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Proximate composition, sensory evaluation and shelf stability of instant snacks produced from tigernuts, orange-fleshed sweet potato starch, and date blend

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ABSTRACT

This study evaluated the proximate composition, sensory properties, and shelf stability of instant snacks (in chip form) from tigernut, orange-fleshed sweet potato (OFSP), and date paste. The produced snacks were subjected to proximate analysis and sensory evaluation, in which three best-selected samples were subjected to 21 days of storage at room temperature and further analyzed. The moisture, ash, crude protein, crude fiber, fat, and carbohydrate contents of the snack samples ranged from 0.10-3.00%, 0.40-2.20%, 1.49-1.52%, 1.67-1.72%, 2.12-2.30%, and 90.69-93.99%, respectively. Sensory evaluation showed significant differences ($p<0.05$) compared to commercial snacks, with the sample containing 100:0- tigernut: OFSP starch receiving high ratings for crunchiness (7.74), taste (7.26), and general acceptability (7.47) with higher acceptance index of 78.20% comparable to commercial coconut chips. During storage, bacterial counts ranged from 1.92×10^3 to 3.00×10^3 CFU/ml, while fungal counts were low, with detectable growth in the final week. Moisture increased slightly (2.92-3.61%), contributing to higher bacterial counts. Peroxide values rose from 18.10 to 20.60 ml M/g but remained within acceptable limits. Their proximate composition and storage suggest suitability for high-energy dietary needs and stable snacks. Thus, an addition to a healthy, nutritious snack list.

Keywords: Date, instant snacks (in chips form), Orange-fleshed sweet potatoes, proximate, sensory properties, shelf stability, tigernut.

INTRODUCTION

The increasing focus on health-conscious eating habits has spurred the demand for nutrient-dense and functional food products, especially snacks. Snacks are light food eaten in between the main meals to assuage hunger (Uzoaga and Kanu, 2020). They are usually used for pleasure rather than the nutrients they contain (Akubor, 2004). Currently, in Nigeria, the demand for snacks is on the increase (Uzoaga and Kanu, 2020). They are mainly produced using wheat flour. Wheat flour, the main ingredient for the production of snacks, is imported and thus, the cost of importation of wheat flour eats deep into the Nigerian economy and has placed a considerable burden on the foreign exchange reserve, in the long run, causing an increase in the price of wheat products (Nwafor et al., 2020). Snacks, being a major part of modern diets, provide a unique opportunity to enhance nutritional value through the incorporation of underutilized but nutrient-rich ingredients.

Tigernuts (*Cyperus esculentus*), orange-fleshed sweet potatoes (OFSP), and dates are promising ingredients with the potential to address nutritional gaps while appealing to consumers' preferences. Tigernut (*Cyperus esculentus var*. *lativum*) is a perennial monocotyledon plant characterized by a tough, erect, fibrous root system (Maduka and Ire, 2018). In southern Nigeria, tigernuts are widely known as 'Aki Hausa,' as they are predominantly cultivated by the Hausa people. Tigernut tubers have a slightly sweet and nutty flavor (Adgidzi *et al.,* 2011), are often consumed raw, and are rich in phosphorus, potassium, and vitamin C (Adel et al., 2015). Additionally, tigernuts are highly valued for their high fiber content, healthy fats, mineral profile, and they have long been recognized for their nutritional and medicinal benefits (Belewu and Belewu, 2007).

Orange-fleshed sweet potato (OFSP) is an excellent source of beta-carotene (pro-vitamin A), along with antioxidants, fibers, minerals, and vitamins (Rodriguez and Kimura, 2004). Its natural sweetness, vibrant color, and flavor enhance food products while addressing vitamin A deficiency, a widespread public health issue in developing regions that can cause temporary and permanent eye damage (Mbaba et al., 2012; Low et al., 2009).

Date palm (*Phoenix dactylifera*) is a flowering plant that produces sweet berries with a sugar content exceeding 50% (Niazi et al., 2017). Date fruits are consumed at various stages of maturation: mature but unripe, ripened, and fully mature (Zaid et al., 2002). Compared to other dried fruits, dates are a reasonable source of vitamins (USDA, 2011). Known for their natural sweetness, dates are rich in antioxidants, vitamins, and minerals that contribute to overall health and product stability (Baliga et al., 2011).

Combining these three ingredients offers an innovative approach to developing functional snacks that are healthy, economical, accessible, and shelf-stable. This research aimed to develop instant snack (in chips form) from tigernut, OFSP, and date blends, focusing on their proximate composition, sensory qualities, and shelf-life stability. By blending these nutrient-rich ingredients, the study sought to create a snack that is both nutritious and appealing to consumers while addressing post-harvest losses and enhancing food security.

