{bc}	17.65±0.07^{bc}	7.15±0.30^{de}	7.22±0.30^{cd}	10.19±0.75^{a}	46.09±0.31^{b}
SP80:BF15:TN5	10.70±0.58^{a}	20.15±1.22^{c}	7.47±0.31^{e}	7.70±0.31^{d}	13.45±0.99^{b}	40.54±0.34^{a}

Values are mean ± standard deviation. Data with superscript in the same row are significantly different at P≤0.05; Keywords: SP =Sweet potato, BF= Breadfruits, TN= Tiger nut

Showed soft and moist textures, while deviations from this range could impact the desired texture and shelf life. To prevent microbial growth, water activity should be maintained between 0.6% and 0.7%, with a recommended moisture level of less than 14% for long-term preservation (Adeleke and Odedeji, 2010).

The sample (SP80:BF15:TN5) had the highest crude fat value while the lowest was recorded from sample (SP65:BF30:TN5). The results revealed crude fat values of 14.56 to 20.15% which indicated a moderate to high level of fat, resulting in cookies with a rich and indulgent texture and flavor. The fat content values of all samples were higher than the recommended value of Protein Advisory Group (PAG) weaning food (Ade-Omowaye et al., 2008).

The values of crude ash range from 5.51 - 7.47% with sample (SP80:BF15:TN5) recording the highest value of ash. The ash content of cookies increased significantly due to the higher ash content of SP and due to externally added fat during the preparation of the cookies. The increase of Breadfruit in the samples up to 100% brought about the lowest values of crude ash of sample (BF 100) at 5.51%.

The fiber content of the cookies ranged from 3.39% to 7.70%, and cookies with higher fiber content can be marketed as healthier options. Higher fiber content is beneficial for digestive health but may affect the cookies' texture and moisture content. Balancing fiber levels is crucial to avoid an overly dry or firm texture (Adegunwa et al., 2017).

The protein content of the cookies ranged from 8.84% to 13.45%, with the proportion of SP and BF influencing these values. BF and SP were found to be rich in protein, indicating that cookies made from these ingredients may supply a significant amount of protein to the body.

Carbohydrate content ranged from 40.54% to 53.11%, with the proportion of BF affecting carbohydrate values. The cookies derived from these ingredients showed variations in carbohydrate content, with some being considered good sources of carbohydrates. Sample (SP65:BF30:TN5) had the highest carbohydrate value of 53.11%.

3.5. Colour Attributes of cookies produced from Sweet Potato, Breadfruits, and Tiger nuts

Table 6 Colour attributes of the cookies produced

Sample	l*	a*	b*	ΔE*
SP 100	21.97 ± 0.01^{a}	4.95 ± 0.08^{c}	14.06 ± 0.08^{a}	17.28 ± 0.10^{a}
BF 100	33.95 ± 0.33^{d}	4.75 ± 0.00^{bc}	21.02 ± 0.10^{d}	23.08 ± 0.16^{c}
(SP65:BF30:TN5)	24.53 ± 0.08^{b}	4.66 ± 0.06^{abc}	15.24 ± 0.11^{b}	17.44 ± 0.13^{a}
(SP70:BF25:TN5)	25.21 ± 0.28^{bc}	4.50 ± 0.03^{ab}	15.73 ± 0.06^{b}	17.71 ± 0.00^{a}
(SP75:BF20:TN5)	25.59 ± 0.63^{c}	4.65 ± 0.21^{abc}	16.55 ± 0.33^{c}	18.49 ± 0.19^{b}
(SP80:BF15:TN5)	24.81 ± 0.31^{bc}	4.38 ± 0.16^{a}	15.31 ± 0.54^{b}	17.39 ± 0.46^{a}

Values are mean ± standard deviation of duplicate determinations. Mean values along the same column with different superscripts are significantly different (p≤0.05). Keywords: SP =Sweet potato, BF= Breadfruits, TN= Tiger nuts, L* =Lightness, a* = green-red axis, b* = blue-yellow axis, ΔE* = Overall colour difference

The color values of the cookies were measured using the L*, a*, b*, and ΔE color space (Table 6). The results were expressed as the means ± standard deviation of double determinations, and mean values along the same column with different superscripts are significantly different (p≤0.05).

The L* value, often referred to as "lightness or darkness," is a colour measurement parameter in the CIELAB colour space, which is commonly used to quantify the perceived brightness or darkness of an object's colour. It ranged from 21.97 to 33.95, with BF 100 having the highest L* value, indicating a moderately bright color, and SP 100 having the lowest L* value, suggesting a relatively darker color. These variations in L* values can be attributed to factors such as ingredient composition, baking time, and lighting conditions during measurement. The darkness or lightness of cookies is influenced by ingredients like sugars and flavorings, and it impacts their use in various culinary applications.

The a* value, signifying redness or greenness, increased from 4.38 to 4.95 with increasing proportions of SWP; and a decrease in the proportion of BF simultaneously. It indicated that redness in the samples increased with the addition of SWP.

From the result, the b* values ranged from 14.06. to 21.02. As the "b*" values of the cookies are positive, it indicates that cookies are on the yellow end of the color spectrum and cookies with the highest value (BF 100) display a significant amount of yellow

The ΔE* value represents the overall color difference between two measurements in the CIELAB color space or serves as a reference point in the CIELAB colour space.

