ISSN: 2754-477X

Journal of Food Technology & Nutrition Sciences

SCIENTIFIC Research and Community

Review Article

Open Access

Effect of African Yam Bean and Sprouted Maize Incorporation on Proximate Composition Functional, Pasting and Sensory Properties of Gari

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ABSTRACT

Background: Gari, a fermented and toasted product from cassava (*Manihot esculenta Crantz*) serves as a major staple food in Nigeria and many West African countries. Standard gari despite its popularity and economic importance is deficient in protein and micronutrient composition, necessitating incorporation with other locally available produce. This study investigated the effect of African yam bean (*Sphenostylis stenocarpa*) and sprouted maize (*Zea mays*) incorporation on proximate composition, functional, pasting and sensory properties of gari.

Methodology: Cassava, African yam bean and sprouted maize were processed into mash and blended in varying ratios (100:0:0), (97:1.5:1.5), (95:2.5:2.5), (90:5:5), (87:6.5:6.5), (85:7.5:7.5), (80:10:10), (77:11.5:11.5), (75:12.5:12.5), (70:15:15), (67:16.5:16.5), (65:17.5:17.5), (60:20:20), (57:21.5:21.5), (55:22.5:22.5), (50:25:25), (47:26.5:26.5), (45:27.5:27.5), (40:30:30), (35:32.5:32.5) respectively prior to fermentation and toasting and represented as samples A to T. Standard analytical methods were used to determine the proximate composition. Functional, pasting and sensory properties were evaluated using established procedures.

Results: Proximate composition shows moisture content value range of (7.43 to 10.40%), ash (1.95 to 3.75%), fat (0.75 to 2.65%), fibre (2.02 to 4.31%), protein (2.95 to 20.98%) and carbohydrate (60.88 to 81.93%). Bulk density, water absorption capacity, oil absorption capacity, swelling index, emulsion capacity and foam capacity values ranged from (0.508 to 0.775g/cm3), (3.05 to 5.85g/ml), (2.15 to 4.52g/g), (1.52 to 2.58), (23.33 to 32.99%) and (5.21 to 9.89%) respectively. Pasting viscosities (peak, trough, breakdown and set back) varied significantly ($p<0.05$) with range of values (338.16 to 387.25RVU), (121.42 to 141.74RVU), (212.26 to 246.21RVU), (390.21 to 435.36RVU) and (252.77 to 305.06RVU), respectively. Peak time and pasting temperature ranged from (4.53 to 6.12 Minutes) and (79.14 to 87.50 0C) respectively. Sensory properties revealed that gari produced from 100% cassava which served as control was the most preferred by a 30 man semi trained panelist with an overall acceptability score of 7.48 followed by sample C (97% cassava mash+1.5% African yam bean +1.5% sprouted maize mash) with score 7.36.

Conclusion: The incorporation of sprouted maize and African yam bean significantly ($p<0.05$) improved the nutritional, functional and pasting qualities of gari.

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Received: March 12, 2026; **Accepted:** March 18, 2026; **Published:** March 25, 2026

Introduction

In the continuous search for solution to the problem of malnutrition mainly among the people of the developing countries, views have been expressed of the need to improve the nutritional quality of our local foods through better processing and fortification.

Gari is one of such basic foods worthy of attention due to its low nutritional composition. Gari derived from fermented cassava (Manihot esculenta Crantz) is one of the most consumed staples in Nigeria and West Africa due to its ease of storage, affordability and versatility in preparation. Despite its wide consumption, traditional gari is predominantly carbohydrate rich and contains low levels of protein, lipids, and essential micronutrients [1]. Gari is a creamy- white partially gelatinized toasted free flowing granular flour with particle size ranging from below 50 microns fine to over 200 microns coarse [2]. Attempts to incorporate gari with leguminous or protein rich sources such as soybean flour have been made which yielded gari with enhanced protein, ash and some functional properties [3].

The inclusion of sprouted cereals and legumes in cassava-based products offers a promising approach to enhance their nutritive value. Sprouting of grains such as maize (Zea mays) activates endogenous enzymes, leading to the breakdown of complex macromolecules and the synthesis of bioactive compounds. Spouting improves protein digestibility, increases some vitamins especially B-complex and reduces antinutritional factors such as phytate and tannins [4]. Sprouting alters starch structure and enzymatic activity, which could influence the functional and pasting properties of composite flours used in gari production.

African yam bean (Sphenostylis stenocarpa) known as Odudu in Igboland is an underutilized lesser known leguminous plant species cultivated widely in various subtropical regions of Africa [5]. African yam bean has been identified as a potential fortificant for energy-dense but protein deficient staples such as cassava due to its high protein content (21-29%), appreciable fiber, and mineral composition. The protein is particularly rich in lysine (up to 9%), a value higher than that of soybean and deficient in Sulphur containing amino acids methionine and cysteine which are available in maize [6].

The consumption of cassava products such as gari, characterizes the food habit of people in the developing countries such as Nigeria. Cassava is well known not only for its high carbohydrate content but also for the poor quality and concentration (<1%) of protein. Consequently, there is the need to develop an acceptable, nutritionally fortified food that could be utilized in these areas where protein intake is low from inexpensive staples such as maize, cassava and African yam bean. Additionally, African yam bean one of the commonly cultivated legumes in Nigeria is nearing extinct due to underutilization as a source of food. This legume is a very good source of protein and other nutrients which are notably lacking in cassava.

Supplementation of cassava with sprouted maize and African yam bean which are highly nutritious could yield gari with improved nutritional value, functional, pasting and sensory properties. It would increase the utilization of African yam bean which is currently being ignored by most consumers despite its high protein content. The incorporation of sprouted maize would improve the content of Sulphur containing amino acid which is deficient in African yam bean. In addition, the rural farmers would be encouraged to produce these crops, obtain marketable products and thus more income would be generated.

The objectives of this study therefore were to evaluate the effect of African yam bean and sprouted maize incorporation on proximate composition, functional, pasting and sensory properties of gari.

Materials and Methods

Source of Raw Materials

Freshly harvested matured cassava roots TME 419 were obtained from National Root Crops Research Institute, Umudike, Abia State, Nigeria. Yellow maize and African yam bean seeds were purchased from a local market in Uzuakoli, Bende Local Government Area, Abia State. The crops were authenticated at the Department of Crop Production and Protection of Faculty of Agriculture, Abia State University, Uturu, Abia State, Nigeria.

