Quality Evaluation and Consumers' Acceptability of Gari Produced from Provitamin A Cassava (Manihot esculenta) and Bambara Groundnut (Vigna subterranean)

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Abstract
Gari, a staple food in many West African countries, is predominantly produced from cassava (Manihot esculenta). However, cassava alone does not provide adequate nutrition, particularly in terms of essential vitamins and minerals. To address this nutritional deficit, provitamin A cassava alongside Bambara groundnut (Vigna subterranean) may enhance the nutritional quality of gari, and promote food security and nutrition in vulnerable communities. This study aims to evaluate the quality of gari produced from provitamin A cassava and Bambara groundnut and assess consumers' acceptability of this fortified gari. The findings reveal that the incorporation of provitamin A cassava and Bambara groundnut significantly improves the nutritional profile of gari and positively influences its acceptability among consumers.
Keywords: Gari, provitamin A cassava, Bambara groundnut, quality evaluation, acceptability, nutritional enhancement
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1. Introduction

Gari is a popular fermented and roasted granulated cassava product widely consumed in West Africa. It is not only a major source of dietary energy but also serves as an important staple food for millions of people in the region. However, gari is predominantly composed of cassava, which is relatively deficient in essential vitamins and minerals, especially vitamin A. Vitamin A deficiency remains a significant public health concern in many developing countries, including those in West Africa. Vitamin A is essential for vision, growth and development and upholding a healthy immune system (Huang et al., 2018). To address this nutritional challenge, efforts have been made to improve the nutritional quality of gari by incorporating Provitamin A cassava (*Manihot esculenta*) which is genetically engineered to contain higher levels of beta-carotene, a precursor of vitamin A and Bambara groundnut (*Vigna subterranean*), a nutrient-rich legume, has been identified as a potential complementary ingredient to enhance the nutritional quality of gari. The combination of provitamin A cassava and Bambara groundnut has the potential to increase the vitamin A content of gari, thereby offering a solution to the vitamin A deficiency problem in the region. Bambara groundnut, on the other hand, is a legume rich in protein, vitamins, and minerals. This study aims to evaluate the quality of gari produced from provitamin A cassava and Bambara groundnut and assess the consumers' acceptability of fortified gari. The study will consider both the nutritional aspects and sensory attributes of the product, as well as consumer preferences.

2. Materials and Methods

Provitamin A cassava (*Manihot esculenta*) was obtained from the Industrial Institute of Tropical Agriculture (IITA), Ibadan, Oyo State. Nigeria. Bambara groundnut (*Vigna subterranea* (*L.) Verdc*.) was procured from a local market in Ogbomoso, Oyo State, Nigeria.

2.1 Preparation of pro-vitamin A cassava

Provitamin A cassava gari was produced using the method described by Olatunde *et al.* (2021). Freshly harvested provitamin A cassava tubers were sorted, cleaned, peeled and washed to remove extraneous material. The cleaned provitamin A cassava was grated using a locally fabricated abrasive grater? The grated provitamin A pulp was packed into a jute sack and pressed to remove it water. The pulp was fermented for 72 hours and sifted to remove rough fibre.

2.2 Preparation of Bambara groundnut

Bambara groundnuts were sorted, cleaned and washed with water, then soaked in water for 12 hours, drained, dehulled and then boiled until it was very soft, drained and kept in a Ziploc bag wrapped in a polythene bag fermented for 72 hours.

3. Production of *gari*

Provitamin A pulp was mixed with varying proportions of Bambara groundnuts 0, 5, 10, 15 and 20% as generated by simplex lattice design (version 6.0) of mixture design, then sieved into grits and roasted at 130°C to produce *gari*.

