



SENSORY ACCEPTABILITY AND STORAGE STABILITY OF TIDBITS PRODUCED WITH FLOUR FROM CASSAVA AND BAMBARA NUT

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Abstract: The study evaluated the sensory acceptability and storage stability of tidbits made with flour from cassava and Bambara nut. Tidbits were produced with blends of flour as depicted by a simplex lattice mixture design using Design Expert software (Version 12.0). The tidbits with the highest overall acceptability scores were packaged in a high-density polyethylene bag, stored for a period of two months, and analyzed for physical, chemical, and microbial properties. The results obtained for the sensory acceptability showed that samples 80:20, 70:30, and conventional (i.e., 30% cowpea flour and 70% HQCF) tidbits were accepted by most of the panelists. The range of values for lightness, redness, and yellowness of samples 80:20, 70:30, and conventional tidbits were: 8.31-46.08, 3.73-28.10, and 13.73-49.73, respectively. The microbial evaluation of tidbits after two months of storage revealed that the sample with 80% high-quality cassava flour and 20% Bambara nut flour was found to be the most sterile. These results underscore the impact of ingredient composition, packaging materials, and storage conditions on the microbial quality of the tidbits throughout the storage period. Importantly, all samples maintained total microbial counts within acceptable safety limits.

Keywords: Bambara nut, cassava, consumer acceptability, microbial quality, storage stability, tidbits

1. Introduction

The increasing demand for nutritious, shelf-stable, and sensory appealing food products has driven innovations in the use of cassava (*Manihot esculenta*) and an underutilized crop such as Bambara nut (*Vigna subterranea*) in composite flour production. Tidbits are fried, crunchy snack food products that are widely consumed across many countries, but consumption is higher in countries with strong snacking culture and convenience food market, i.e., the United States, Australia, and Argentina, with an estimated 124.1 kg, 121.6 kg, and 109.4 kg per person per year, respectively [1]. Globally, there are urgent concerns about food and nutrition insecurity, with significant potential for sustainability contributions. In

an attempt to address this problem, diversification of the agricultural system for alternative food for humans is encouraged. Cassava is a starchy root crop widely cultivated in Sub-Saharan Africa, known for its high carbohydrate content, low cost, and processing adaptability [2]. However, cassava is inherently low in protein and other essential nutrients, necessitating its combination with legumes like Bambara nut to enhance its nutritional profile. Bambara nut is a drought-resistant legume rich in protein, essential amino acids, and functional food components such as dietary fibre and antioxidants [3]. The sensory acceptability of food products encompassing taste, texture, aroma, appearance, and overall acceptability is crucial in determining consumer

preference and marketability. Previous studies have shown that composite flours from cassava and legumes can be successfully incorporated into baked and fried goods without compromising sensory attributes [4]. Specifically, the inclusion of Bambara nut flour has been found to improve the flavor and mouthfeel of products due to its nutty taste and emulsifying properties [5]. Storage stability is critical for ensuring product quality and safety over time. Storage stability of a newly developed food product, to a great extent, determines its commercial success [6]. Parameters such as moisture content, lipid oxidation, microbial load, and sensory deterioration are important indices in evaluating the storage stability of tidbit products. The interaction between cassava starch and Bambara nut protein may influence the water activity and structural matrix of the eventual food product being developed, potentially extending shelf life [7]. Moreover, the antioxidant potential of Bambara nut could help reduce oxidative rancidity during storage. Given the nutritional synergy and functional benefits of cassava and Bambara nut flours, investigating the sensory acceptability and storage stability of tidbits formulated from their blends is essential. This not only supports value addition to indigenous crops but also aligns with global efforts to promote food security, sustainable agriculture, and the development of functional snack foods. Therefore, the study assessed sensory acceptability and storage stability of tidbits produced with flour from cassava and Bambara nut.

2. Materials and methods

2.1. Materials

Cassava roots (IITA-TMS-0700593) were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, and Bambara groundnut from a local farm at Mokwa, Niger State. Other ingredients such

as vegetable oil, crayfish, spice, and salt were procured at Mandate market, Ilorin, Kwara State, Nigeria.

2.2. Preparation of high-quality cassava flour (HQCF)

The high-quality cassava flour (HQCF) used for the study was produced from four varieties of low postharvest physiologically deteriorated (PPD) and one variety of high postharvest physiologically deteriorated (PPD) cassava, with a flash dryer with a model (LPG series) was used to rapidly dry cassava mash into fine flour using hot air, ensuring low moisture content and good product quality as described by Alimi et al. [8]. The flow chart for the production of HQCF is presented in Figure 1.