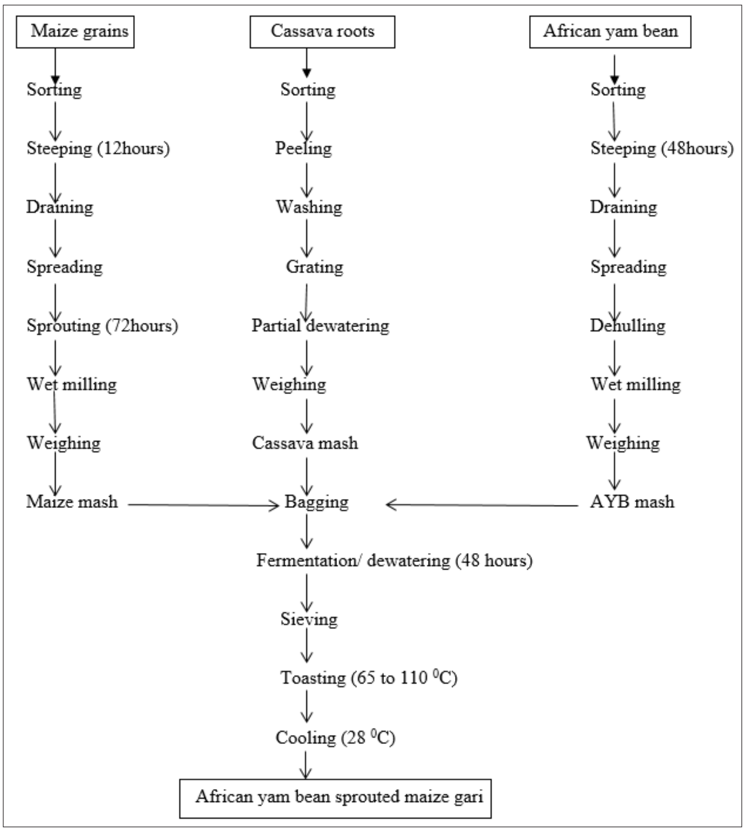

Figure 1: Process Scheme for Production of African Yam bean Sprouted Maize Gari

Preparation of Cassava Mash

Hundred kilograms (100kg) of matured cassava roots was sorted, peeled washed with potable water and grated to produce fine cassava mash which was collected into clean plastic buckets.

Preparation of African yam Bean Mash
Thirty kilograms (30kg) of African yam bean seeds was sorted to remove dirt, broken seeds and other extraneous materials. It was subsequently soaked in potable water (1:4w/v) for 48 hours to absorb water which facilitates dehulling and wet milling. After 48 hours of soaking the African yam bean was manually dehulled and wet milled into paste using an attrition mill (STEEL MAN MILL MODEL, FFC45TIGMAX-GX160) and allowed for 40 minutes in a perforated jute bag to drain to the desired consistency.

Preparation of Sprouted Maize Mash
Thirty kilograms (30kg) of maize grains was manually sorted to remove dirt, broken kernels and other foreign materials. The grains were soaked in potable water (1:3w/v) for 12hours at an ambient temperature of 280C to absorb water and facilitate germination. It was drained and spread on a moist jute bag kept at a damp place and allowed to germinate. Water was sprinkled at mornings and evenings and allowed to germinate after 72 hours at ambient temperature of about 280C. Germination was stopped when the radicle attained a length of 2mm. The sprouted grain was wet milled using an attrition mill (STEEL MAN MILL, MODEL, FFC45TIGMAX-GX160) with added (1:1w/v) to obtain a smooth paste.

Blending of Cassava Mash, African Yam Bean Mash and Sprouted Maize Mash
Cassava mash after partial dewatering to reduce the moisture content to 65% was weighed and blended with the required weights of African yam bean mash and sprouted maize mash as represented in Table I. The various combinations were thoroughly blended in a clean stainless-steel basin for 10 minutes packed in perforated jute bags and allowed to ferment for 48hours after dewatering with a hydraulic press until a firm cake was formed.

Sieving and Toasting
The fermented and dewatered cake was manually pulverized and sieved with a clean fine mesh sieve of pore size 2mm to obtain uniform particle sizes. The fibrous materials were removed as chaff. Toasting was carried out using a cast iron toasting pan placed on fire wood heat generated stand and the temperature maintained between 65 to 1100C until a dried gari was obtained. The gari was allowed to cool at room temperature, packaged in an airtight polyethylene bag until required for analysis. The process scheme for the production of gari with incorporated sprouted maize mash and African yam bean seed mash is presented in figure 1.

Analyses
Determination of Proximate Composition
Moisture content, protein, crude fat, crude fibre and ash were determined by standard methods according to James while the carbohydrate was determined using the difference method [7].

Determination of Functional Properties
The functional properties of the gari samples was determined in accordance with the method described by Onwuka [8].

Bulk Density
A measured amount of the gari samples as filled into the weighed calibrated measuring cylinder till the 10mL mark. The measured cylinder was continuously tapped until there was no further change in the sample level. The bulk density was calculated in g/ml.

Swelling Index
One gram of the gari sample was weighed into a 10mL graduated cylinder with the dry bulk volume noted. Five milliliters of distilled water was added and the volume occupied by the sample was recorded. The sample was allowed to stand undistributed in water for an hour and the volume was again recorded. The resulting volume of water known as the supernatant was decanted measured and recorded. The water absorption capacity was determined as the absorbed percentage of water.

Water Absorption Capacity
One gram of the sample was carefully measured and placed in a graduated centrifuge tube. A high-speed mixer was utilized to thoroughly mix the sample with 10mL of distilled water for duration of 30 seconds. The mixture was left undistributed at room temperature for 30 minutes and subsequently centrifuged at a speed of 3500 revolution per minute for 30 minutes.

Oil Absorption Capacity
One gram of the sample was carefully measured and placed in a graduated centrifuge tube. A high-speed mixer was utilized to thoroughly mix the sample with 10mL of distilled water for duration of 30 seconds. The mixture was left undisturbed at room temperature for 30 minutes and subsequently centrifuged at a speed of 3500 revolution per minute for 30 minutes. The resulting volume known as the supernatant was decanted measured and recorded. The oil absorption capacity was determined as the percentage of oil absorbed.

Emulsion Capacity
Two grams of the sample was mixed with 25 mL of distilled water at room temperature and blended for 30 seconds in a Kenwood blender (BL 330 Series). After complete dispersion, 25 mL of vegetable oil was gradually added and blending continued for 30 seconds. The mixture was quickly transferred to a graduated measuring cylinder and after 5 minutes, the entire height was measured as well as the height of the emulsion layer. Emulsion capacity is expressed as the amount of oil emulsified and held per gram of the sample.