The study is significant as it aligns with global efforts to combat malnutrition through innovative, affordable, and nutrient-dense convenience foods with broad market appeal, particularly in regions prone to micronutrient deficiencies (FAO, 2013). Additionally, evaluating sensory attributes and shelf stability provided critical insights into consumer acceptability and product marketability, ensuring the feasibility of this novel food product for industrial applications.

The findings have the potential to diversify healthy snack options and promote the sustainable utilization of underutilized crops, contributing to both improved nutrition and agricultural sustainability.

MATERIALS AND METHODS

Experimental design and raw materials

A completely randomized design was used and generated a total of 6 samples (50:50, 60:40, 70:30, 80:20, 90:10 and 100:0 for Tigernut and OFSP starch, respectively), while date quantity was constant (30g). Coconut instant snack chips a commercial sample was also used to compare with the produced sample. Umuspo 3 OFSP (sourced from National Root Crop Research Institute Umudike, Abia State) and brown Tigernut variety (sourced from Eke-Awka market, Awka South, Anambra State, Nigeria), and date (sourced from Eke-Awka market, Awka South, Anambra State, Nigeria), were used for the production.

Orange flesh sweet potato (OFSP) starch production

The OFSP starch was prepared according to Soison et al. (2015) with minor modifications (by replacing white sweet potatoes with orange fleshed sweet potatoes). The OFSP roots were purchased from the National Root and Crops Research Institute Umudike (NRCRI) farm, manually peeled, washed, and milled with water (in the ratio of 1:1 W/W) to a fine paste, and were filtered with cheesecloth. After the filtration, the residue was subjected to extraction with water (1:0.5, w/w). The filtrate was then allowed to sediment for three hours, followed by the dewatering process. The settled starch was re-suspended in water, allowed to sediment and decantation was followed to obtain wet starch, which was pressed and oven-dried at 50^0C for 6 hours to get OFSP starch.

Date paste production

The date paste was prepared according to Sanchez et al. (2011). The date was washed under running water to remove dust and macroscopic contamination. It was scalded at 100^0C (1:1 water/fruit) for three minutes; the seeds and peels were removed, and the pulp was ground to paste.

Instant Tigernut-OFSP snack (in chips form) production

The instant tigernut-OFSP snacks with date were prepared according to Ogundipe et al. (2010) with little modifications (by substituting Cassava starch and sugar with OFSP starch and date paste, respectively). The tigernut kernel was sorted and washed. It was then wet milled with a blender into a coarse mash. The date paste and OFSP starch were added to the tigernut coarse mash and properly mixed into a thick slurry. The thick slurry was poured into a baking pan, flattened, divided into square shapes, and baked at 170 ^{0}C for 20 minutes. After the baking process, the snacks were allowed to cool and later packaged, as seen in (Table 1 and Figure 1).

Table 1. Raw material ingredients ratio in grams.

Tigernut	OFSP	Date paste
50	50	30
60	40	30
70	30	30
80	20	30
90	10	30
100	0	30

Proximate composition

Moisture content determination

The moisture, fat, crude protein, ash, and crude fiber content of the fresh OFSP, tigernut, date, and snacks (produced and market sample) were determined using the standard method of AOAC (2010) while the carbohydrate was estimated by difference according to Pearson (1976).

Sensory evaluation

A semi-trained panel of 20 judges made up of (10) male and (10) female staff and students of the Department of Food Science and Technology, Nnamdi Azikiwe University, Awka was used. The panelists were educated on the respective descriptive terms of the sensory scales and requested to evaluate the various Snack samples (produced samples and commercial samples) for taste, color, crunchiness, mouthfeel, and overall acceptability using a 9-point Hedonic scale, where 9 was equivalent to like extremely and 1 meant dislike extremely. Presentation of coded samples was done randomly, and potable water was provided for rinsing of mouth in between the respective evaluations (Iwe et al., 2002).

Total microbial count

The total microbial count was done according to the method described by Uzoaga and Kanu (2020). The Nutrient Agar (for bacteria count) and Potato Dextrose Agar (for fungi count) media were prepared by weighing out appropriate grams of the agars, and dissolving them in their equivalent volumes of distilled water as stipulated by the manufacturer of the various media. The media was sterilized in an autoclave for 15 minutes at 121^{0}C (Uzoaga and Kanu, 2020).