2.3. Production of Bambara nut flour

Wholesome Bambara nut seeds (var. SAMNUT 21) were sourced from Mokwa, Niger State, and manually sorted to eliminate defective seeds and extraneous materials, ensuring quality control (raw material selection). Seeds were soaked for 24 h with periodic decanting every 6 h to promote dehulling and leaching of anti-nutritional factors, minimizing nutrient degradation (hydration and pre-treatment). Sprouting was conducted for 72 h to induce biochemical transformations, reducing carbohydrate and lipid concentrations while enhancing protein content and amino acid bioavailability (malting). Post-germination, seeds were dried in two phases: first at 70 °C for 14 h to achieve $\leq 12\%$ moisture, followed by solar-assisted drying at 60 °C for 24 h using a parabolic solar dryer (NSPRI-PSSD) to stabilize the malted product (drying technique).

Dried seeds were finely milled, using a mechanical hammer mill (GFS-18 model) into fine particle flour, sieved (250 μm), and packaged in high-density polyethylene bags to preserve functional and nutritional integrity ahead of analysis (Milling and Packaging) [5,9,10,11].

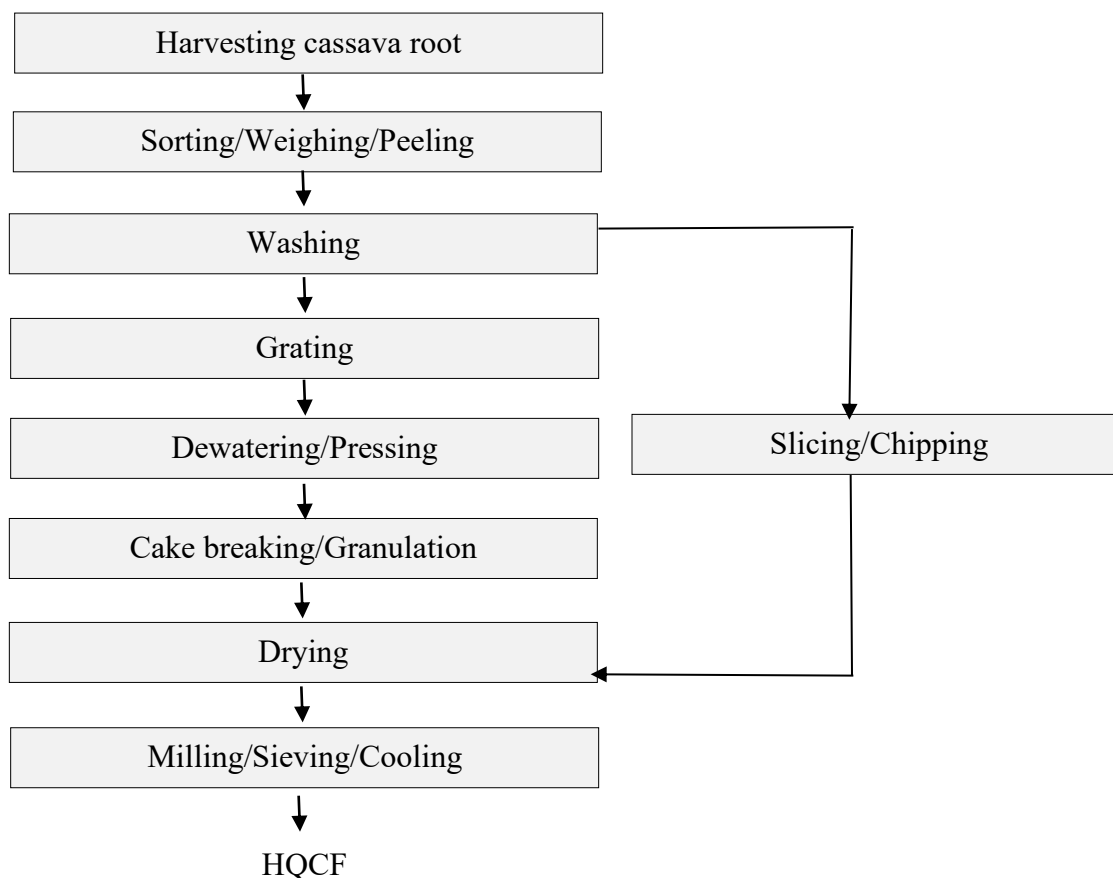


Fig. 1. Flow chart for the production of high-quality cassava flour [8]

2.4. Experimental design

D-optimal simple lattice design (version 12.0), for two-component mixtures expanded with internal points with constraints, was used to investigate some attributes as well as sensory, physical, chemical, and microbial qualities of flour mixtures composed of high-quality cassava flour (X_1) and Bambara nut (X_2) as independent variables and some quality attributes of tidbits, made from these

mixtures, as dependent variables. A total of eight combinations were generated, as shown in Table 1.

2.5. Preparation of the flour blends

One hundred grams (100 g) each, comprising high-quality cassava flour and Bambara nut flour, were blended as depicted by the design expert. The blended flour was used for the production of the tidbits, as indicated in the formulation and recipe.

Table 1.