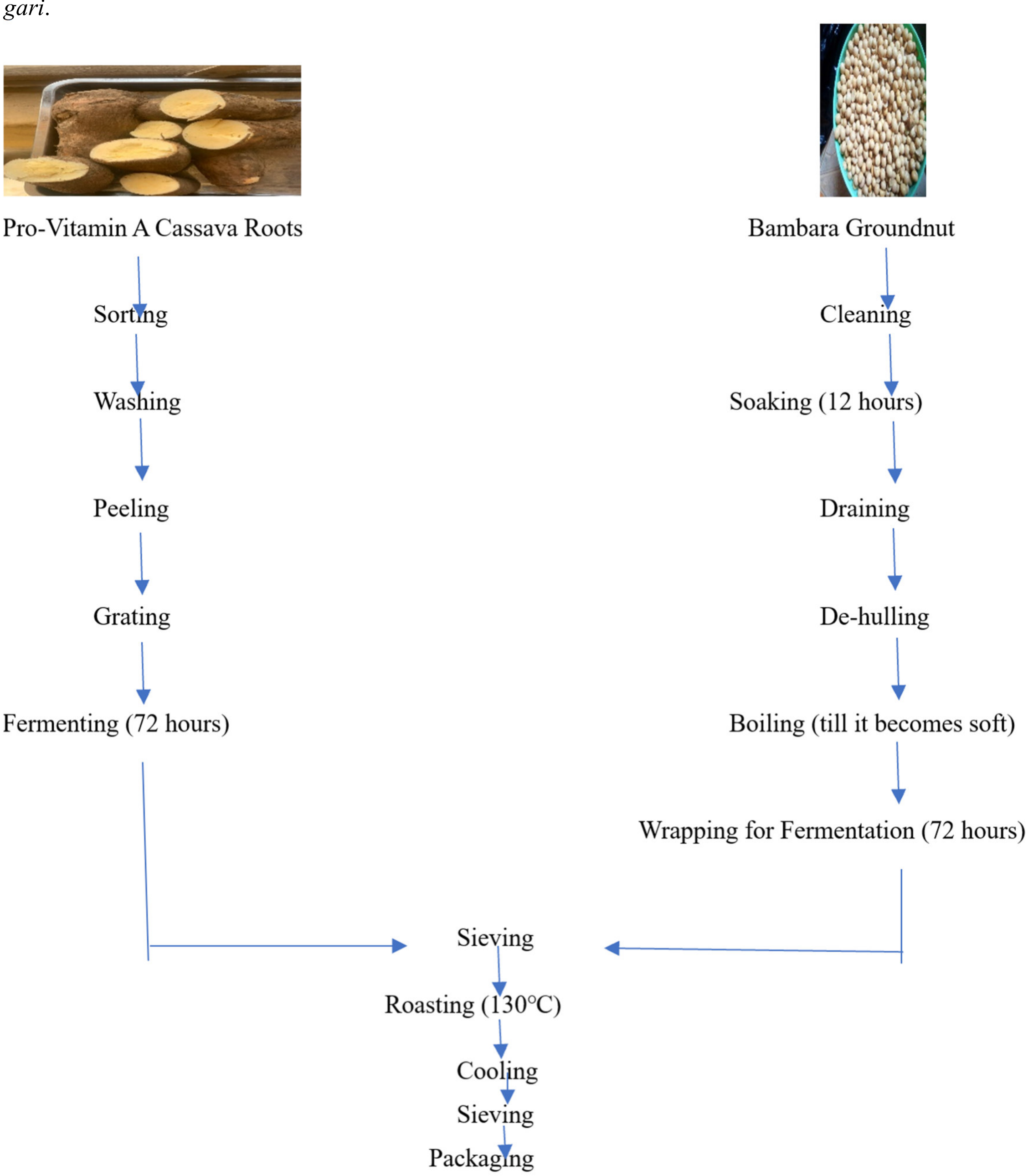
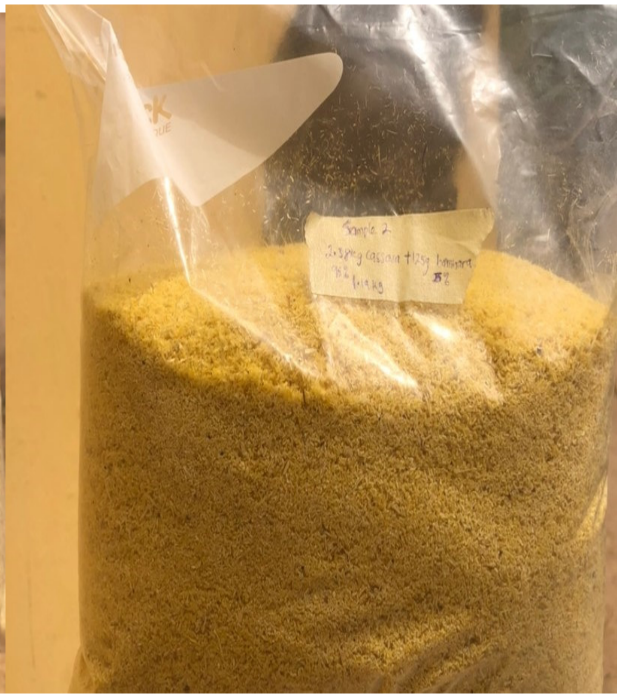
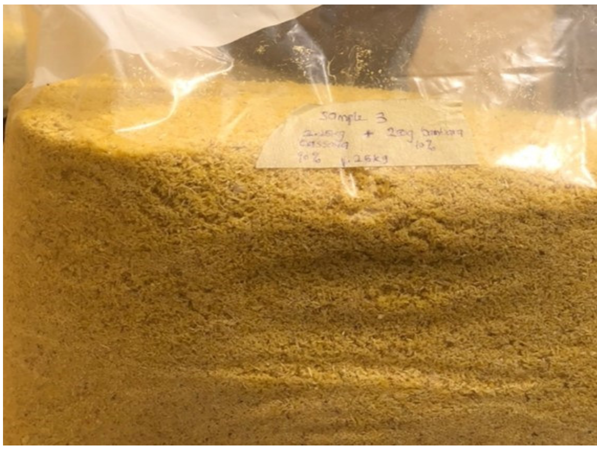