Foam Capacity
Two grams of the sample was blended with 100mL distilled water in warring blender and whipped at 1600rpm for 5 minutes. The mixture was poured into a 250 mL measuring cylinder and the volume after 30 seconds was recorded. Volumes were recorded before and after homogenization and the percentage increase in the volume was calculated as foam capacity.

Pasting Properties
The pasting properties of the sample were determined by the use of a Rapid Visco Analyzer (RVA). About 3.5g of the sample was weighed into a dried canister. Then 25 mL of distilled water was added and was thoroughly stirred. The sample was heated from 50 to 950C at a rate of 1.5 0C per minute and was held at that temperature for 15 minutes then cooled to 500C. The following parameters were read: peak viscosity, set back viscosity, trough viscosity, breakdown viscosity, final viscosity, peak time and pasting temperature.

Sensory Evaluation
The sensory evaluation of the gari samples were assessed by a 30 man semi trained panelists comprising students and other staffs drawn from the faculty. The panelists were supplied with the coded samples of gari in clean dried plates and requested to evaluate the samples base on taste, colour, texture, aroma and overall acceptability using a 9-point hedonic scale.

doi.org/10.47363/JFTNS/2026(8)231

Statistical Analysis

Analysis of variance (ANOVA) was used to determine the level of significance according to the method of Steel and Torrie [9]. Least Significant Difference was used to separate the means where significant difference was detected at $p<0.05$.

Results

Table 1: Blending Ratios of Cassava, AFRICAN Yam BEAN and Sprouted Maize Mash (%)

Sample	Cassava	African yam bean	sprouted maize
A	100	0	0
B	97	1.5	1.5
C	95	2.5	2.5
D	90	5	5
E	87	6.5	6.5
F	85	7.5	7.5
G	80	10	10
H	77	11.5	11.5
I	75	12.5	12.5
J	70	15	15
K	67	16.5	16.5
L	65	17.5	17.5
M	60	20	20
N	57	21.5	21.5
O	55	22.5	22.5
P	50	25	25
Q	47	26.5	26.5
R	45	27.5	27.5
S	40	30	30
T	35	32.5	32.5

Table 2: Proximate Composition of Gari Produced from Cassava, African Yam Bean and Sprouted Maze Mash Blends

Samples	Moisture (%)	Ash (%)	Fat (%)	Fibre (%)	Protein (%)	Carbohydrate (%)
A	$10.40^{a}\pm0.28$	$1.95^{p}\pm0.07$	$0.75^{p}\pm0.07$	$2.02^{t}\pm0.04$	$2.95^{t}\pm0.21$	$81.93^{a}\pm0.35$
B	$10.32^{a}\pm0.14$	$1.90^{p}\pm0.14$	$0.77^{p}\pm0.14$	$2.10^{s}\pm0.00$	$3.73^{s}\pm0.11$	$81.18^{b}\pm0.04$
C	$9.70^{bc}\pm0.00$	$2.10^{o}\pm0.00$	$0.85^{o}\pm0.00$	$2.15^{r}\pm0.07$	$5.25^{r}\pm0.25$	$79.95^{c}\pm0.18$
D	$9.65^{bc}\pm0.07$	$2.22^{n}\pm0.07$	$1.10^{n}\pm0.00$	$2.32^{q}\pm0.00$	$7.83^{q}\pm0.32$	$76.88^{d}\pm0.18$
E	$9.48b^{cd}\pm0.06$	$2.30^{m}\pm012$	$1.20^{m}\pm0.07$	$2.40^{p}\pm0.07$	$8.10^{p}\pm0.25$	$76.532^{c}\pm0.39$
F	$9.35^{de}\pm0.07$	$2.35^{m}\pm0.17$	$1.31^{l}\pm0.07$	$2.65^{o}\pm0.10$	$9.48^{o}\pm0.00$	$74.86^{f}\pm0.28$
G	$9.21^{ef}\pm0.14$	$2.41^{l}\pm0.00$	$1.42^{k}\pm0.00$	$2.73^{n}\pm0.05$	$11.58^{n}\pm0.11$	$72.65^{g}\pm0.11$
H	$9.14^{ef}\pm0.06$	$2.50^{k}\pm0.08$	$1.55^{j}\pm0.07$	$2.95^{m}\pm0.14$	$12.80^{m}\pm0.11$	$71.06^{h}\pm0.21$
I	$8.95^{fg}\pm0.07$	$2.62^{j}\pm0.05$	$1.65^{i}\pm0.00$	$3.00^{l}\pm0.00$	$13.83^{l}\pm0.00$	$69.95^{i}\pm0.07$
J	$8.81^{gh}\pm0.08$	$2.65^{ij}\pm0.00$	$1.70^{h}\pm0.07$	$3.12^{k}\pm0.10$	$14.18^{k}\pm0.14$	$69.54^{j}\pm0.21$
K	$8.65^{hi}\pm0.00$	$2.73^{hi}\pm0.00$	$1.76^{h}\pm0.00$	$3.20^{j}\pm0.00$	$15.05^{j}\pm0.00$	$68.61^{k}\pm0.14$
L	$8.60^{hi}\pm0.05$	$2.80^{gh}\pm0.09$	$1.82^{g}\pm0.07$	$3.30^{i}\pm0.07$	$16.18^{i}\pm0.11$	67.30l±0.18
M	$8.45^{hij}\pm0.07$	$2.95^{fg}\pm0.07$	$1.91^{f}\pm0.00$	$3.40^{h}\pm0.00$	$16.49^{h}\pm0.12$	$66.80^{m}\pm0.32$
N	$8.31^{ij}\pm0.18$	$3.03^{f}\pm0.00$	$1.95^{f}\pm0.07$	$3.54^{g}\pm0.05$	$17.00^{g}\pm0.32$	$66.17^{n}\pm0.18$
0	$8.21^{ij}\pm0.14$	$3.14^{ef}\pm0.11$	$2.10^{f}\pm0.04$	$3.65^{f}\pm0.07$	$17.88^{f}\pm0.09$	$65.02^{o}\pm0.18$
P	$8.02^{i}\pm0.07$	$3.28^{de}\pm0.16$	$2.23^{e}\pm0.07$	$3.70^{e}\pm0.05$	$18.89^{e}\pm0.22$	$63.88^{p}\pm0.00$
Q	$7.81^{j}\pm0.19$	$3.40^{d}\pm0.00$	$2.32^{d}\pm0.14$	$3.96^{d}\pm0.09$	$19.87^{d}\pm0.32$	$62.64^{q}\pm0.14$
R	$7.64^{k}\pm0.00$	$3.54^{c}\pm0.17$	$2.40^{c}\pm0.09$	$4.17^{c}\pm0.09$	$20.24^{c}\pm0.32$	$62.01^{r}\pm0.10$
S	$7.51^{l}\pm0.012$	$3.65^{b}\pm0.12$	$2.52^{b}\pm0.10$	$4.25^{b}\pm0.15$	$20.50^{b}\pm0.19$	$61.57^{s}\pm0.12$
T	$7.43^{mj}\pm0.18$	$3.75^{a}\pm0.00$	$2.65^{a}\pm0.07$	$4.31^{a}\pm0.05$	$20.98^{a}\pm0.22$	$60.88^{t}\pm0.18$