Blending ratio of the constituent flours			
S/N	HQCF (g)	BNF (g)	SAMPLE CODE
1	80.00	20.00	HQCF ₈₀ BNF ₂₀
2	65.00	35.00	HQCF ₆₅ BNF ₃₅
3	70.00	30.00	HQCF ₇₀ BNF ₃₀
4	60.00	40.00	HQCF ₆₀ BNF ₄₀
5	75.00	25.00	HQCF ₇₅ BNF ₂₅
6	80.00	20.00	HQCF ₈₀ BNF ₂₀
7	60.00	40.00	HQCF ₆₀ BNF ₄₀
8	70.00	30.00	HQCF ₇₀ BNF ₃₀

2.5. Production of tidbits

The method of Alimi et al. [8], with slight modification, was used. Each flour blend and proportionate ingredients (crayfish, onion/pepper, salt, and Maggi at 4 g, 136 g, 4 g, and 4 g respectively) were mixed thoroughly in 200 mL of water.

Each sample was extruded into the groundnut hot oil to which sliced onion was added for additional flavor, fried in a deep hot vegetable oil until golden brown at 190 °C for 12 min. using a deep fryer (Model:Moulimex). The fried Tidbits were allowed to cool at room temperature (25 °C) for 25 min. and then subsequently packed into high-density polyethylene for airtightness to prevent moisture absorption.

2.6. Sensory evaluation of the tidbits

Clearance was obtained from the ethical committee of the Department of Food Processing, Nigeria Stored Products Research Institute.

No coercion to participate, full disclosure of study requirements and risks were explained to the participant as a group. There was no release of panelists' data without their knowledge, and the participant has the ability to withdraw from the sensory evaluation at any time.

Sensory evaluation of the tidbit samples was done individually immediately after the frying process at the sensory laboratory under fluorescent light and ambient temperature (26 ± 2 °C). A group of fifty (50) semi-trained panelists consisting of industrial students and staff of Nigeria Stored Products Research Institute, who were familiar with tidbits, were asked to score the sensory attributes (texture, crunchiness, colour, appearance, aroma, and overall acceptance).

Each tidbit was evaluated based on its degree of likeness using a scale of 1–9, where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely, using the technique explained by Iwe [12].

2.7. Storage stability analyses of the tidbits

The most acceptable tidbit from sensory evaluation was packed in an air-tight high-density polyethylene bag and stored under ambient conditions of 26 ± 2 °C at 60% R.H for 2 months. Mainly to observe significant changes and help to assess the shelf life, stability, and overall quality of fried tidbit snacks, as it provides reliable data for recommending shelf life and suitable storage conditions. Samples were taken every month and subjected to physical, chemical, and microbial analysis.

2.8. Changes in the physical properties of tidbits

2.8.1. Colour properties

The chromatic profile of the tidbit was evaluated employing a Minolta CR-410 chromameter (Konica Minolta, Japan), following methodological frameworks outlined by [13,14]. Before analysis, the device underwent calibration using a standard protocol involving the zero-calibration mask and a white reference plate to ensure measurement accuracy.

The tidbit samples were placed on sterile petri dishes for imaging, enabling the precise acquisition of surface colour metrics. Key parameters recorded included lightness (L^*), red-green component (a^*), and yellow-blue component (b^*), essential indicators of visual quality and product appeal.

2.8.2. Changes in the chemical properties of tidbits during storage

2.8.2.1. Determination of moisture content

Moisture content analysis was conducted following the procedure outlined by AOAC [15]. Precisely 5 g of the sample were introduced into a pre-dried and pre-weighed moisture container. This container, along with its contents, was subsequently placed in a GALLENKAMP oven model SG3–08–169 (UK) and subjected to heating at 105 °C for 3 h. post-heating, the sample was removed and allowed to cool in a desiccator to prevent

moisture uptake from the environment. After cooling, the container was reweighed. This cycle of heating for one additional hour, followed by cooling and weighing, was repeated until a constant mass was attained. Moisture content was then computed based on the total weight loss observed, using the standard calculation formula:

$$\text{Moisture content} = \frac{W_1 - W_2}{W} \times 100 \quad (1)$$

Where W_1 = Weight of pan + fresh sample;
 W_2 = weight of pan + dry sample
 W = Weight of sample

2.8.2.2. Determination of free fatty acid (FFA)

Free fatty acid content was quantified following the analytical procedure established by Pearson's [16]. A 5-gram portion of each sample was placed in a 250 mL Erlenmeyer flask. Subsequently, 50 mL of a neutral solvent mixture comprising diethyl ether and ethanol was introduced, along with 0.5 mL of phenolphthalein indicator. The mixture was stirred thoroughly to ensure complete dissolution of the sample. The resulting solution was then titrated with 0.1 M sodium hydroxide (NaOH) until a stable pink hue was observed for 15 seconds, indicating the endpoint of the titration. The volume of NaOH required to reach this endpoint was recorded as the titre, and the FFA percentage was calculated, expressed as linolenic acid, the predominant fatty acid present in the extrudates.

$$\% \text{ FFA} = \text{Titre value} \times 0.0276 \text{ g} \times 100/\text{wt} \quad (2)$$