A measured weight of 1 g of the respective samples was added to conical flasks containing 9 ml of sterile nutrient broth. The samples were shaken vigorously to homogenize and allowed to stand for 30 minutes before dilution. Test tubes containing 9 ml of sterile distilled water were set up in a rack and labeled 10^{-1} to 10^{-5}. The ten-fold serial dilution technique was employed in diluting the samples by pipetting 1 ml from the conical flask containing the sample into the tube labeled 10^{-1} and, it was properly mixed. A 1 ml was similarly pipetted from this tube to the second tube labeled 10^{-2}. This was repeated for all the tubes till the 5th tube, and about 1 ml from the 3rd dilution was plated out on Nutrient Agar (NA) and Potato Dextrose Agar (PDA), using the pour plate method of inoculation. Each petri dish was properly labeled and incubated at 37 ^{0}C for NA plates and at room temperature for PDA plates. A colony count was done after 24 hours for bacteria and 48 hours for fungi. The total bacterial/fungal count was expressed in CFU/mL.

Peroxide value

The peroxide value was determined according to the method of Onwuka (2018). About 10 g of the sample was placed in a beaker, about 200 ml of hexane was added, and a foil was used to cork the beaker. It was allowed to stand for 48 hours to enable oil extraction. After 48 hours, the content was filtered, and the filtrate was placed in an oven at 105^{o}C till all the hexane volatilized out. About 1 gram of the oil was weighed into a clean dry boiling tube, and while still in the liquid state, 1 g of powdered potassium iodide and 20 ml of solvent mixture (2 volume glacial acetic acid + 1 volume chloroform) was added. The tube was placed in boiling water to enable the liquid to boil vigorously for not more than 30 seconds. The content was quickly transferred into a flask containing 20 ml of potassium iodide solution (5%). The tube was washed out twice with 25 ml water and was titrated with 0.002 M sodium thiosulphate solution using a starch indicator. A blank was performed at the same time.

$$\text{Peroxide value (Meq Peroxide/kg)} = \frac{\text{S- B} \times \text{M} \times 1000}{\text{Sample weight (g)}}$$