Mean values on the same column with different superscripts are significantly different (P<0.05).
A=cassava 100%,AYB 0%, SM 0%, B= cassava 97%, AYB 1.5%, SM 1.5%, C=cassava 95%, AYB 2.5%, SM 2.5%, D=cassava 90%, AYB 5%, SM 5%, E=cassava 87%, AYB 6.5%, SM 6.5%, F=cassava 85, AYB 7.5%, SM 7.5%, G=cassava 80%, AYB 10%, SM 10%, H=cassava 77%, AYB 11.5%, SM 11.5%, I=cassava 75%, AYB 12.5%, SM 12.5%, J=cassava 70, AYB 15%, SM 15%, K=cassava 67%, AYB 16.5%, SM 16.5%, L=cassava 65%, AYB 17.5%, SM 17.5%, M=cassava 60%, AYB 20%, SM 20%, N=cassava 57%, AYB 21.5%,SM 21.5%,O=cassava 55%,AYB=22.5%, SM 22.5%, P=cassava 50%,AYB 25%,SM 25%, Q=cassava 47%, AYB 26.5%, SM 26.5%, R= cassava 45%, AYB 27.5%, SM 27.5%, S=cassava 40%, AYB 30%, SM 30%, T=cassava 35%, AYB 32.5%, SM 32.5%. AYB= African yam bean. SM= sprouted maize.

Table 3: Functional Properties of Gari Produced from Cassava, African Yam Bean and Sprouted Maze Mash Blends

Samples	BD (g./cm^3)	WAC(g/ml)	OAC (g/g)	SI	EC (%)	FC (%)
A	0.775^{a}±0.02	3.05^{t}±0.14	2.15^{t}±0.07	2.58^{a}±0.06	23.33^{t}±0.18	5.21^{q}±0.16
B	0.750^{b}±0.02	3.20^{s}±0.00	2.35^{s}±0.00	2.52^{b}±0.00	24.10^{s}±0.16	5.42^{p}±0.00
C	0.734^{c}±0.00	3.40^{r}±0.07	2.52^{r}±0.07	2.50^{b}±0.01	24.738^{r}±0.00	5.60^{o}±0.07
D	0.728^{d}±0.06	3.55^{q}±0.07	2.60^{q}±0.12	2.46^{c}±0.11	25.01^{q}±0.08	5.82^{n}±0.07
E	0.714^{e}±0.17	3.70^{p}±0.09	2.75^{p}±0.03	2.36^{cd}±0.21	25.38^{p}±0.11	5.87^{m}±0.00
F	0.698^{f}±0.23	3.90^{o}±0.22	2.85^{o}±0.07	2.30^{ef}±0.31	25.66^{o}±0.00	5.95^{l}±0.11
G	0.686^{f}±0.11	4.15^{n}±0.00	2.92^{n}±0.07	2.28^{gh}±0.21	26.12^{n}±0.06	6.01^{k}±0.02
H	0.671^{fg}±0.08	4.20^{m}±0.07	3.15^{m}±0.11	2.24^{ij}±0.00	26.75^{m}±0.11	6.24^{j}±0.02
I	0.658^{i}±0.05	4.35^{l}±0.11	3.25^{l}±0.00	2.20^{j}±0.00	27.04^{l}±0.08	6.40^{i}±0.10
J	0.643^{g}±0.00	4.60^{k}±0.02	3.33^{l}±0.07	2.18^{j}±0.01	27.51^{k}±0.00	6.62^{h}±0.12
K	0.628^{i}±0.06	4.75^{j}±0.00	3.50k^{l}±0.23	2.15^{j}±0.02	27.96^{j}±0.08	6.80^{g}±0.07
L	0.620^{j}±0.07	4.80^{i}±0.07	3.62^{ij}±0.00	2.12^{k}±0.03	28.55^{i}±0.19	6.97^{f}±0.09
M	0.614^{k}±0.00	5.00^{h}±0.08	3.70^{hi}±0.07	2.08^{k}±0.09	29.98^{h}±0.00	7.50^{e}±0.09
N	0.598^{l}±0.14	5.15^{g}±0.07	3.85^{gh}±0.07	1.98^{k}±0.16	30.22^{g}±0.14	7.54^{e}±0.12
O	0.577^{m}±0.09	5.20^{f}±0.30	3.98^{fg}±0.20	1.92^{l}±0.11	30.79^{f}±0.17	7.90^{f}±0.10
P	0.570^{n}±0.30	5.25^{e}±0.23	4.05^{ef}±0.12	1.90^{m}±0.07	31.03^{e}±0.10	8.21^{e}±0.08
Q	0.554^{o}±0.23	5.40^{d}±0.20	4.15^{de}±0.07	1.84^{m}±0.07	31.59^{d}±0.09	8.60^{d}±0.12
R	0.540^{p}±0.12	5.55^{c}±0.15	4.28^{bc}±0.24	1.76^{n}±0.09	32.10^{c}±0.12	8.98^{c}±0.10
S	0.522^{q}±0.08	5.65^{b}±0.12	4.35^{ab}±0.13	1.60^{o}±0.23	32.40^{b}±0.18	9.45^{b}±0.09
T	0.508^{r}±0.21	5.85^{a}±0.01	4.52^{a}±0.07	1.52^{o}±0.20	32.99^{a}±0.18	9.89^{a}±0.08