Figure 1: Flowchart for the Production of *Gari* from Pro-Vitamin A Cassava and Bambara Groundnut

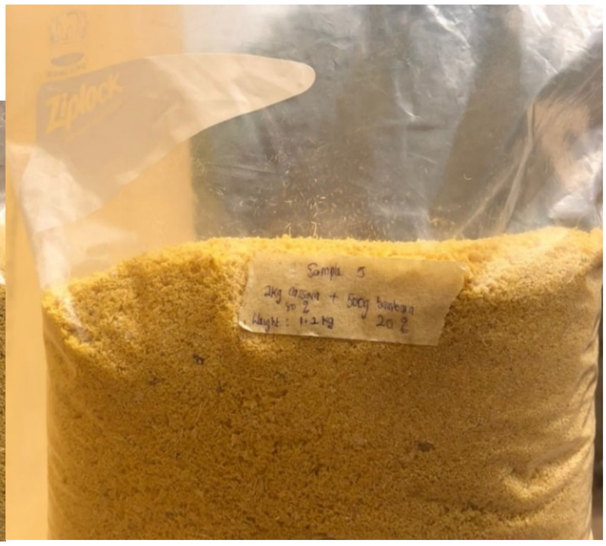
100% Pro-Vitamin A Cassava *Gari*



95% PVAC: 5% Bambara Groundnut



90% PVAC: 10% Bambara Groundnut



80% PVAC: 20% Bambara Groundnut

Plate 1; Images of *gari* produced from pro-vitamin A cassava and bambara groundnut

4. Proximate analyses

The moisture, crude protein, crude fat, ash, crude fibre, and carbohydrate (by difference) of provitamin A gari were determined by the AOAC (2005) method. Total energy ,total titrable acidity and beta carotene were determined AOAC (2005) method.

5. Chemical Analysis

The total hydrogen cyanide content, the total titratable acidity and pH of provitamin A gari were determined by AOAC (2005). was determined by Onyeagba *et al.,* (2004) method.

6. Physico-chemical Analysis

The water absorption capacity, swelling capacity and solubility index were determined by the AOAC (2005) method.

7. Sensory Evaluation

Sensory evaluation was carried out with 50 untrained panellists who were regular *gari* consumers comprising of staff and students of the Ladoke Akintola University of Technology, Ogbomoso (LAUTECH), Oyo State. Sensory evaluation was conducted in compliance with the ethical guidelines of LAUTECH. Each panellist was served with 5 randomly arranged provitamin A gari samples on coded clean ceramic plates. Water was provided for mouth rinsing in between sample tastings. Panellists were requested to evaluate the colour, texture, taste, aroma, appearance and overall acceptability of provitamin A gari using the 9-point hedonic scale, with 1 representing dislike extremely while 9 representing like extremely.

8. Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA) using Statistical Package for Social Science (SPSS) version 20 and all analyses were replicated. Duncan's multiple ranges were used to separate the means. Statistically significant differences were determined at $p < 0.05$.

9. Results and discussion

9.1 Nutritional composition of Pro-Vitamin A *Gari*

The nutritional composition of the gari samples is presented in Table 1. Moisture content is essential in the storability of food products. The level of moisture content ranged from 3.83-8.67% with sample CB3 having the highest value while sample CB1 had the lowest value. The addition of Bambara groundnut determines the percentage of the moisture content in the samples. Birk *et al.* (2006) and Airadion et al. (2014) report that good quality gari with less than 14% moisture content has a long shelf life. The results of all samples of provitamin B gari had lower moisture content, which will the gari samples to have a longer shelf life. The ash content usually predicts the mineral content of food materials. Sample CB5 (3.83%) had the highest ash content. The results of the gari samples indicate that the higher the amount of Bambara groundnuts added the higher the percentage of ash contents. The sample results in this study were higher than the 1.0% reported by Akingbala *et al.,* (2005). The crude protein content of the samples ranged from 6.35% - 8.05%. Sample CB5 had the highest value. The percentage of Bambara groundnuts added determines the level of increase in the protein content and also, improves the protein content of the gari samples. Similarly, all the gari samples were significantly different ($p<0.05$). The results of this study contradict the crude protein content (2.3 - 2.55%) of *gari* reported by Komolafe *et al.* (*2010*). The production of *gari* from pro-vitamin A cassava and Bambara groundnut will be an added advantage compared to conventional *gari* helping consumers who have limited access to protein sources. The crude fibre content of the samples ranged from 0.56% to 0.71%. sample CB5 had the highest crude fibre content (0.71%). The higher the amount of Bambara groundnuts added the higher the percentage of crude fibre content in each of the samples. Similarly, the fibre content of all the samples was significantly different ($p<0.05$). Vegetable fibre helps the digestive system to prevent constipation and peristalsis movement of the bowel (Abu *et al., 2010).* The level of crude fat content ranged from 0.24% to 0.31% with sample CB5 having the highest value while sample CB1 had the lowest value. The crude fat content for all the samples was significantly different ($p<0.05$). The sample results were lower than those reported for *gari*, which could be due to varietal differences (Atuna *et al.,* 2021). The carbohydrate content of the samples ranged from 80.42% to 86.01%. Sample CB1 had the highest value (86.01%). The addition of Bambara groundnuts reduces the carbohydrate content in the samples. The total energy content ranged from 354.19 kcal/100g to 371.64 kcal/100g with Sample CB1 having the highest value, the results were not surprising because *Gari* is a major source of carbohydrates. The beta-carotene content of the samples ranged from 3.72 mg/100g and 18.27 mg/100g. Sample CB3 had the highest value. The beta-carotene content of all the samples was significantly different ($p<0.05$). Pro-vitamin A cassava increases the beta-carotene content in all the samples.

Table 1: Nutritional Composition of *gari* produced from pro-vitamin A cassava and bambara groundnut

Sample	Moisture %	Ash %	Crude protein %	Crude fibre %	Fat %	CHO %	Total Energy Kcal/100g	Beta-carotene Mg/100g
CB1	3.83±0.28^{c}	3.00±0.00^{b}	6.35±0.04^{e}	0.56±0.00^{e}	0.24±0.00^{e}	86.01±0.33^{a}	371.64±1.16^{a}	3.72±0.45^{d}
CB2	6.83±0.29^{b}	2.83±0.29^{b}	6.61±0.04^{d}	0.58±0.00^{d}	0.25±0.00^{d}	82.88±0.25^{b}	360.27±1.15^{b}	7.14±0.45^{b}
CB3	8.67±0.28^{a}	1.93±0.11^{c}	6.97±0.07^{c}	0.62±0.00^{c}	0.27±0.00^{c}	81.54±0.33^{c}	356.48±1.44^{c}	18.27±0.39^{a}
CB4	8.33±0.29^{a}	2.83±0.28^{b}	7.12±0.02^{b}	0.63±0.00^{b}	0.27±0.00^{b}	80.81±0.26^{d}	354.19±1.15^{c}	7.59±0.82^{b}
CB5	6.67±0.58^{b}	3.83±0.29^{a}	8.05±0.04^{a}	0.71±0.00^{a}	0.31±0.00^{a}	80.42±0.53^{d}	356.70±2.00^{c}	5.54±0.23^{c}