Where: S = Sample titer (mL), B = Blank titer (mL), M = Molarity of thiosulphate

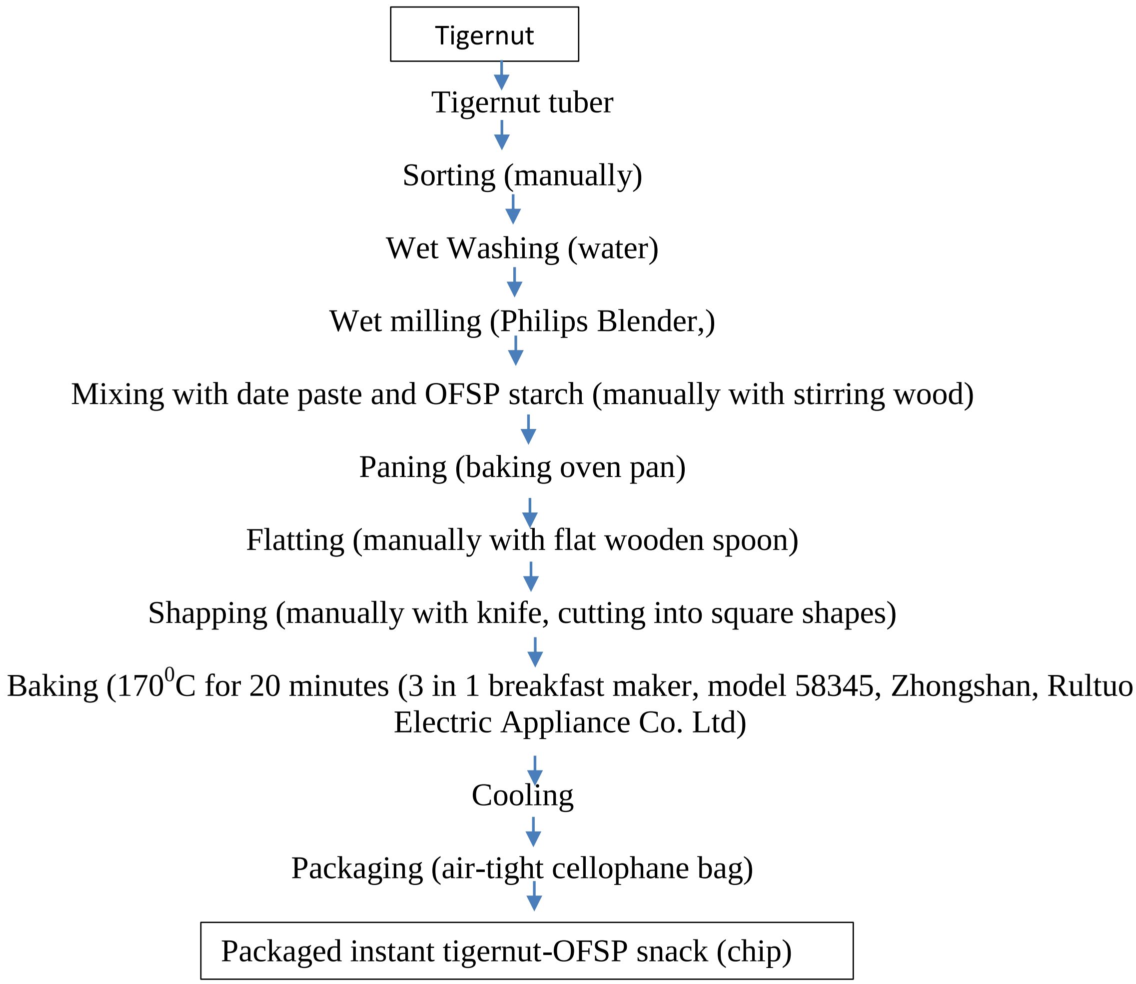

Figure 1. Tigernut-OFSP Instant snack (chip) sweetened with date production (Source: Ogundipe et al., 2010 with little modifications (by substituting Cassava starch and sugar with OFSP starch and date paste, respectively).

Storage of the packaged baked instant snacks

The baked instant tigernut-OFSP snacks with date paste were packaged with an airtight thick polythene pouch and stored at room temperature for a period of three weeks and shelf stability parameters (moisture content, microbial load, and peroxide value) were checked on a weekly basis by picking up one packaged airtight sample from the entire stored instant snack samples.

Statistical analysis

The various results obtained during the study were subjected to statistical analysis of variance (ANOVA) using SPSS version 23 and means separated using the Duncan Multiple Range test where significant differences existed at $p<0.05$.

RESULTS AND DISCUSSION

The proximate composition of the fresh raw samples of tigernuts, date, and OFSP starch

The proximate composition of the fresh raw samples of Tigernut, date, and OFSP starch is presented in (Table 2).

Moisture Content

The moisture contents of fresh tigernut, OFSP, and date were 3.28%, 0.20%, and 73.60%, respectively. The moisture content of tigernut aligns with the findings of Oladele and Aina (2007), who reported 3.25%. The moisture content of the fresh OFSP (Umu spo3 genotype) is consistent with the value of 0.19% reported

Table 2. Proximate composition (%) of the raw samples of tigernuts, date paste and OFSP starch.

Parameter	Tigernut (brown variety)	OFSP (Umusop3) starch	Date paste
Moisture	3.28^{b}±0.20	0.20^{c}±0.10	73.60^{a}±2.0
Protein	9.7^{a}±0.85	1.23^{c}±0.5	1.95^{b}±0.92
Crude fiber	5.62^{a}±0.59	2.0^{b}±0.9	0.34^{c}±0.1
Fat	35.43^{a}±1.37	1.8^{b}±0.8	1.65^{b}±0.6
Ash	4.25^{a}±1.4	1.50^{b}±0.7	0.95^{c}±0.07
Carbohydrate	41.72^{b}±0.1	93.27^{a}±43.97	22.51^{c}±22.77

Values are means ± standard deviation of two replicas. Means with the same superscript along a row shows no significance at (p>0.05).

by Onyemachi et al., (2018) for the OFSP (Lsd genotype at 5 months maturity). Similarly, the moisture content of the date corresponds with Yahaya et al., (2015), who reported 73.61% for variety-01.

Crude Protein Content

The crude protein contents of fresh tigernut, OFSP, and date were 9.70%, 1.23%, and 1.95%, respectively. The crude protein of tigernut closely matches the 9.73% reported by Oladele and Aina (2007). However, the crude protein value of OFSP differs from that reported by Onyemachi et al., (2018), possibly due to differences in species type. The crude protein content of the date aligns with Yahaya et al., (2015), who reported 1.95% for variety-01.

Crude Fiber Content

The crude fiber contents of tigernut, OFSP, and date were 5.62%, 2.00%, and 0.34%, respectively. The crude fiber value of tigernut is consistent with the 5.63% reported by Oladele and Aina (2007). The crude fiber of OFSP is close to the 1.55% reported by Onyemachi et al., (2018) for the NRSP genotype at 5 months maturity. Similarly, the crude fiber content of the date matches the 0.34% reported by Yahaya et al., (2015) for variety-01.