Mean values on the same column with different superscripts are significantly different (P<0.05).
A=cassava 100%,AYB 0%, SM 0%, B= cassava 97%, AYB 1.5%, SM 1.5%, C=cassava 95%, AYB 2.5%, SM 2.5%, D=cassava 90%, AYB 5%, SM 5%, E=cassava 87%, AYB 6.5%, SM 6.5%, F=cassava 85, AYB 7.5%, SM 7.5%, G=cassava 80%, AYB 10%, SM 10%, H=cassava 77%, AYB 11.5%, SM 11.5%, I=cassava 75%, AYB 12.5%, SM 12.5%, J=cassava 70, AYB 15%, SM 15%, K=cassava 67%, AYB 16.5%, SM 16.5%, L=cassava 65%, AYB 17.5%, SM 17.5%, M=cassava 60%, AYB 20%, SM 20%, N=cassava 57%, AYB 21.5%,SM 21.5%,O=cassava 55%,AYB=22.5%, SM 22.5%, P=cassava 50%,AYB 25%,SM 25%, Q=cassava 47%, AYB 26.5%, SM 26.5%, R= cassava 45%, AYB 27.5%, SM 27.5%, S=cassava 40%, AYB 30%, SM 30%, T=cassava 35%, AYB 32.5%, SM 32.5%. AYB= African yam bean. SM= sprouted maize

Table 4: Pasting Properties of Gari Produced from Cassava, African Yam Bean and Sprouted Maze Mash Blends

Samples	PV(RVU)	TV(RVU)	BV (RVU)	FV (RVU)	SV(RVU)	PT(^{0}C)	PT(mins)
A	387.25^{a}±1.50	141.74^{a}±0.28	246.21^{a}±1.61	431.13^{b}±1.42	290.09^{cd}±1.35	79.14^{i}±0.03	4.53^{g}±0.01
B	386.12^{a}±1.41	141.55^{a}±0.35	246.04^{a}±0.00	430.02^{b}±3.56	280.27^{cd}±0.79	79.36^{i}±0.27	4.62^{f}±0.00
C	379.19^{ab}±0.04	141.44^{d}±0.16	222.08^{a}±0.21	396.70^{f}±0.97	252.77.^{h}±1.12	79.85^{h}±0.26	4.65^{ef}±0.01
D	361.25^{c}±0.10	132.22^{cd}±0.62	216.69^{bcd}±0.79	422.03^{c}±0.32	289.11^{cd}±0.31	80.34^{g}±0.26	4.71^{e}±0.01
E	360.04^{c}±0.04	132.01^{cd}±0.20	226.65^{c}±0.21	421.15^{c}±0.46	287.30^{cd}±0.42	80.50^{fg}±0.26	4.82^{d}±0.06
F	359.19^{bc}±0.69	133.68^{cd}±0.62	225.05^{b}±0.79	411.28^{e}±3.31	276.11^{f}±0.40	80.94^{f}±0.26	4.86^{d}±0.01
G	372.27^{b}±0.25	133.33^{b}±1.34	227.42^{b}±1.32	399.67^{f}±1.60	266.30^{g}±0.35	81.31^{ef}±0.04	4.91^{cd}±0.02
H	370.85^{bc}±0.76	133.30^{ef}±0.56	216.42^{de}±1.25	390.21^{g}±3.30	265.12^{g}±3.87	81.62^{e}±0.01	4.99^{c}±0.09
I	353.96^{de}±0.01	136.16^{b}±0.39	222.85^{bcd}±1.92	410.36^{e}±1.60	275.67^{f}±7.15	81.95^{e}±0.03	5.08^{c}±0.05
J	349.02^{de}±0.96	127.73^{e}±0.75	221.71^{bcd}±1.25	399.19^{f}±0.11	270.18^{f}±0.05	82.49^{de}±0.26	5.10^{c}±0.01
K	349.58^{de}±0.61	128.08^{e}±0.30	222.92^{bcd}±1.92	400.28^{e}±1.33	288.16^{cd}±2.54	82.68^{de}±0.18	5.23^{bc}±0.07

L	350.52^{de}±0.70	128.10^{e}±0.63	224.94^{bc}±0.08	415.89^{d}±0.05	305.06^{a}±0.58	83.14^{d}±0.63	5.30^{b}±0.15
M	346.75^{de}±0.19	125.61^{fg}±0.60	223.14^{bc}±0.93	435.36^{a}±2.20	303.01^{a}±0.60	84.41^{cd}±0.00	5.38^{b}±0.06
N	348.12^{f}±0.61	125.42^{fg}±0.38	223.26^{bc}±1.25	434.78^{a}±0.11	294.18^{bc}±1.13	84.65^{c}±0.63	5.49^{ab}±0.00
O	346.73^{e}±0.67	124.02^{gh}±0.68	220.14^{d}±1.92	418.19^{cd}±1.32	287.26^{bc}±0.83	85.10^{cd}±0.25	5.61^{ab}±0.12
P	346.50^{de}±0.61	122.79^{h}±0.50	217.14^{e}±0.23	411.28^{e}±0.21	298.16^{b}±0.63	85.80^{b}±0.63	5.74^{a}±0.09
Q	345.18^{e}±0.96	122.28^{h}±0.63	215.92^{e}±1.25	410.04^{e}±0.05	297.52^{b}±0.58	86.10^{ab}±0.12	5.84^{a}±0.07
R	345.27^{e}±0.19	135.36^{bc}±0.47	213.64^{ef}±1.27	420.95^{c}±0.65	292.18^{cd}±0.91	86.53^{ab}±0.18	5.97^{a}±0.06
S	339.12^{f}±0.25	133.78^{bc}±0.10	212.26^{f}±1.32	427.54^{b}±1.20	294.18^{b}±0.45	86.85^{a}±0.27	6.12^{a}±0.10
T	338.16^{f}±0.70	121.42^{i}±0.24	213.66^{f}±1.02	392.64^{g}±1.65	289.48^{c}±0.25	87.50^{a}±0.30	5.49^{a}±0.08

