Evaluation of the Chemical, Functional, and Sensory Properties of Gari Produced with Palm Oil (*Elaeis guineensis*), Soybean (*Glycine max*), and Defatted Coconut (*Cocos nucifera*) Flour

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Abstract—

Background*: Increasing the nutrient density of commonly consumed foods will increase nutrient intake and ensure nutrition security.*

Objectives*: The study evaluated the chemical composition, functional, and sensory properties of Gari produced with palm oil, soybean, and defatted coconut flour.*

Methodology: *Fresh cassava roots was processed for gari using traditional methods. Soybean and coconuts were made into flour using standard procedures. The blends were formulated in ratios of Garri: soybean: coconut: and palm oil to obtain four samples 75:15:5:5; 65:20:10:5; 55:25:15:5; and 100: 0. The samples were evaluated for chemical, functional, and sensory properties using standard methods. IBM Statistical Product for Service Solution software (version 21) was used to analyze the data collected. Data was presented with descriptive statistics (frequencies, percentages, means, standard deviation). The means were compared and separated with Analysis of variance and Duncan multiple range test.*

Results: *The samples had moisture (9.5 to 10.83%), crude protein (1.27 to 11.52%), fat (1.06 to 14.29%), ash (0.62 to 2.47%), carbohydrate (86.60 to 59.70%), and energy (360.98 to 413.41Kcal). Calcium (2.15 to 15.81mg), sodium (0.83 to 11.51mg), magnesium (3.81 to 9.27mg), phosphorus (3.48 to 9.17mg), potassium (0.64 to 16.21mg), iron (0.22 to 2.83mg), zinc (0.41 to 1.82mg), vitamins A (19.42 to 201.42µg), thiamin (0.12 to 0.31mg), riboflavin (0.26 to 0.52mg), niacin (0.31mg to 0.92mg), vitamin C (6.11 to 10.28mg), vitamin E (0.17 to 0.52mg) tannin (0.28 to 0.57mg), alkaloid (0.11 to 0.48mg), flavonoids (0.41 to 0.72mg), saponin (0.16 to 0.47mg), phytate (0.02 to 0.23mg), and hydrogen cyanide as hydrogen cyanide (7.32 to 16.44mg) were also detected. Bulk density (0.72 to 0.84g/ml), water absorption capacity (1.07 to 1.56g/g), oil absorption capacity (1.61 to 2.42g/g), foam capacity (21.66 to 31.61%), foam stability (18.53 to 22.15%), swelling index (2.05 to 4.81%), and gelatinization temperature (70.31 to 78.62^{0}C) were determined. Samples 55:25:15:5, 75:15:5:5, 65:20:10:5 and 75:15:5:5, were preferred for color (7.46), texture (7.61), taste (7.43), and aroma (7.35) respectively. Sample 75:15:5:5; and 65:20:10:5 was more acceptable.*

Conclusion: *Garri produced with soybean, coconut, and red palm oil improved the nutrient composition and acceptability.*

Keywords— Chemical and functional, sensory properties, Gari production; soybean; coconut; palm oil.

I. INTRODUCTION

Cassava (*Manihot esculenta*) is a popular food crop in the tropics. It was originally introduced into Africa from tropical America in 1558 by the Portuguese [1]. It has other names as manioca, mandioca. It is to Africa farmers what rice is to Asian farmers. Cassava roots is rich in carbohydrates, calcium, other essential minerals, vitamins B and C. Its yields more carbohydrate per hectare than cereals [2]. Cassava crop can be grown at significant lower cost because it thrives well in poor soil with minimal labor. Its roots have poor storage status due to high humidity, thus must be used up immediately or processed into shelf-stable products after harvest. These products include Fufu, Gari, and Tapioca. More than 70% of cassava root is processed into Gari a popular staple [3]. It is produced when freshly harvested cassava roots are peeled, washed, milled, fermented for seventy-two hours (72) hours, dewatered and fried. Gari is a very good source of carbohydrate especially starch, and fiber, but poor in proteins. It is commonly consumed by most households; the frequency of consumption is high among poor household. The dependency on Gari by these households may exclude other nutritious foods and constitute a huge malnutrition problem. World health Organization has a record of 2.5 billion overweight/obese adults, 390 underweight adults, 149 million stunted (too short for age) under-5 children, 45 million wasted (too thin for height), more than 37 million overweight/obese, with approximately 50% mortality linked to undernutrition especially in low-and- middle-income countries [4]. Several studies underscore the prevalence of malnutrition in small sections; severe acute malnutrition and stunting was reported as 4.4%, and 9.9% [5], while stunting, wasting and underweight was 47.6%, 8.8% and 25.6% respectively in Ebonyi a state in Nigeria [6]. These situations could be related to inadequate consumption of essential nutrients amongst other factors.