Where, W_t = Weight of sample; 0.0276 g = Molecular weight of linolenic

2.8.2.3. Determination of acid value

A 5-gram portion of the sample was precisely weighed into a 250 mL volumetric flask. To this, 50 mL of a solvent system comprising equal parts ethanol and diethyl ether, neutralized using 0.5 M potassium hydroxide, was introduced. The mixture was heated for 10 min. to facilitate thorough

dissolution, then allowed to cool to room temperature. Following this, 1 mL of phenolphthalein indicator was added, and the flask contents were vigorously shaken to ensure proper mixing. The solution was titrated against 0.5 M potassium hydroxide until a persistent pink coloration was observed for approximately 15 seconds, indicating the titration endpoint [17]. A blank titration, following identical steps but without the sample, was conducted in parallel. The acid value was then determined using the appropriate calculation formula.

$$\text{Acid Value} = \frac{TD \times N \times 56.1}{M} \quad (3)$$

Where TD = Titre differences = B – S
B = Titre value blank; S = Titre value of sample
M = Molarity of the titrating solution, KOH used herein
M = Mass of sample (g)

2.8.3. Changes in the microbial quality of tidbits during storage

The method explained by Amankwah et al. [18] was used for the microbiological analysis of the tidbit samples. Tidbit from cassava and Bambara nut flour was subjected to microbiological analyses (total bacteria and mould counts) instantly after frying and during storage. One gram of the fried tidbit was serially diluted by dissolving in 9 mL of distilled water. Using the pour plate process, each diluent was plated out on a nutrient agar for bacterial count and a Potato dextrose agar for fungal counts. The plates were then incubated at 37 °C for 48 h for bacterial growth and at 27 °C for 72 h for fungal growth.

2.9. Statistical analysis

Each analysis was carried out in three replications. Data obtained from this study were subjected to statistical analysis. Means, analysis of variance was carried out using SPSS version 21.0, and the differences

between the mean values were evaluated at $p \leq 0.05$ using Duncan's multiple range test.

3. Results and Discussion

3.1. Sensory acceptability of the tidbits

This discussion evaluates the sensory attributes of tidbits produced from various combinations of High-quality cassava flour (HQCF), Bambara nut flour (BNF), and cowpea flour (CPF), as presented in Table 2. The sensory attributes assessed include appearance, colour, aroma, taste, texture, crunchiness, and overall acceptability. The appearance and colour of the tidbit samples with higher proportions of HQCF (HQCF70% + CPF30% and HQCF70% + BNF30%) recorded the highest appearance scores (7.52±1.42 and 7.16±1.43, respectively). In contrast, the sample with wheat flour (WF60% + BNF40%) had the lowest score (4.48±2.02), suggesting that consumers preferred the visual appeal of cassava-based tidbits over those made with wheat. This is consistent with Adebowale [19], who reported that cassava-based snacks exhibit a desirable light-yellow appearance and better uniformity. Aroma scores ranged

from 4.92±1.98 (WF60% + BNF40%) to 7.16±1.73 (HQCF80% + BNF20%). Cassava-rich samples tended to have better aroma, likely due to less beany odor. Ajayi [20] noted that Bambara nut, when properly processed, can improve aroma due to its nutty and mildly sweet scent. Taste was highest in HQCF70% + CPF30% (7.08±1.80) and lowest in WF60% + BNF40% (3.64±1.87). The more acceptable taste of cassava-legume blends may stem from a natural sweetness and protein balance. This agrees with findings by Onwuka [21]. Texture and crunchiness were notably high in HQCF80% + BNF20% and HQCF70% + CPF30%. HQCF contributes to firmer, crispier textures, as observed by Otegbayo [22], due to its higher starch and low-fat contents. The lowest values were recorded in the wheat-based sample. HQCF70% + CPF30% had the highest acceptability (7.40±1.92), followed by HQCF80% + BNF20% 7.20±1.35). The wheat sample was least accepted (3.88±1.72). These results align with Chikwendu [23], who highlighted the superior acceptability of cassava-legume snacks.

Table 2.