Mean values on the same column with different superscripts are significantly different (P<0.05).
A=cassava 100%,AYB 0%, SM 0%, B= cassava 97%, AYB 1.5%, SM 1.5%, C=cassava 95%, AYB 2.5%, SM 2.5%, D=cassava 90%, AYB 5%, SM 5%, E=cassava 87%, AYB 6.5%, SM 6.5%, F=cassava 85, AYB 7.5%, SM 7.5%, G=cassava 80%, AYB 10%, SM 10%, H=cassava 77%, AYB 11.5%, SM 11.5%, I=cassava 75%, AYB 12.5%, SM 12.5%, J=cassava 70, AYB 15%, SM 15%, K=cassava 67%, AYB 16.5%, SM 16.5%, L=cassava 65%, AYB 17.5%, SM 17.5%, M=cassava 60%, AYB 20%, SM 20%, N=cassava 57%, AYB 21.5%,SM 21.5%,O=cassava 55%,AYB=22.5%, SM 22.5%, P=cassava 50%,AYB 25%,SM 25%, Q=cassava 47%, AYB 26.5%, SM 26.5%, R= cassava 45%, AYB 27.5%, SM 27.5%, S=cassava 40%, AYB 30%, SM 30%, T=cassava 35%, AYB 32.5%, SM 32.5%. AYB= African yam bean. SM= sprouted maize. PV= Peak viscosity, TV= Trough viscosity, BV= Breakdown viscosity, FV= Final viscosity, SV= Setback viscosity, PT= Pasting temperature, PT= Pasting time.

Table 5: Sensory Properties of Gari Produced from Cassava, African Yam Bean and Sprouted Maze Mash Blends

Samples	Colour	Aroma	Taste	Texture	Acceptability
A	7.52^{a}±0.28	7.44^{a}±0.07	7.38^{a}±0.07	7.22^{a}±0.04	7.48^{a}±0.21
B	7.45^{a}±0.14	7.35^{a}±0.14	7.30^{a}±0.14	7.18^{ab}±0.00	7.36^{ab}±0.11
C	7.40^{bc}±0.00	7.30^{b}±0.00	7.25^{bc}±0.00	7.15^{ab}±0.07	7.30^{b}±0.25
D	7.32^{bc}±0.07	7.22^{c}±0.07	7.15^{bc}±0.00	7.08^{b}±0.00	7.20^{bc}±0.32
E	7.25^{bcd}±0.06	7.10^{d}±012	7.05^{c}±0.07	7.00^{bc}±0.07	7.12^{c}±0.25
F	7.15^{de}±0.07	7.00^{e}±0.17	6.95^{d}±0.07	6.92^{c}±0.10	7.00^{d}±0.00
G	7.05^{ef}±0.14	6.90^{f}±0.00	6.85^{de}±0.00	6.85^{d}±0.05	6.92^{d}±0.11
H	6.97^{ef}±0.06	6.82^{g}±0.08	6.78^{e}±0.07	6.78^{e}±0.14	6.85^{d}±0.11
I	6.90^{fg}±0.07	6.75^{h}±0.05	6.70^{f}±0.00	6.70^{f}±0.00	6.75^{de}±0.00
J	6.82^{gh}±0.08	6.65^{i}±0.00	6.60^{g}±0.07	6.62^{g}±0.10	6.65^{e}±0.14
K	6.75^{hi}±0.00	6.55^{j}±0.00	6.50^{h}±0.00	6.55^{h}±0.00	6.55^{f}±0.00
L	6.65^{hi}±0.05	6.48^{k}±0.09	6.42^{i}±0.07	6.48^{i}±0.07	6.45^{i}±0.11
M	6.58^{hij}±0.07	6.40^{l}±0.07	6.35^{j}±0.00	6.38^{j}±0.00	6.38^{k}±0.12
N	6.50^{ij}±0.18	6.32^{m}±0.00	6.28^{k}±0.07	6.30^{k}±0.05	6.30^{l}±0.32
0	6.45^{ij}±0.14	6.28^{n}±0.11	6.22^{l}±0.04	6.25^{l}±0.09	6.25^{m}±0.09
P	6.40^{i}±0.07	6.25^{o}±0.16	6.18^{m}±0.07	6.15^{m}±0.09	6.20^{n}±0.22
Q	6.38^{j}±0.19	6.22^{p}±0.00	6.15^{n}±0.14	6.05^{n}±0.15	6.12^{o}±0.32
R	6.30^{k}±0.00	6.18^{q}±0.17	6.10^{o}±0.09	5.94^{o}±0.05	6.02^{p}±0.32
S	6.22^{l}±0.012	6.10^{r}±0.12	6.12^{p}±0.10	5.86^{p}±0.05	5.9^{q}±0.19
T	6.15^{mj}±0.18	6.02^{a}±0.00	6.00^{q}±0.07	5.80^{q}±0.05	5.78^{r}±0.22

Mean values on the same column with different superscripts are significantly different (P<0.05).
A=cassava 100%,AYB 0%, SM 0%, B= cassava 97%, AYB 1.5%, SM 1.5%, C=cassava 95%, AYB 2.5%, SM 2.5%, D=cassava 90%, AYB 5%, SM 5%, E=cassava 87%, AYB 6.5%, SM 6.5%, F=cassava 85, AYB 7.5%, SM 7.5%, G=cassava 80%, AYB 10%, SM 10%, H=cassava 77%, AYB 11.5%, SM 11.5%, I=cassava 75%, AYB 12.5%, SM 12.5%, J=cassava 70, AYB 15%, SM 15%, K=cassava 67%, AYB 16.5%, SM 16.5%, L=cassava 65%, AYB 17.5%, SM 17.5%, M=cassava 60%, AYB 20%, SM 20%, N=cassava 57%, AYB 21.5%,SM 21.5%,O=cassava 55%,AYB=22.5%, SM 22.5%, P=cassava 50%,AYB 25%,SM 25%, Q=cassava 47%, AYB 26.5%, SM 26.5%, R= cassava 45%, AYB 27.5%, SM 27.5%, S=cassava 40%, AYB 30%, SM 30%, T=cassava 35%, AYB 32.5%, SM 32.5%. AYB= African yam bean. SM= sprouted maize.

Discussion

Proximate Composition of gari Produced from Cassava, African Yam Bean and Sprouted Maze Mash Blends

Table 2 shows the proximate Composition of gari from cassava, African yam bean and sprouted maze mash blends. The incorporation of African yam bean and sprouted maize into cassava based gari significantly influenced its proximate composition. The moisture content ranged from 7.43 to 10.40% with the lowest moisture found in gari samples with 35% cassava, 32.5% African yam bean and 32.5% sprouted maize. The moisture content of the gari decreased with increase in incorporation of African yam bean and sprouted maize in the blends. The reduction in moisture could be as a result of lower moisture – binding capacity of protein-rich African yam bean and sprouted maize mash compared to cassava starch. The result was in agreement with the findings of Adebowale, who reported decreased moisture content in cassava products supplemented with legume flour [10]. Low moisture content increases shelf stability and reduces microbial spoilage [11].