Fat Content

The fat contents of tigernut, OFSP, and date were 35.43%, 1.80%, and 1.65%, respectively. The fat content of tigernut aligns with Oladele and Aina (2007), who reported 35.42%. The fat content of OFSP is comparable to the 1.25% reported by Onyemachi et al., (2018) for the NRSP genotype at 5 months maturity. The fat content of the date is consistent with the 1.67% reported by Yahaya et al., (2015) for variety-01.

Ash Content

The ash contents of tigernut, OFSP, and date were 4.25%, 1.50%, and 0.95%, respectively. The ash content of tigernut matches the 4.25% reported by Oladele and Aina (2007). The OFSP value is similar to the 1.31% reported by Onyemachi et al., (2018) for the NRSP genotype at 5 months maturity. The ash content of the date is close to the 0.98% reported by Yahaya et al., (2015) for variety-01.

Carbohydrate Content

The carbohydrate contents of tigernut, OFSP, and date were 41.22%, 95.27%, and 54.15%, respectively. The carbohydrate content of tigernut is consistent with the 41.22% reported by Oladele and Aina (2007). However, the carbohydrate content of OFSP differs from the 31.87% reported by Onyemachi et al., (2018) for the NRSP genotype at 5 months maturity. This variation may be attributed to differences in the maturity stage, as younger OFSP typically contains higher carbohydrate levels (Onyemachi et al., 2018). The carbohydrate content of the date matches the 54.15% reported by Yahaya et al., (2015) for variety-01.

The proximate composition of instant snacks from Tigernut, OFSP starch, and date blends

The proximate composition of instant snacks made from tigernut, OFSP starch, and date blends is presented in (Table 3).

Moisture Content

The moisture content of the instant tigernut-OFSP snack with date paste samples ranged from 0.10% to 3.00%. No significant difference (p > 0.05) was observed between the commercial sample and other samples,

Table 3. Proximate composition (%) of the instant snack made from Tigernut, OFSP and date paste blends.

Sample (T:OFSP)	Moisture	Protein	Fiber	Fat	Ash	CHO
50:50	$0.70^{c}\pm0.3$	$1.50^{a}\pm0.7$	$1.71^{a}\pm0.8$	$2.24^{a}\pm1.0$	$1.70^{a}\pm0.8$	$92.1^{b}\pm0.4$
60:40	$1.20^{a}\pm0.5$	$1.50^{a}\pm0.7$	$1.71^{a}\pm0.8$	$2.29^{a}\pm1.0$	$2.20^{a}\pm1.0$	$91.2^{c}\pm0.9$
70:30	$0.10^{d}\pm0.1$	$1.50^{a}\pm0.7$	$1.67^{a}\pm0.7$	$2.30^{a}\pm1.0$	$0.40^{c}\pm0.1$	$94.1^{a}\pm0.3$
80:20	$1.00^{c}\pm0.5$	$1.49^{a}\pm0.1$	$1.68^{a}\pm0.7$	$2.18^{a}\pm1.0$	$1.50^{a}\pm0.7$	$92.2^{b}\pm0.4$
90:10	$3.00^{a}\pm1.4$	$1.51^{a}\pm0.7$	$1.67^{a}\pm0.7$	$2.21^{a}\pm1.0$	$0.90^{b}\pm0.4$	$90.8^{d}\pm0.8$
100:0	$2.70^{b}\pm1.3$	$1.52^{a}\pm0.7$	$1.71^{a}\pm0.8$	$2.15^{a}\pm1.0$	$1.00^{b}\pm0.4$	$90.1^{d}\pm0.1$
Com.	$1.00^{c}\pm0.4$	$1.53^{a}\pm0.7$	$1.72^{a}\pm0.8$	$2.12^{a}\pm1.0$	$1.90^{a}\pm0.8$	$91.8^{c}\pm0.2$

Values are means ± standard deviation of two replicas. Means with the same superscript along a column shows no significant at ($p>0.05$). Where T= Tigernut, OFSP= Orange Fleshed Sweet Potato, CHO= Carbohydrate, Com= Commercial sample.

except for the 90:10 tigernut-to-OFSP starch ratio. Variations in moisture content likely reflect differences in the proportions of fresh ingredients. Low moisture levels are consistent with Ogundipe et al., (2010), who found that snacks with moisture content above 12% have reduced storage stability. The recorded low moisture levels (below 5.20-6.50% range reported by Ogundipe et al., 2010) enhance the shelf life of these snacks, as higher moisture levels promote spoilage and microbial growth (Heong et al., 2011).