Sensory scores of the tidbits produced with flour from cassava and Bambara nut

Samples	Appearance	Colour	Aroma	Taste	Texture	Crunchiness	Overall acceptability
HQCF _{80.00} :BNF _{20.00}	6.92±1.31 ^{bc}	7.04±1.28 ^{bc}	7.16±1.73 ^{bc}	6.80±1.76 ^d	6.96±1.57 ^d	7.80±1.92 ^d	7.20±1.35 ^{de}
HQCF _{65.00} :BNF _{35.00}	7.04±1.43 ^{bc}	6.96±1.10 ^{bc}	6.64±1.47 ^{bc}	6.08±1.58 ^{cd}	5.96±1.79 ^{cd}	5.72±1.79 ^c	6.32±1.46 ^{cd}
HQCF _{70.00} :BNF _{30.00}	7.16±1.07 ^{bc}	6.80±1.12 ^{bc}	6.72±1.54 ^{bc}	6.96±1.40 ^d	6.88±1.47 ^d	7.32±1.82 ^d	7.16±1.18 ^{de}
HQCF _{60.00} :BNF _{40.00}	6.92±1.12 ^{bc}	6.48±1.23 ^b	6.00±1.56 ^b	5.28±1.84 ^{bc}	5.24±1.45 ^{bc}	5.04±1.24 ^c	5.80±1.23 ^{bc}
HQCF _{75.00} :BNF _{25.00}	7.00±1.35 ^{bc}	6.88±0.93 ^{bc}	6.76±1.51 ^{bc}	6.40±1.53 ^d	6.28±1.57 ^d	6.76±1.88 ^d	6.60±1.35 ^{cde}
HQCF _{80.00} :BNF _{20.00}	6.92±1.31 ^{bc}	7.04±1.28 ^{bc}	7.16±1.73 ^{bc}	6.80±1.76 ^d	6.96±1.57 ^d	7.80±1.92 ^d	7.20±1.35 ^{de}
HQCF _{60.00} :BNF _{40.00}	6.92±1.12 ^{bc}	6.48±1.23 ^b	6.00±1.56 ^b	5.28±1.84 ^{bc}	5.28±1.45 ^{bc}	5.04±1.24 ^c	5.80±1.23 ^{bc}
HQCF _{70.00} :BNF _{30.00}	7.16±1.43 ^{bc}	6.80±1.12 ^{bc}	6.24±1.54 ^{bc}	6.96±1.40 ^d	6.88±1.47 ^d	7.32±1.82 ^d	7.16±1.18 ^{de}
WF _{60.00} :BNF _{40.00}	4.48±2.02 ^a	4.92±2.08 ^a	4.92±1.98 ^a	3.64±1.87 ^a	3.04±1.54 ^a	2.40±1.47 ^a	3.88±1.72 ^a
HQCF _{70.00} :CPF _{30.00}	7.52±1.42 ^c	7.56±1.26 ^c	7.04±1.59 ^c	7.08±1.80 ^d	6.80±2.07 ^d	7.60±1.73 ^d	7.40±1.92 ^c

Values are mean ± standard deviation. Mean values with different superscripts within the same column are significantly different at 5% level. HQCF: High-quality cassava flour; BNF: Bambara nut flour; WF: Wheat Flour; CPF: Cowpea flour

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3.2. Changes in the colour properties of the tidbit during storage

Colour attributes such as lightness (L^*), redness (a^*), and yellowness (b^*) are critical indicators of product appeal and are influenced by ingredient composition, processing, and storage conditions Wang [24]. Lightness (L^*) reflects how bright or dark a sample is, Redness (a^*) measures the intensity of red-green tones, and Yellowness (b^*) represents blue-yellow shades. At month 0 (fresh samples): All samples displayed relatively high L^* values, indicating good initial brightness. This is an important quality attribute influencing consumer acceptance. This indicates minimal pigment degradation, oxidation, or browning reactions at the initial stage of storage. It also reflects that the processing conditions used during production preserved the natural color characteristics of the product [25]. Sample HQCF₇₀CPF₃₀ had the lowest L^* (33.85), suggesting a darker appearance, possibly due to cowpea flour's natural pigments. This study explains that cowpea seed coats contain natural pigments such as phenolic compounds and flavonoids responsible for cream, red, brown, and black colour variations, which influence flour colour and food product appearance [26]. This same sample also had significantly higher a^* (28.10) and b^* (73.52), showing a

deeper reddish-yellow colour, likely due to increased Maillard reaction precursors and pigmented proteins in cowpea flour [27]. After 1 month of storage, all samples showed a dramatic drop in lightness (L^*). This may be attributed to moisture migration and non-enzymatic browning reactions, particularly Maillard and caramelization [28]. The redness (a^*) and yellowness (b^*) values also decreased across the board, indicating loss of red and yellow tones. This is consistent with storage-related oxidative processes and the breakdown of polyphenolic compounds reported in comparable cereal- legume snack products [29].

After 2 months of storage, a slight recovery in lightness (L^*) was observed for HQCF₈₀BNF₂₀ and HQCF₇₀BNF₃₀, but HQCF₇₀CPF₃₀ continued to decline. Reduction in a^* values continued, indicating sustained degradation of red pigments. b^* values dropped notably, especially for HQCF₇₀CPF₃₀, which may reflect a significant loss of carotenoids or flavonoids under storage [30]. Storage stability hurts sensory appeal by altering colour.

This aligns with the findings of Ezeocha [31], who found that cassava-based snacks exhibited significant colour changes due to lipid oxidation and protein-sugar interactions.

Table 3.