Crude fat content of the gari ranged from 0.75 to 2.65%, with lowest crude fat content found in gari with 100% cassava, 0% African yam bean and 0% sprouted maize which served as the control sample. The fat content increased with increased in incorporation of African yam bean and sprouted maize. This could be as a result of the sprouted and African yam bean being richer in lipids when compared with cassava. Sprouting has been reported to enhance lipid mobilization and synthesis of essential fatty acids. Ajayi reported an increase in fat content (1.23 to 2.03%) of Sakada (a cassava based meal) fortified with African yam bean mash [12].

Ash content ranged from 1.95 to 3.75%. Ash provided approximation of the mineral composition [13]. Ash was found to increase with increase in incorporation African yam bean and sprouted maize. The supplementation provided additional micronutrients. Sprouting improves mineral bioavailability by reducing antinutritional factors that usually bind minerals in their insoluble forms [14].

The crude fibre content ranged from 2.02 to 4.31%. The fibre content increases proportionally with the level of African yam bean incorporation. African yam bean contains high levels of dietary fibre, which promotes gastrointestinal health and reduces glycemic response. Sprouted maize also contributes slightly to the fibre content due to the presence of partially degraded cell wall materials. Crude fibre plays an important role in digestion ad bowel movement. According to FAO/WHO, the recommended crude fibre contents of food products should not exceed 5% [15]. The crude fibre content was similar to the value 2.31 to 2.93% range reported by Okoye for gari fortified with toasted African yam bean seed flour [16].

The crude protein content ranged from 2.95 to 20.98%. A significant increase in protein was observed with the incorporation of African yam bean and sprouted maize. Cassava is primarily a starchy crop and contains low protein level. Sprouting improves protein quality by increasing amino acid availability through enzymatic hydrolysis of storage proteins [17]. Additionally, the increase in protein could be attributed to the fermentation process of cassava mash which is known to improve the nutritional value of foods and hydrolysis of protein molecules by microbial cells involved in the fermentation which became part of the fermented product [18].

The total carbohydrate content ranged from 60.88 to 81.93%. The carbohydrate content of the gari decreased with increase in percentage of African yam and sprouted maize. Gari produced from 100% cassava, 0% African yam bean and 0% sprouted maize expectedly had the highest content of carbohydrate 81.93%. This value was lower 82.12% reported by Okoye and Obi for gari from 100% cassava mash [13]. Enzymatic hydrolysis during spouting partially converts starch into reducing sugar, leading to a measurable reduction in total carbohydrate levels. Overall, the incorporation of African yam bean and sprouted maize enhances the nutritional balance of gari by increasing its protein, fat, fibre and mineral fractions while reducing the carbohydrate fraction [14].

Functional Properties of Gari Produced from Cassava, African Yam Bean and Sprouted Maize Mash Blends

Table 3 shows the functional properties of gari from cassava, African yam and sprouted maize mash blends. The incorporation of African yam bean and sprouted maize significantly influenced the pasting properties. According to Idowu, Functional properties are those parameters that determine the application and end use of food materials for various food products [19].

The bulk density ranged from 0.508 to 0.775g/ml. The bulk density was similar to the range of (0.06 to 0.77g/ml) obtained by Obinna-Echem and Amgbeye for gari fortified with soybean flour and (0.615 to 0.625g/ml) reported by Bankole for gari fortified with Bambara groundnut flour [20,21]. Bulk density decreases with increase in incorporation of African yam bean and sprouted maize. This could be as a result of enzymatic breakdown of starch granules during sprouting which produces a more porous and less compact structure. The protein and fibre fractions from African yam bean also contribute to the residual particle compactness, leading to a lighter product. Low bulk density reduces weight of finished food product and the cost of transportation [10].

The water absorption capacity ranged from 3.05 to 5.85g/g. water absorption capacity is an index of the ability of flour product to associate with water under conditions where water is limited [22]. Water absorption capacity of gari increased significantly with the incorporation of African yam and sprouted maize. This could be attributed to partial hydrolysis of starch and protein during germination which increases the availability of hydrophilic groups capable of binding water. In addition, the high protein content of African yam bean enhances water binding capacity through polar side chains of amino acids. Increased water absorption capacity is beneficial for instant or ready to eat gari, as it promotes rapid reconstitution in hot water, improving the convenience of preparation [23].

The oil absorption capacity ranged from 2.15 to 4.52g/g. The oil absorption capacity is the binding of fat by nonpolar side chain of proteins. The incorporation of African yam bean and sprouted maize could enhance the oil absorption capacity because proteins and degraded starch fragments can entrap oil within their matrices. Improved oil absorption capacity could enhance flavor retention and mouthful in gari consumed dry or with soups [24].

There was a significant difference ($p<0.05$) in the emulsion capacity of the gari. Emulsion capacity ranged from 23.33 to 32.99%. The emulsion capacity of gari increased with increase in incorporation of African yam bean and sprouted maize. Legumes are known to have high emulsion capacity than most other food sources. Etong reported an increase in value1.60 to 2.58g/g with increase in proportion of Bambara groundnut flour in wheat/

Bambara groundnut flour blends [25]. High emulsion capacities as observed in this study are positive indication gari could have excellent emulsifying properties in various applications [26]. The enhancement in emulsifying ability could be attributed to the higher protein content and structural modifications induced by sprouting. During germination, enzymatic activities such as proteolysis lead to the partial breakdown of large protein molecules into smaller peptides and amino acids. These peptides possess both hydrophobic and hydrophilic groups, enabling them to effectively adsorb at oil- water interfaces and stabilize emulsions [14].

The swelling index of the sample ranged from 1.52 to 2.58. Values obtained were significantly different ($p>0.05$) and decreased with increase in the proportion of African yam bean and sprouted maize. The decrease in swelling index exhibited could be as a result of the dilution of native cassava starch by non-starchy components from African yam bean and partial degradation of starch molecules in sprouted maize [23]. In addition, the decrease in values with increase in the proportion of African yam bean and sprouted maize suggests that African yam bean and sprouted maize has low swelling index compared to cassava. Ukpabi and Ndimele reported that high quality gari has swelling power of up to four times its original volume in water [27]. According to Sanni a good swelling power is an indicator of high quality gari when it is soaked in water for direct consumption or reconstitution in hot water to form paste [2].