Mean values along the same column with different superscripts are significantly different (p<0.05)
Key:
CB1 = 100% pro-vitamin A cassava
CB2 = 95% pro-vitamin A cassava – 5% bambara groundnut
CB3 = 90% pro-vitamin A cassava – 10% bambara groundnut
CB4 = 85% pro-vitamin A cassava – 15% bambara groundnut
CB5 = 80% pro-vitamin A cassava – 20% bambara groundnut.

9.2 Chemical composition of Pro-Vitamin A *Gari*

Table 2 presents the result of the chemical composition of pro-vitamin a gari with Bambara groundnut samples. The hydrogen cyanide content decreased from 1.67 mg/kg in sample CB1 to 0.59 mg/kg in the CB5. The more the addition of Bambara groundnuts in the samples, the lower the hydrogen cyanide content present in the samples. The results suggest that the addition of Bambara groundnut might prevent hydrogen cyanide poisoning (Atuna *et al.,* 2021). Similarly, provitamin A processing such as grating, fermentation and roasting have substantial reduction on hydrogen cyanide present in fresh cassava roots (Eleazu *et al*. 2011). The amount of hydrogen cyanide in all the samples was lower than the recommended safe level of 10 mg/kg of cyanide in cassava products (Egesi, 2011). The pH is an indication of the acid content in food. The pH values for the samples ranged from 4.44 to 4.48 with Sample CB5 having the highest value. The pH values of the samples fall within the recommended range of 3.5-4.5 for acid fermented products (NIS, 2005). All the samples were slightly acidic because of fermentation period during processing. The total titratable acidity (TTA) for the samples ranged from 0.28% to 0.36% with sample CB5 having the highest value. The more the addition of Bambara groundnuts the higher the TTA values. The samples TTA fall within the recommended standard of 0.6-1.2 for cassava-*gari* (Oduro *et al.,* 2000).

Table 2. Chemical Composition of *gari* produced from pro-vitamin A cassava and bambara groundnut

Sample	HCN (Mg/100g)	pH	TTA (Mg/100g)
CB1	1.67±0.45^{a}	4.46±0.04^{ab}	0.28±0.00^{e}
CB2	1.04±0.58^{ab}	4.48±0.01^{ab}	0.29±0.00^{d}
CB3	0.92±0.65^{ab}	4.44±0.01^{b}	0.31±0.00^{c}
CB4	0.59±0.38^{b}	4.44±0.01^{ab}	0.32±$o.oo^{b}$
CB5	0.59±0.38^{b}	4.48±0.02^{a}	0.36±0.00^{a}

Mean values along the same column with different superscripts are significantly different (p<0.05)
Key:
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CB2 = 95% pro-vitamin A cassava – 5% bambara groundnut
CB3 = 90% pro-vitamin A cassava – 10% bambara groundnut
CB4 = 85% pro-vitamin A cassava – 15% bambara groundnut
CB5 = 80% pro-vitamin A cassava – 20% bambara groundnut.

9.3 Physico-chemical Properties of Provitamin A Gari

Table 3 presents data on the physico-chemical properties of pro-vitamin A gari samples. The level of water holding capacity ranged from 332.67 to 395.67% with sample CB3 having the highest value while sample CB5 had the lowest value. The results indicate that sample CB3 was well dried and absorbed more water when soaked, which was an important property of starchy food with smaller particle size (Awoyale et al., 2020). The swelling capacity of the samples ranged from 9.53 to 11.41%. Sample CB3 had the highest value (11.41%). Sample CB5 with highest addition of Bambara groundnut had the lowest swelling capacity. The results from this study were comparable with the values reported by Adesokan et al. (2023). Similarly, quality gari usually swells three times its original size (Awoyale et al., 2020). The solubility index of the samples ranged from 4.33 to 10.67%. The solubility index in the samples was significantly different (p<0.05). The solubility index replicates the extent of intermolecular cross bonding between granules and the higher solubility starches, the higher the amylose contents (Chisenga et al., 2019).