Changes in colour properties of the tidbits during storage				
Months	Sample	Lightness	Redness	Yellowness
0	HQCF ₈₀ BNF ₂₀	45.97±2.33 ^a	16.58±0.63 ^a	47.10± 1.91 ^a
	HQCF ₇₀ BNF ₃₀	46.08±1.01 ^a	15.60±2.60 ^a	49.73±2.43 ^a
	HQCF ₇₀ CPF ₃₀	33.85±7.52 ^a	28.10±1.62 ^b	73.52±10.07 ^a
1	HQCF ₈₀ BNF ₂₀	10.87±0.66 ^a	6.33±0.40 ^a	15.57±0.34 ^a
	HQCF ₇₀ BNF ₃₀	10.70±0.60 ^a	6.42±0.10 ^a	15.26±0.55 ^a
	HQCF ₇₀ CPF ₃₀	13.62±3.21 ^a	7.38±3.02 ^a	15.24±.01 ^a
2	HQCF ₈₀ BNF ₂₀	15.86±3.56 ^a	5.00±0.28 ^a	21.24±1.85 ^b
	HQCF ₇₀ BNF ₃₀	17.59±1.89 ^a	4.78±0.42 ^a	21.92±1.44 ^b
	HQCF ₇₀ CPF ₃₀	8.31±1.03 ^a	3.73±1.24 ^a	13.73±1.62 ^a

Values are mean ± standard deviation. Mean values with different superscripts within the same column are significantly different at 5% level. HQCF: High-quality cassava flour; BNF: Bambara nut flour; WF: Wheat Flour; CPF: Cowpea flour

3.3. Changes in the moisture content of the tidbits during storage

The moisture contents of tidbits produced from cassava and Bambara nut during storage are presented in Fig. 2. The moisture contents of tidbits from month 0 to month 2 ranged from 4.16% to 4.34%, 5.51% to 7.04%, and 6.41 to 8.32%, respectively. An increase in the moisture content of the tidbits as storage duration progresses is mainly due to moisture absorption from humid air (hygroscopic nature of the product), water vapor transfer through semi-permeable packaging materials, and moisture migration within the food matrix over time.

These processes are driven by environmental humidity and storage conditions, resulting in gradual moisture gain over prolonged storage [32]. Such a trend is common in baked or fried snacks, especially when stored in humid conditions or non-moisture-proof packaging. Increased moisture can lead to textural degradation and microbial spoilage, and can accelerate chemical reactions such as lipid hydrolysis.

This observation is supported by Otegbayo [33], who found that cassava-based snacks showed similar moisture absorption behavior during storage in humid environments.

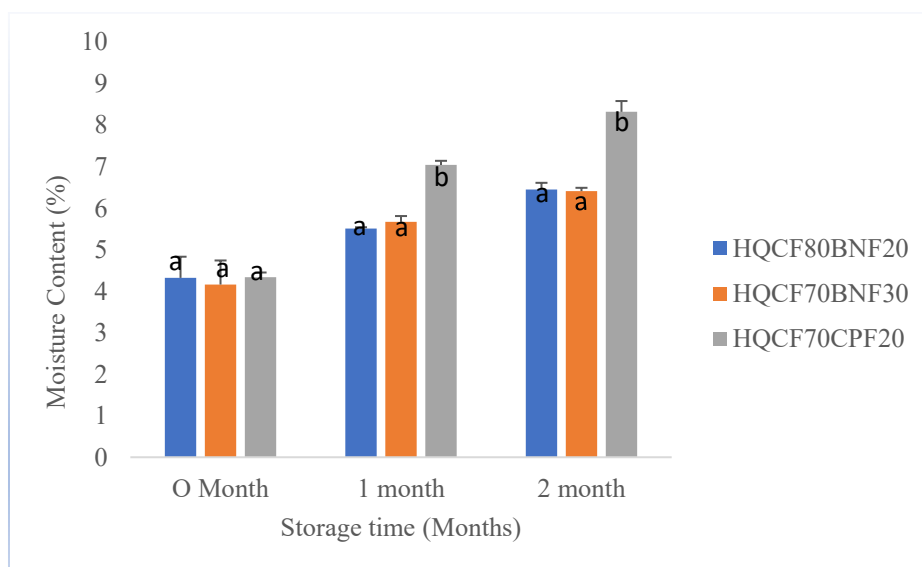


Fig. 2. Change in the moisture content of the tidbit during storage

3.4. Changes in the acid value of tidbit during storage

The changes in acid value of tidbit during storage is presented in Fig. 3, acid values of tidbit from month 0 – month 2 ranged from 0.10 to 0.41 mg KOH/g, 0.43 to 1.21 mg KOH/g, and 0.61 to 2.18 mg KOH/g, from month 0 to month 2, respectively.

There was a relative increase in the acid value of the tidbits over the storage period,

indicating hydrolytic rancidity caused by the release of free fatty acids from triglycerides. This degradation is likely catalyzed by lipase activity, moisture, or oxygen exposure during storage [34].

According to Adebowale [35], lipid-rich legume-based flours like Bambara nut are particularly prone to acid value increases, especially under sub-optimal storage conditions.