Foam capacity ranged from 5.21 to 9.89%. The values obtained were significantly different ($p>0.0$) and increased with increase in proportion of African yam bean and sprouted maize. Foam capacity of a material is a function of its protein quality. Proteins are primarily responsible for foam formation because they can unfold and form a continuous cohesive film around the air bubbles, reducing surface tension and stabilizing foam structures [17].

Pasting Properties of Gari Produced from Cassava, African Yam Bean and Sprouted Maize Mash Blends

Table 4 shows the pasting properties of gari produced from cassava, African yam bean and sprouted maize mash blends. The incorporation of African yam bean and sprouted maize showed significant variations when compared with the gari produced from 100% cassava (Control). Pasting properties help to predict the behavior of starch- based food system as it affects some properties such as the aesthetics, texture, and digestibility of the final food products [28]. The peak viscosity which reflects the maximum swelling of starch granules during heating ranged from ranged from 338.16 to 387.25RVU. 100% cassava gari (sample A) had the highest peak viscosity value, while sample (T) containing 35% cassava, 32.5% African yam bean and 32.5% maize had the least value. There was no clear trend in the values obtained with increase in African yam bean and maize in the gari samples. However, the least value obtained for sample N (35% cassava, 32.5% African yam bean and 32.5% sprouted maize) in conformity with the report of Ikegwu who demonstrates that legumes generally have lower peak viscosity compared to cereals and tuber crops [29]. The peak viscosity of the control is similar to that reported by Awoyale for back slopped and spontaneously fermented cassava mash [30]. The decrease in the peak viscosity in samples containing African yam bean and spouted maize suggest that the African yam bean and sprouted maize gari samples may have allowed more water binding ability as evidenced in the water absorption capacity of the gari samples.

The trough viscosity of the samples ranged from 121.42 to 141.74RVU, with the lowest found in gari sample with 35% cassava, 32.5% African yam bean and 32.5 % sprouted maize and the highest found in gari with 100% cassava. The trough viscosity which is also known as the holding strength is the minimum viscosity after the peak, normally occurring around the commencement of sample cooling. The lower trough viscosity of the samples containing African yam bean and sprouted maize compared to the control implies that the samples with African yam bean and spouted maize may not form very stiff and firm gel (eba). This suggests that the composite gari samples had reduced resistance to disintegration during heating. The weakening of starch granule integrity may be due to the interference of non-starch components such as proteins and fibres, which disrupt the continuous starch, network [24].

The breakdown viscosity of the control was significantly higher ($p>0.05$) than that of the sample incorporated with African yam bean and sprouted maize. Values obtained ranged from 212.26 to 246.21 RVU. These values are higher than that (64.59 to 94.825 RVU) reported by Awoyale et al. for gari from back slopped and spontaneously fermented cassava mash, but comparable with some of the values (124.17 to 218.75 RVU) reported by Ogueke for different samples of gari [30,31]. Breakdown viscosity reflects the ability of the sample to withstand sheer stress and heating during cooking. This implies that the starch grains of the gari with high levels of African yam bean and maize lack the integrity to withstand stress from the mechanical agitation in visco-analyzer and therefore raptured earlier leading to decreased viscosity.

The final viscosity obtained ranged from 390.21 to 435.36 RVU with samples T (35% cassava, 32.55% African yam bean and 32.5% sprouted maize) having the least value. Final viscosity indicates the change in viscosity after the sample was held at 50oC. It shows the ability of the starch to form stable and viscous paste after cooking [32]. The final viscosity of the control is higher than 279.46 to 337.55 for gari from back slopped and spontaneously fermented cassava mash [30]. Final viscosity marks the ability of starch to form viscous paste after cooking and cooling [33]. The decrease in final viscosity of the gari with higher level of African yam bean and sprouted maize inclusion implies that African yam bean and maize decreased the ability of the gari to form stiff gel on cooling. However, the gari with African yam bean and sprouted maize incorporation were still moldable when stirred in hot water for the preparation of stiff gel (eba). This is a desirable quality for consumers as the stiff gel (eba) is molded with the palm, and consumed by dipping in soup or stew before swallowing [34].

Set back viscosity of the samples ranged from 252.77 to 305.06 RVU and showed no trend. Setback viscosity measures the tendency for retrogradation [35]. Lower setback values indicate reduced association of starch molecules during cooling, which improves shelf stability and reduces staling [2]. The setback viscosity of the control is comparable to values obtained for gari from back slopped and spontaneously fermented cassava mash [30]. The addition of African yam bean and sprouted maize may have lowered the degree of polymerization of the gari starch thereby leading to lower set back in most of the samples.

Pasting temperature ranged from 79.14 to 87.500C. The control had the significantly lower pasting temperature than the samples containing African yam bean and maize. This is similar to the result reported by Obinna-Echem and Amgbeye [20] for gari fortified with soybean and lower than the values reported by Ogueke [31]. The pasting temperature increased with increase in incorporation of African yam bean and sprouted maize which indicates the higher temperatures were needed to initiate gelatinization in the composite samples. This could be attributed to protein starch interactions and reduced starch availability which retards gelatinization [36].

Pasting time of the samples ranged from 4.53 to 6.12 minutes. The result showed that it took longer time to achieve the viscosity; this means that more time at higher temperature is required for the garri to be stiff for molding. Increase in pasting time is an indication of longer cooking time [2].

Sensory Scores of Gari Produced from Cassava, African Yam Bean and Sprouted Maize Blends

The sensory scores for the gari samples are presented in Table 4. The incorporation of African yam bean and sprouted maize caused a significant ($p<0.05$) effect on the sensory parameters evaluated. Highest overall acceptability (7.48) was recorded for the control 100% cassava followed by sample C (97% cassava, 1.5% African yam bean and 1.5%sprouted maize) with an overall acceptability score of 7.36. There was a gradual decline in colour, texture, aroma and overall acceptability as incorporation of African yam bean and sprouted maize increases. Although the gari samples were accepted by the consumers, the acceptability gradually declined with increase in incorporation of African yam bean and sprouted maize.

Conclusion

The incorporation of African yam bean and sprouted maize into cassava gari significantly influenced its nutritional quality, more especially protein, fibre and mineral contents. Functional and pasting properties were modified, indicating the interaction between starch and non-starch components such as protein and fibre. High substitution levels of African yam and sprouted maize resulted in slight decline in the sensory scores. Moderate inclusion yielded gari with improved nutritional and acceptable sensory quality. Consequently, African yam bean and sprouted maize could be utilized in gari production to improve its protein content and enhance food security.

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