Crude Protein Content

Crude protein levels ranged from 1.49% to 1.52%, with no significant difference ($p > 0.05$) between the samples and the commercial snack. This suggests that snacks made with 100% tigernut compared favorably with the commercial sample. The protein content in this study was lower than the 6.60-7.50% range reported by Ogundipe et al., (2010). The reduced protein content may result from protein denaturation caused by high oven-drying temperatures, as noted by Bradbury et al., (1999). Despite this, tigernut remains a rich protein source, beneficial for children, lactating mothers, and the elderly (Fedha et al., 2010).

Crude Fiber Content

Crude fiber content ranged from 1.67% to 1.72%, significantly lower than the 5.62% in fresh tigernut. The reduction may result from structural changes during hot air drying, which can cause cell wall breakdown and nutrient loss (Lewicki and Pawlak, 2005). This aligns with observations that high-temperature drying affects food structure and nutrient retention (Aguilera, 2005). The crude fiber content was lower than the 6.25-7.12% reported by Ogundipe et al., (2010), but these snacks remain a good source of fiber, which supports digestion, prevents constipation (Okanlawon, 2000), and reduces cholesterol absorption (Lisa et al., 1997).

Fat Content

Fat content ranged from 2.15% to 2.30%, showing no significant difference ($p > 0.05$) compared to the commercial snacks (2.12%). This result contrasts with the 2.22-11.22% fat content range reported by Ogundipe et al., (2010). The lower fat content likely reflects oil loss during oven drying (Jabeen et al., 2015). Reduced fat levels make these snacks suitable for cardiovascular health and obesity prevention.

Ash Content

Ash content ranged from 0.40% to 2.20%. All samples, including the 100% tigernut snack, compared favorably with the commercial product. These values were lower than the 2.70-3.60% range reported by Ogundipe *et al.* (2010). Differences may result from varietal and agroecological factors, as well as drying processes, which can influence mineral retention (Mohammed et al., 2016).

Carbohydrate Content

Carbohydrate content ranged from 90.1% to 94.1%, significantly higher than the 60.17-69.70% reported by Ogundipe et al., (2010). This is likely due to the high carbohydrate levels in the raw ingredients and the reduction of other components during processing. The high carbohydrate content positions these snacks as an excellent energy source, especially for physically active individuals and children. As Bender (2005) notes, energy content is critical in food formulations for high-energy-demand groups.

The sensory evaluation of the instant snacks made from Tigernut, OFSP starch, and date blends

Table 4 presents the sensory evaluation of instant snacks made from tigernut, OFSP starch, and date blends. Significant differences ($p < 0.05$) were observed in taste, color, mouthfeel, and general acceptability between the control sample (100% tigernut), the other produced samples, and the commercial snacks, except for crunchiness.

The 100% tigernut snack closely matched the commercial snack in sensory attributes, with scores for taste (7.2 vs. 8.32), color (7.32 vs. 8.32), mouthfeel (7.11 vs. 8.21), and general acceptability (7.47 vs. 8.42). The crunchiness scores were also comparable (7.74 vs. 8.21). The sample with a 90:10 tigernut-to-OFSP starch ratio ranked second in overall sensory performance, indicating that a lower ratio of OFSP starch improved sensory attributes and made the snack more competitive with the commercial product, which was made from coconut.

All snacks scored above 7 on the 9-point Hedonic scale, indicating that they were "liked moderately" to "liked very much." Notably, the 100% tigernut snack was the most preferred among the produced samples with a higher acceptance index of 78.20%, making it a strong product for inclusion in the healthy instant snacks category. The general acceptability of the instant tigernut-OFSP snacks with date paste produced ranked higher (7.47) than that reported by Uchechi et al., (2020) and Chinaka, (2024) for biscuits made from wheat and processed tigernut blends (4.89 maximum) and extruded stip snacks from cocoyam (50%), soybean (40%), and tigernut (10%) (transcends 5.00), respectively. However, the three best samples with formulation ratios of 80:20, 90:10, and 100:0 for tigernut: OFSP were subjected to 21 days of room temperature (±27^{0}C) storage.

The moisture content and peroxide value of instant tigernut-OFSP snacks with date paste stored over three weeks at room temperature (%)

Table 5 displays the proximate composition and peroxide value of instant snacks made from tigernut, OFSP starch, and date blends, stored at room temperature for three weeks.