Table 3. Physicochemical properties of *gari* produced from pro-vitamin A cassava and bambara groundnut

Sample	WAC %	Swelling Capacity %	Solubility Index %
CB1	367.33 ± 1.53^{ab}	10.57 ± 0.19^{ab}	6.00 ± 0.00^{c}
CB2	356.00 ± 6.24^{ab}	11.11 ± 0.02^{a}	4.33 ± 0.57^{d}
CB3	395.67 ± 57.71^{a}	11.41 ± 1.35^{a}	7.33 ± 1.15^{bc}
CB4	351.67 ± 5.03^{ab}	10.44 ± 0.07^{ab}	7.67 ± 0.57^{b}
CB5	332.67 ± 10.06^{b}	9.53 ± 0.35^{b}	10.67 ± 1.15^{a}

Mean values along the same column with different superscripts are significantly different (p<0.05)

Key:

CB1 = 100% pro-vitamin A cassava
CB2 = 95% pro-vitamin A cassava – 5% bambara groundnut
CB3 = 90% pro-vitamin A cassava – 10% bambara groundnut
CB4 = 85% pro-vitamin A cassava – 15% bambara groundnut
CB5 = 80% pro-vitamin A cassava – 20% bambara groundnut.

Sensory evaluation of Pro-Vitamin A Gari

The mean sensory scores of Provitamin A gari and Bambara groundnuts were presented in Table 4. The sensory attributes evaluated were texture, aroma, taste, appearance, colour and overall acceptability. Sample CB1 had the highest score for texture, sample CB2 had the highest score for aroma, taste and appearances while sample CB3 had the lowest score in almost all the attributes evaluated. The results suggest that the addition of Bambara groundnuts positively impact its sensory attributes as reflected in their scores.

Table 4**:** Sensory evaluation of *gari* produced from pro-vitamin A cassava and bambara groundnut

Sample	Texture	Aroma	Taste	Appearance	Color	Overall acceptability
CB1	7.80 ± 1.28^{a}	6.70 ± 0.97^{ab}	7.00 ± 1.65^{ab}	6.70 ± 1.26^{a}	6.45 ± 1.85^{a}	7.15 ± 1.08^{ab}
CB2	7.2 ± 1.05^{ab}	7.35 ± 0.98^{a}	7.60 ± 1.19^{a}	7.05 ± 1.93^{a}	6.55 ± 1.93^{a}	7.55 ± 1.19^{a}
CB3	6.55 ± 1.76^{b}	6.45 ± 1.14^{b}	5.90 ± 2.40^{b}	6.40 ± 1.67^{a}	6.50 ± 1.84^{a}	6.45 ± 1.67^{b}
CB4	6.70 ± 1.17^{b}	6.50 ± 1.31^{b}	6.30 ± 1.26^{b}	6.60 ± 2.01^{a}	6.55 ± 1.95^{a}	6.85 ± 1.22^{ab}
CB5	6.75 ± 1.68^{b}	6.75 ± 0.85^{ab}	6.30 ± 1.38^{b}	6.65 ± 1.78^{a}	6.85 ± 2.03^{a}	7.05 ± 1.32^{ab}

Mean values along the same column with different superscripts are significantly different (p<0.05)

Key:

CB1 = 100% pro-vitamin A cassava
CB2 = 95% pro-vitamin A cassava – 5% bambara groundnut
CB3 = 90% pro-vitamin A cassava – 10% bambara groundnut
CB4 = 85% pro-vitamin A cassava – 15% bambara groundnut
CB5 = 80% pro-vitamin A cassava – 20% bambara groundnut.

10.0 Conclusion

The samples experienced a varying degree of increase in the proximate components, beta carotene, pH, total titratable acidity and solubility index. Gari produced from sample CB2 had the highest sensory scores in all the attributes evaluated. The incorporation of provitamin A and Bambara groundnuts enhances the vitamin A content of gari, making it a potential solution to vitamin A deficiency in the region. The positive reception of fortified gari by consumers suggests that it has the potential to become a popular and nutritious food choice in West Africa.

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