The global community through the sustainable development goals 1 (No poverty), 2 (Zero hunger), and 3 (Good health and well-being) seeks to ensure healthy lives and promote well-being for all at all ages. These goals are expected to establish nutrition security for all. By implication a steady access, availability and affordability of foods that will ensure wellbeing, prevent, and treat disease in all groups. These wake-up call to all sectors involved in nutrition and wellbeing include the development of sustainable varied foods that will ensure good health. Researchers are constantly engaged in growing more foods, defining new ways of increasing pest and disease resistant varieties, upgrading old foods, and developing new ones. The value-addition of commonly consumed foods through food blending could ensure the availability of essential nutrients to the consumers. Foods significantly rich in nutrients like carbohydrates, protein, essential minerals, vitamins, and fiber could be blended to ensure nutrients adequacy and wellness. Soybean (*Glycine max*) is a legume common and available in the tropics. It is very rich in high-quality proteins that could be compared with those from animal sources (meat and dairy). The huge health benefits of soybean in growth, and prevention of diseases have been underscored [7]. Coconut (*Cocos nucifera*) is another popular crop rich in lipids (energy), proteins, fiber, and other functional dietary components. Its nutrition and health benefits were well documented [8]. Palm oil (*Elaeis guineensis*) is used globally. Its balanced fatty acid composition makes a valuable product in industrial applications. Palm oil is very good source of pro-vitamin A and vitamin E [9]. The rich array of nutrients and health qualities of these common and available food crops needs to be harnessed to ensure nutrition security for all. Consequently, this study produced Gari with soybean, defatted coconut flour, and palm oil and evaluated the chemical, physical, and sensory properties to ascertain its contribution to nutrition security.

II. MATERIALS AND METHODS

2.1 Study design:

The study employed experimental design.

2.2 Study area:

The study was conducted in the Food and Analytical laboratories of the College of Applied Food Sciences and Tourism, Michael Okpara University of Agriculture Umudike, Abia State Nigeria.

2.3 Source, Identification, and processing of the samples:

2.3.1 Source of the crops:

Freshly harvested cassava roots were obtained from National Root Crop Research Institute (NRCRI), Umudike Abia State Nigeria. The soybean, coconuts, and palm oil were bought from different stalls in a local market Ori-Ugba Storage Stalls Umuahia Abia State Nigeria.

2.3.2 Identification of the samples:

The cassava roots, soybean, coconuts, and palm oil were identified as *Manihot esculenta*, *Glycine max*, *Cocos nucifera* and *Elaeis guineensis* respectively by Dr. Onyeonagu Chike C. A Crop Scientist in the Department of Agronomy (CCSS), Michael Okpara University of Agriculture Umudike.

2.3.3 Processing of cassava roots into Garri, soybean, and coconuts into flours:

Excess sand was removed from the cassava roots, the roots were peeled manually, washed with clean tap water, and grated with mechanical grater (Grinding mill petrol engine GX200 - 6.5hp) to reduce the particle size. The grated cassava was packed in jute bag, tied firmly with rope, and placed in a hydraulic press (to remove excess water) and allowed to ferment for 3 days (72 hours), at room temperature. The dewatered cassava mass was fragmented with traditional sieve (10mm sieve size) and divided into four parts. The first part was fragmented with the cassava sieve and roasted in a saucepan (25cm deep) over a gas burner for 30 minutes with continuous stirring. The freshly roasted Garri was allowed to cool and labelled the control. The remaining three parts was kept ready for blending. The soybean bean flour was made using IITA method [10]. The soybeans were sorted to separate whole seeds from extraneous materials. The seeds were soaked for 24 hours, drained in a colander, and boiled with tap water for 60 minutes. The boiled soybeans were drained, dehulled, and dried in an Infitek laboratory oven (DOF – H Series) for 10 hours at 150^0C. The dried seeds were winnowed and milled to fine flour in a grinder (St Donkey powder crusher- Leshan Dongchaun) with 5mm sieve. The flour was packed for use. The coconut flour was prepared as described by Okafor and Usman [11]. The coconut was cracked, and the endocarp detached from the hard pericarp using kitchen knife. The dark covering of the endocarp was scraped off with knife and the white part milled into a paste in an SKU wet and Dry grinder (50 -60kg). The liquid component was removed, and the residue washed thoroughly in hot water to reduce the oil content. The washed coconut mass was oven-dried at 50^0C in Surgifield laboratory oven for 24 hours and re-milled into fine flour and package for use. Freshly made palm oil was obtained from the local market.