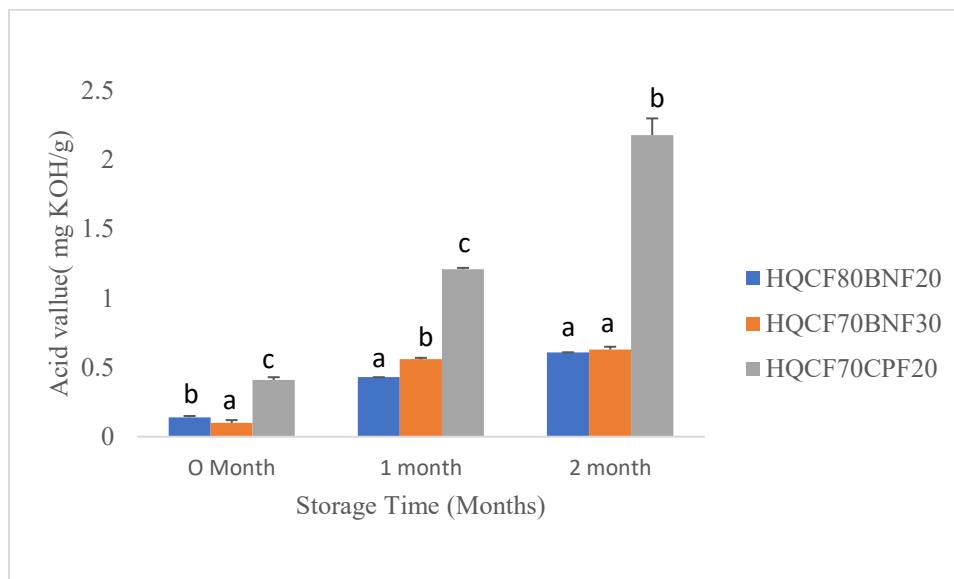


Fig. 3. Change in acid value of the tidbit during storage

3.5. Changes in the free fatty acid (FFA) of tidbit during storage

The changes in the free fatty acid values of the tidbits produced with blends of flour from cassava and Bambara nut during storage are presented in Fig. 4. The free fatty acid values of the tidbits have a range of values 0.05-0.21%, 0.22-0.61%, and 0.31-1.09% from month 0 to month 2, respectively. This figure shows a steady increase in FFA content throughout the storage period. Free fatty acids result from enzymatic hydrolysis of fats, often exacerbated by moisture uptake and lipase activity [36]. Omodamiro & Akpabio [37] observed a similar trend in cassava-legume composite snacks and highlighted that the presence of unsaturated fats in Bambara nut flour makes the product highly sensitive to lipid degradation over time.

3.6. Changes in microbial qualities of the tidbits during storage

The initial total viable microbial counts (month 0) for tidbits produced using high-quality cassava flour (HQCF) and Bambara nuts are presented in Table 4. Total bacteria count ranged from 6.0×10^3 to 3.2×10^4

CFU/g among samples HQCF₈₀BNF₂₀, HQCF₇₀BNF₃₀, and HQCF_{70.00}CPF_{30.00}, with sample HQCF_{70.00}CPF_{30.00} exhibiting the highest count and sample HQCF₇₀BNF₃₀ the lowest. These variations may be attributed to the inherent microflora of HQCF and Bambara nuts, environmental exposure, and handling during tidbit production. Notably, no growth was detected for coliforms and fungi during month 0, indicating an absence of fecal contamination and airborne spores. Sample HQCF₇₀BNF₃₀ was observed to be the most sterile at this initial stage. By month 1, total bacterial counts ranged from 2.0×10^3 to 1.1×10^5 CFU/g, with sample HQCF₈₀BNF₂₀ recording the highest count and sample HQCF_{70.00}CPF_{30.00} the lowest. Coliform counts ranged from 3.0×10^3 to 1.2×10^5 CFU/g, again with sample HQCF₈₀BNF₂₀ showing the highest load and sample HQCF_{70.00}CPF_{30.00} the lowest. Fungal counts were between 2.4×10^4 and 3.0×10^5 CFU/g, with sample HQCF₇₀BNF₃₀ recording the highest and samples HQCF₇₀BNF₃₀ and HQCF_{70.00}CPF_{30.00} displaying the lowest. Sample HQCF_{70.00}CPF_{30.00} was determined to be the