Moisture content

An increasing trend in moisture content was observed across all samples over the three-week storage period. Moisture levels rose from 3.27% to 3.61% for the 80:20 blend, 3.05% to 3.43% for the 90:10 blend, and 2.92% to 3.12% for the 100:0 blend. This suggests the snacks absorbed moisture from the environment, likely due to non-airtight packaging or high room humidity. Gopika and Usha (2020) noted that moisture gain during storage is influenced by temperature, relative humidity, and the quality of packaging materials.

The observed moisture contents exceeded the 2.74% reported by Gopika and Usha (2020), for sweet cookies after 15 days of storage but remained well below the 10% threshold generally specified for flour and dried food products (Ogundipe et al., 2010). These low moisture contents suggest good shelf life and storage stability, as lower moisture levels reduce spoilage and microbial growth (Heong et al., 2011).

Peroxide value

Peroxide values, which indicate the degree of rancidity, also increased over the storage period. For the 80:20, 90:10, and 100:0 blends, values rose from 19.20 to 20.60 meqO_2/g, 18.93 to 20.40 meqO_2/g, and 18.10 to 19.93 meqO_2/g, respectively. The initial values were higher than the 3.08% reported by Gopika and Usha (2020) for masala cookies on their production date, likely due to the 14% fat content of tigernut (Okorie and Onyeneke, 2012).

Despite the increase, peroxide values remained within the acceptable range for food, as rancidity typically occurs when peroxide values exceed 20 to 40 meq/kg (Ajayi et al., 2006). The moderate peroxide values observed may be attributed to the fat content of brown tigernut, which is lower than that of yellow tigernut. Increased moisture content can accelerate primary oxidation, leading to the formation of free radicals and subsequent increases in peroxide values (Gopika and Usha, 2020).

The findings indicate that the instant tigernut-OFSP snacks with date paste remained stable and safe for consumption throughout the three-week storage period. Both the moisture and peroxide values suggest that the snacks can maintain quality and safety beyond this period when stored under similar conditions.

Total microbial count of the instant tigernut-OFSP snacks with date paste stored for three weeks at room temperature.

The total bacterial and fungal counts of the instant snacks made from tigernut, OFSP starch, and date blends during a three-week storage period at room temperature are shown in Tables 6 and 7, respectively.

The bacterial load ranged from 1.92×10^3 to 3.00×10^3 cfu/ml for the 80:20 tigernut and OFSP starch sample ratio over the three-week storage period. At zero weeks (production time), bacterial counts for the 90:10 and 100:0 samples were below detectable limits. This is likely

Table 4. Sensory evaluation of the instant snack made from Tigernut, OFSP and date paste blends.

Samples	Taste	Colour	Crunchiness	Mouthfeel	General acceptability
50:50	5.42^{d}±1.26	5.37^{cd}±0.96	5.79^{b}±1.08	5.89^{c}±0.99	5.32^{d}±0.99
60:40	5.21^{d}±1.13	5.16^{d}±0.83	6.11^{b}±0.94	5.32d±1.11	5.16^{d}±1.21
70:30	5.84^{c}±0.83	5.26^{cd}±0.81	5.53^{b}±1.58	5.42d±0.77	5.47^{d}±0.77
80:20	4.95^{e}±1.18	5.79^{cd}±1.81	5.53^{b}±1.26	6.00^{c}±1.15	5.74^{c}±1.45
90:10	6.26^{c}±1.94	6.05^{c}±1.51	5.53^{b}±1.65	5.89^{c}±1.56	5.89^{c}±1.82
100:0	7.26^{b}±1.41	7.32^{b}±1.42	7.74^{a}±0.87	7.11^{b}±1.56	7.47^{b}±1.39
Commercial	8.32^{a}±0.82	8.32^{a}±0.82	8.21^{a}±1.13	8.21^{a}±0.85	8.42^{a}±0.84

Values are means ± standard deviation of two replicate. Means with the same superscript along a column shows no significant at (p>0.05).

Table 5. The proximate composition and peroxide value of the three best-selected instant snacks made from Tigernut, OFSP starch and date blends stored over 21 days in room temperature (%).