2.4 Formulation of Gari-soybean-coconut-palm oil blends:

The three remaining portions of sifted cassava mass were blended with soybean flour, defatted coconut flour, and palm oil in the ratios of 75:15:5:5, 65:20:10:5, and 55:25:15:5. The blends were roasted individually as the first portion (in a saucepan over a gas burner for 30 minutes with continuous stirring) and labelled as GSCO1, GSCO2 and GSCO3. The unblended Gari (100%) served as control.

2.5 Chemical evaluation of the Soybean-defatted Coconut-Palm oil- Gari blends:

The four Gari blends were evaluated for proximate composition (moisture, ash, protein, fat, fiber) using AOAC [12] methods. Percentage (%) Carbohydrate = (100 – M +P+F+A+F) was obtained by difference, where M = moisture, P = Protein, F = fat, A = ash, f = fiber. The energy value was calculated using Atwater factor = (4xP) + (9XF) + (4xC) Kcal; where P – protein, F = fat, C= Carbohydrate. The micronutrients composition (calcium, iron, potassium, sodium, magnesium, beta-carotene, thiamin, riboflavin, niacin, vitamin C) and the antinutrients (tannin, phytate, saponin, flavonoids, phenol) were analyzed according to AOAC methods [12].

2.6 Evaluation of the functional properties of the Soybean-defatted Coconut-Palm oil- Gari blends:

The swelling index of the Gari blends was determined as described by Ukpabi and Ndimele [13]. Fifty grams of each sample were placed into 500ml measuring cylinders to which 300ml cold water was added. The mixture was allowed to stand for four hours. The swelling level was observed, and the index calculated as the multiples of the original level. The bulk density of each sample was determined as described by Nwanekezie et al., [14]. Two grams of each sample measured into 5ml graduated cylinder, the bottom of the cylinder was tapped ten (10) times and the final volume taken. The bulk density was obtained by calculating the mass per unit volume of sample (Bulk density = mass of sample ÷ volume of the sample after tapping). The water and oil absorption capacity (WAC, OAC) were determined with the method as described in Wang et al., [15]. A gram of each Gari sample was placed into a 5ml centrifuge tube and 10ml of water or oil added. The samples were mixed thoroughly and allowed to stand for 30minutes at room temperature, then centrifuged at 2000rpm for 30 minutes. The volumes of the free water or oil supernatant were noted in a 10ml measuring cylinder and calculated as $V_1 = V_2 \div W$, where V_1 = initial volume, V_2 = final volume, W = weight of sample. (Note: the density of water is 1g/ml, density of oil depends on the type of oil and can be determined at 0.92g/ml). The foam capacity of the samples was determined as described by Onwuka [16]. Two grams of each sample was placed inside an electric blender with 100ml distilled water, and the knob turned on. The warring blending was poured into a 250ml measuring cylinder and the volume recorded after 30 seconds. The foam capacity is expressed as percentage increase in volume. Foam capacity (%increase in volume or % whipping ability) = $V_1 – V_1 \div V_2$ X 100. Onwuka [16] method was used to determine the gelation temperature. Each sample (100g) was mixed in 10ml distilled water in a test tube. The mixture was heated in a boiling bath with continuous stirring for 30 seconds. The temperature was taken after gelatinization was observed.

2.7 Sensory evaluation of the Soybean-defatted Coconut-Palm oil- Gari blends:

The sensory properties of the Gari samples were determined as described Iwe [17]. A total of 20 semi-trained panelist was purposively selected from the campus community for the evaluation. The samples were properly coded and presented in labelled plates, and rated for color, flavor, texture, taste, and overall acceptability using a 9-point hedonic scale, where 9 =

liked extremely, 8 = liked very much, 7 = liked moderately, 6 = liked slightly, 5 = neither liked nor disliked, 4 = disliked slightly, 3 = disliked moderately, 2 = disliked very much, 1 = disliked extremely. Evaluation forms and drinking water for mouth rinse after each testing was given to the panelists. They were instructed not to communicate during the study.