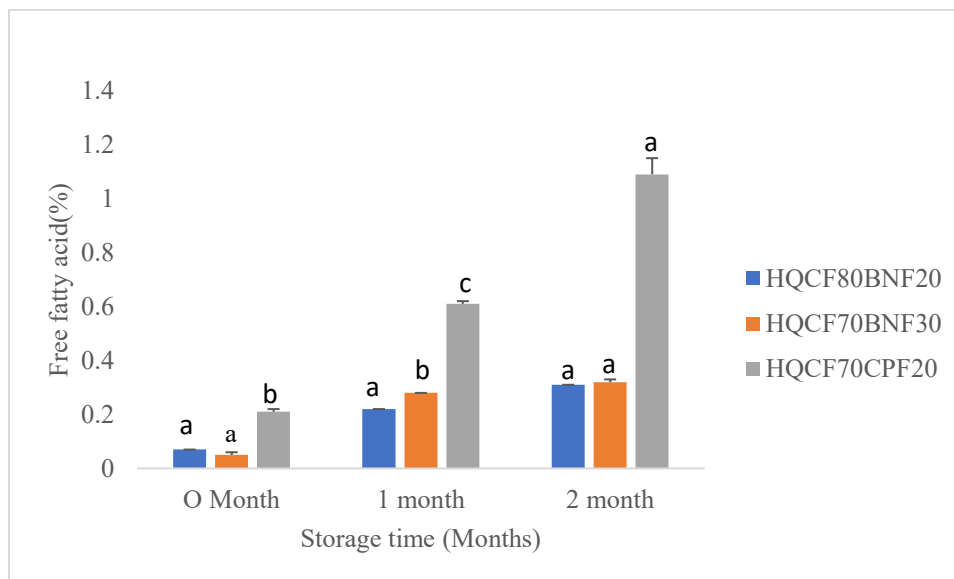


Fig. 4. Change in the free fatty acid of tidbit during storage

most sterile at this stage. By month 2, total bacterial counts increased to a range of 1.5×10^5 to 2.3×10^5 CFU/g, with sample HQCF₇₀BNF₃₀ showing the highest count and sample HQCF₈₀BNF₂₀ the lowest. Coliform counts ranged from 3.7×10^4 to 1.3×10^5 CFU/g, with sample HQCF₈₀BNF₂₀ recording the highest and sample HQCF₇₀BNF₃₀ recording the lowest. Fungal counts varied between 4.8×10^4 and 9.6×10^4 CFU/g, with sample HQCF₈₀BNF₂₀ once again showing the highest count and sample HQCF₇₀BNF₃₀ the lowest. These microbial levels remain within the acceptable threshold of $5.30 \log_{10}$ CFU/mL, as recommended by the International Commission on Microbiological Specifications for Foods [30], and also align with the Standards Organization of Nigeria (SON) guidelines, which permit aerobic plate counts between 10^4 and 10^6 CFU/g or mL for food products. Notably, at Month 2, sample HQCF₈₀BNF₂₀ was found to be the most

sterile, followed by sample HQCF_{70.00}CPF_{30.00}, while sample HQCF₇₀BNF₃₀ exhibited the least sterility. The fluctuations in microbial counts observed across the samples over time may be influenced by antagonistic and synergistic interactions of probiotic microorganisms within the medium, which can suppress pathogenic species.

The suspected microorganisms isolated include: *Bacillus* spp., *Staphylococcus aureus*, *Escherichia coli*, *Enterobacter aerogenes*, *Saccharomyces cerevisiae*, *Candida* spp., *Aspergillus flavus*, *Aspergillus niger*, *Fusarium* spp., *Rhizopus* spp., and *Penicillium* spp. The microbial profiles of individual samples are shaped by multiple factors, including: the quality and composition of raw ingredients and utensils used, packaging materials, storage conditions, water activity (a_w), moisture content, and hygiene practices during handling, particularly during packaging.

Table 4.

Changes in microbial properties of tidbits during storage				
Month	Samples	Total heterotrophic counts (cfu/g)	Total coliform counts (cfu/g)	Total fungal counts (cfu/g)
0	HQCF ₈₀ BNF ₂₀	2.4 x 10 ⁴	0	0
	HQCF ₇₀ BNF ₃₀	6.0 x 10 ³	0	0
	HQCF _{70.00} CPF _{30.00}	3.2 x 10 ⁴	0	0
1	HQCF ₈₀ BNF ₂₀	1.1 x 10 ⁵	1.2 x 10 ⁵	3.0 x 10 ⁵
	HQCF ₇₀ BNF ₃₀	2.3 x 10 ⁴	3.2 x 10 ⁴	2.5 x 10 ⁴
	HQCF _{70.00} CPF _{30.00}	2.0 x 10 ³	3.0 x 10 ³	2.5 x 10 ⁴
2	HQCF ₈₀ BNF ₂₀	1.5 x 10 ⁵	3.7 x 10 ⁴	4.8 x 10 ⁴
	HQCF ₇₀ BNF ₃₀	2.3 x 10 ⁵	9.4 x 10 ⁴	9.6 x 10 ⁴
	HQCF _{70.00} CPF _{30.00}	1.7 x 10 ⁵	1.3 x 10 ⁵	8.1 x 10 ⁴

4. Conclusion

Tidbits produced with blends of flour from cassava (HQCF) and Bambara nut (BNF) and HQCF with CPF, i.e., HQCF₈₀BNF₂₀ and HQCF₇₀BNF₃₀, respectively, had higher sensory scores when compared to wheat-based samples. HQCF–legume composite formulations exhibit favorable sensory attributes, indicating good consumer acceptability and strong potential for commercial application within functional and value-added food product development. There was a relative decline in the chemical composition (moisture content, acid value, and free fatty acid levels) of tidbits produced with flour from cassava and Bambara nut during storage. All samples maintained total microbial counts within acceptable safety limits.

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