Week	Sample	Moisture content	Peroxide value
0	80:20	3.27^{b}±0.02	19.20^{b}±0.10
	90:10	3.05^{b}±0.30	18.93^{b}±0.30
	100:0	2.92^{c}±0.07	18.10^{c}±0.10
1	80:20	3.33^{b}±0.03	19.80^{a}±0.10
	90:10	3.13^{b}±0.03	19.60^{a}±0.20
	100:0	2.96^{c}±0.01	18.80^{b}±0.20
2	80:20	3.45^{b}±0.02	20.50^{a}±0.10
	90:10	3.25^{b}±0.02	20.10^{a}±0.10
	100:0	3.05^{b}±0.01	19.40^{b}±0.10
3	80:20	3.61^{a}±0.01	20.60^{a}±0.26
	90:10	3.43^{b}±0.01	20.40^{a}±0.10
	100:0	3.12^{b}±0.01	19.93^{a}±0.30

Values are means ± standard deviation of two replicas. Means with the same superscript along a column shows no significant at (p>0.05).

Table 6. Total bacteria count of the three best-selected instant snacks made from Tigernut, OFSP starch, and date blends stored over 21 days in room temperature.

Samples (Tigernut:OFSP starch)	Week 0	Week 1	Week 2	Week 3
80:20	No growth	$1.92^{c} \times 10^{3}$	$2.52^{b} \times 10^{3}$	$3.0^{a} \times 10^{3}$
90:10	No growth	No growth	No growth	No growth
100:0	No growth	No growth	No growth	No growth

Values are means ± standard deviation of two replicas. Means with the same superscript along a row shows no significance at (p>0.05) OFSP = Orange fleshed sweet potato.

due to the baking process, which effectively destroyed and inactivated the microorganisms present in the snacks at production (Giwa and Ibrahim, 2012). The 80:20 ratio, however, had higher moisture content (as shown in Table 4), which could have contributed to the bacterial growth observed during storage.

Table 7. Total fungi count of the three best-selected instant snacks made from Tigernut, OFSP starch, and date blends stored over 21 days in room temperature.

Samples (Tigernut:OFSP starch)	Week 0	Week 1	Week 2	Week 3
80:20	No growth	No growth	No growth	$1^{c} \times 10^{3}$
90:10	No growth	No growth	No growth	$2^{b} \times 10^{3}$
100:0	No growth	No growth	No growth	$6^{a} \times 10^{3}$

Values are means ± standard deviation of two replicas. Means with the same superscript along a column shows no significant at (p>0.05) OFSP = Orange fleshed sweet potato.

After three weeks of storage, the bacterial counts for all samples remained within acceptable limits (1,920–3,000 cfu/ml), well below the microbiological standard for snacks (TVC < 100,000 cfu/ml) as outlined by Giwa and Ibrahim (2012). This indicates that the snacks remained shelf-stable and safe for consumption even after three weeks of storage.

Fungal growth was undetectable in all samples from zero weeks to week two of storage. However, by the third week, fungal growth was observed, with counts ranging from 1 cfu/ml for the 80:20 ratio, 2 cfu/ml for the 90:10 ratio, and 6 cfu/ml for the 100:0 ratio. The sample with the highest fungal count (100:0) can be attributed to its lower moisture content (3.12%) compared to the other samples (3.61% and 3.43%) as shown in Table 5.

These fungal counts are still within the acceptable consumption limit of 1,000 cfu/g, as reported by Giwa and Ibrahim (2012). This finding aligns with the results reported by Gopika and Usha (2020) for sweet cookies, which showed no fungal growth after 45 days of storage. The fact that the major spoilage organisms for tigernut are bacteria, not fungi, may explain the low fungal growth observed (Chukwu et al., 2013).

The results indicate that the snacks remain microbiologically safe throughout the three-week storage period, with both bacterial and fungal counts well within acceptable limits for human consumption.

CONCLUSION

The instant tigernut-OFSP snacks with date paste analyzed are rich in protein, fiber, ash, and carbohydrates, making them energy-dense and suitable for physically active individuals, including children. With their high carbohydrate and low-fat content, these snacks provide a healthier alternative to traditional high-fat options associated with cardiovascular risks. While the raw tigernut exhibited notable protein (9.70%), fiber (5.6%), and ash (4.23%) levels, these values decreased during processing due to the application of heat.

Sensory evaluation favored the 100% tigernut and 30% date (100:0) sample, with ratings for color, taste, mouthfeel, and overall acceptability comparable to that of commercial snacks. Additionally, the snacks demonstrated competitive crunchiness, enhancing their appeal.

Shelf stability tests confirmed that the snacks remained safe for consumption up to three weeks, with bacterial and fungal counts within acceptable microbiological limits. Although moisture and peroxide values showed slight increases during storage, the peroxide levels remained within safe limits.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest

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