2.8 Statistical analysis:

The data gathered were subjected to statistical analysis using IBM Statistical Product for Service Solution (SPSS) version 21 and presented as means and standard deviation. The means were compared with analysis of variance (ANOVA) and separated using Duncan's multiple range test at 5% significance level ($p < 0.05$).

III. RESULT

The proximate composition range of the Gari blends was 9.25% to 10.83% moisture, protein was 1.27% to 11.52%, fat 1.06% to 14.29%, ash 0.62% to 2.47%, crude fiber 1.21% to 1.91%, carbohydrate 66.37% to 86.60%, and energy 360.98Kcal to 413.41Kcal (table 1).

TABLE 1
PROXIMATE COMPOSITION OF SOYBEAN-DEFATTED COCONUT-PALM OIL- GARI BLENDS

Samples	Moisture (%)	Crude protein (%)	Fat (%)	Ash (%)	Crude fiber (%)	Carbohydrate (%)	Energy (Kcal)
GSCO1	$10.83^{a} \pm 0.04$	$6.31^{c} \pm 0.01$	$6.86^{c} \pm 0.02$	$1.74^{c} \pm 0.01$	$1.66^{c} \pm 0.01$	$72.62^{b} \pm 0.00$	$377.42^{c} \pm 0.25$
GSCO2	$10.65^{b} \pm 0.04$	$8.86^{b} \pm 0.02$	$10.16^{b} \pm 0.01$	$2.16^{b} \pm 0.02$	$1.82^{b} \pm 0.01$	$66.37^{c} \pm 0.01$	$392.28^{b} \pm 0.01$
GSCO3	$10.13^{c} \pm 0.04$	$11.52^{a} \pm 0.02$	$14.29^{a} \pm 0.01$	$2.47^{a} \pm 0.01$	$1.91^{a} \pm 0.01$	$59.70^{d} \pm 0.01$	$413.41^{a} \pm 0.18$
TG	$9.25^{d} \pm 0.03$	$1.27^{d} \pm 0.02$	$1.06^{d} \pm 0.03$	$0.62^{d} \pm 0.01$	$1.21^{d} \pm 0.01$	$86.60^{a} \pm 0.02$	$360.98^{d} \pm 0.25$

Values are mean ± standard deviation of duplicate samples determinations. $^{a-d}$ Means with similar superscripts within the same column are not significantly different (p>0.05). GSCO1 = 75% Gari: 15% Soybean flour: 5% coconut flour: 5% palm oil, GSCO2 = 65% Gari: 20% Soybean flour: 10% coconut flour: 5% palm oil; GSCO3 = 55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil; TG = 100% Traditional Gari (control).

The mineral composition of the blends shows that sample GSCO3 (55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil), had more calcium (15.81%), sodium (11.51%), magnesium (9.27%), phosphorus (9.17%), potassium (16.21%), iron (2.83%), and zinc (1.82%) compared to the other blends (table 2). The control (100% Gari) had least content of all the selected minerals evaluated except magnesium (4.66%). Sample GSCO1 had the least content of magnesium (3.81%).

TABLE 2
MINERAL COMPOSITION OF SOYBEAN-DEFATTED COCONUT-PALM OIL-GARI BLENDS.

Samples	Calcium (mg/100g)	Sodium (mg/100g)	Magnesium (mg/100g)	Phosphorus (mg/100g)	Potassium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
GSCO1	$5.26^{c} \pm 0.01$	$2.87^{c} \pm 0.03$	$3.81^{d} \pm 0.01$	$6.12^{c} \pm 0.01$	$2.16^{c} \pm 0.03$	$1.12^{c} \pm 0.02$	$1.07^{d} \pm 0.01$
GSCO2	$10.22^{b} \pm 0.02$	$4.67^{b} \pm 0.02$	$6.14^{b} \pm 0.03$	$7.62^{b} \pm 0.03$	$10.42^{b} \pm 0.01$	$2.21^{b} \pm 0.01$	$1.65^{b} \pm 0.02$
GSCO3	$15.81^{a} \pm 0.01$	$11.51^{a} \pm 0.01$	$9.27^{a} \pm 0.02$	$9.17^{a} \pm 0.01$	$16.21^{a} \pm 0.01$	$2.83^{a} \pm 0.01$	$1.82^{a} \pm 0.01$
TG	$2.15^{d} \pm 0.02$	$0.83^{d} \pm 0.02$	$4.66^{d} \pm 0.02$	$3.48^{d} \pm 0.02$	$0.64^{d} \pm 0.01$	$0.22^{d} \pm 0.02$	$0.41^{c} \pm 0.01$