It considers the differences in L*, a*, and b* values to provide a single value that quantifies the overall perceptual difference in colour. The ΔE* value of cookies decreased from 23.08 to 17.28. The decrease is a result of the decreasing value of BF used in the fortification of the SWP. A decrease in the ΔE* value indicates a reduction in the color difference of the samples, which suggests that the colors are becoming more similar (in terms of hue, lightness, and saturation).

3.6. Sensory attributes of cookies produced from Sweet Potato, Breadfruits, and Tiger nut

Table 7 presents the sensory evaluation results for cookies made from sweet potatoes, breadfruits, and tiger nuts, including assessments of texture, mouthfeel, taste, color, and overall acceptability.

The results revealed significant differences ($p<0.05$) in texture, mouthfeel, taste, color, and overall acceptability among the cookies. The variation in sensory attributes can be attributed to differences in panelists' preferences and the quality of the final cookie products.

In terms of color, cookies with 100% breadfruit content received the highest score (7.52%), but this score decreased (to 6.14%) with increased sweet potato content, resulting in a dark brown color that was less favored by the panelists.

Taste, a primary factor in product acceptability, ranged from 4.90% to 6.14%. Cookies made with 100% sweet potato (Sample SP 100) had the sweetest taste (6.14%), while those with 100% breadfruit (Sample BF 100) had the lowest taste score. The moderate taste ratings (4.90% to 6.14%) suggest that the cookies are likely to be palatable and enjoyable to a wide range of consumer.

Aroma, which influences the acceptance of baked food products, varied from 4.81 to 5.71. Cookies with 100% breadfruit content had the lowest aroma score, while the sample with the (SP80:BF15:TN5) combination had the highest aroma score. The moderate aroma ratings (4.81 to 5.71) indicate that the cookies had noticeable but not overpowering aromas

Crunchiness ranged from 5.71% to 6.62%, with Sample SP 100 having the highest crunchiness score. Texture varied from 5.76% to 7.05%, increasing with higher sweet potato content. Cookies with softer or firmer textures cater to diverse consumer preferences.

Overall acceptability ratings ranged from 5.00% to 6.62%, suggesting that the cookies are likely to be acceptable and enjoyable to most consumers. Sample SP 100 stood out for its excellent taste, texture, and overall sensory experience. Other combinations, such as (SP70:BF25:TN5), (SP75:BF20:TN5), and (SP80:BF15:TN5), also received appreciable scores across various sensory attributes.

Table 7 Sensory evaluation of cookies produced

Samples	Colour	Taste	Aroma	Crunchiness	Texture	Overall Acceptability
SP 100	6.95 ± 1.28^{ab}	6.14 ± 1.20^{b}	5.67 ± 1.02^{a}	6.62 ± 1.32^{a}	7.05 ± 1.47^{b}	6.62 ± 0.92^{c}
BF 100	7.52 ± 1.12^{b}	4.90 ± 1.87^{a}	4.81 ± 1.75^{a}	6.57 ± 1.50^{a}	5.76 ± 1.64^{a}	5.00 ± 2.17^{a}
(SP65:BF30:TN5)	6.57 ± 1.21^{a}	5.86 ± 1.62^{ab}	5.14 ± 1.62^{a}	5.71 ± 1.27^{a}	5.81 ± 1.08^{a}	5.52 ± 1.91^{ab}
(SP70:BF25:TN5)	6.14 ± 1.65^{a}	6.05 ± 1.91^{b}	5.62 ± 1.28^{a}	5.81 ± 1.36^{a}	6.29 ± 1.31^{ab}	6.14 ± 1.65^{bc}
(SP75:BF20:TN5)	6.33 ± 1.35^{a}	5.67 ± 1.43^{ab}	5.57 ± 0.98^{a}	$6.52\pm1.29^{a,}$	6.24 ± 1.22^{ab}	6.24 ± 1.14^{bc}
(SP80:BF15:TN5)	6.19 ± 1.44^{a}	5.48 ± 1.66^{ab}	5.71 ± 1.49^{a}	6.05 ± 1.20^{a}	6.33 ± 1.06^{ab}	6.24 ± 1.00^{bc}

Values are mean ± standard deviation. Data with different superscripts in the same row are significantly different at $P\leq0.05$; Keyword: SP = Sweet potato, BF = Breadfruits, TN = Tigernuts

4. Conclusion

The analysis of composite flours made from sweet potato, breadfruit, and tiger nut revealed significant differences in their nutritional composition, functional properties, and color attributes. Sweet potato-based flours had higher moisture and carbohydrate content, while breadfruit-based flours had more ash content. Tiger nut inclusion increased the crude fat content in the composite flours. Functional property analysis showed variations in bulk density, water absorption capacity, oil absorption capacity, swelling power, solubility index, and dispersibility, which are crucial for different culinary applications. Breadfruit-based flours had higher oil absorption capacity, making them suitable for oil-based recipes. The color analysis displayed differences in lightness, redness-greenness, yellowness-blueness, and total color difference among the composite flours. Sweet potato-based flours were lighter, while breadfruit-based flours were redder. These color variations can impact consumer preferences and product development. Overall, these diverse characteristics provide exciting opportunities for culinary innovation, allowing for tailored dietary choices and the creation of unique food products.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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