Values are mean ± standard deviation of duplicate samples determinations. $^{a-d}$ Means with similar superscripts within the same column are not significantly different (p>0.05). GSCO1 = 75% Gari: 15% Soybean flour: 5% coconut flour: 5% palm oil, GSCO2 = 65% Gari: 20% Soybean flour: 10% coconut flour: 5% palm oil; GSCO3 = 55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil; TG = 100% Traditional Gari (control).

The vitamin composition range of the Soybean-defatted coconut-palm oil Gari blends (table 3) shows the same trend as the mineral composition. Sample GSCO3 (55% Garri: 25% Soybean flour: 15% coconut flour: 5% palm oil), had more beta-carotene (201.42 µ/100g), thiamin (0.32mg), riboflavin (0.52mg), niacin (0.92mg), vitamin C (10.28mg), and vitamin E (0.52mg). the control had least content of the evaluated vitamins.

TABLE 3
VITAMIN COMPOSITION OF SOYBEAN-DEFATTED COCONUT-PALM OIL-GARI BLENDS

Samples	Beta-carotene (μ/100g)	Thiamin (mg/100)	Riboflavin (mg/100)	Niacin (mg/100)	Vitamin C (mg/100)	Vitamin E (mg/100)
GSCO1	$140.64^{c} \pm 0.03$	$0.18^{c} \pm 0.01$	$0.34^{c} \pm 0.01$	$0.41^{c} \pm 0.01$	$9.53^{c} \pm 0.01$	$0.41^{c} \pm 0.01$
GSCO2	$162.82^{b} \pm 0.03$	$0.24^{b} \pm 0.01$	$0.45^{cb} \pm 0.01$	$0.67^{b} \pm 0.00$	$10.02^{b} \pm 0.02$	$0.47^{b} \pm 0.01$
GSCO3	$201.42^{a} \pm 0.02$	$0.31^{b} \pm 0.01$	$0.52^{a} \pm 0.02$	$0.92^{a} \pm 0.01$	$10.28^{a} \pm 0.01$	$0.52^{c} \pm 0.02$
TG	$19.42^{d} \pm 0.02$	$0.12^{d} \pm 0.01$	$0.26^{d} \pm 0.01$	$0.31^{d} \pm 0.02$	$6.11^{d} \pm 0.01$	$0.17^{d} \pm 0.01$

Values are mean ± standard deviation of duplicate samples determinations. $^{a-d}$ Means with similar superscripts within the same column are not significantly different (p>0.05). GSCO1 = 75% Gari: 15% Soybean flour: 5% coconut flour: 5% palm oil, GSCO2 = 65% Gari: 20% Soybean flour: 10% coconut flour: 5% palm oil; GSCO3 = 55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil; TG = 100% Traditional Gari (control).

Values are mean ± standard deviation of duplicate samples determinations. $^{a-d}$ Means with similar superscripts within the same column are not significantly different (p>0.05). GSCO1 = 75% gari: 15% Soybean flour: 5% coconut flour: 5% palm oil, GSCO2 = 65% Gari: 20% Soybean flour: 10% coconut flour: 5% palm oil; GSCO3 = 55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil; TG = 100% Traditional Gari (control).

Table 4 shows the antinutrient composition of the Gari blends. All the antinutrients studied were more in sample GSCO3 (55% Garri: 25% Soybean flour: 15% coconut flour: 5% palm oil) – tannin (0.57mg), alkaloids (0.48mg), flavonoids (0.72mg), saponin (0.47mg), and phytate (0.23mg), except hydrogen cyanide which was highest (16.44mg) in the control (100% traditional Garri).

TABLE 4
ANTINUTRIENTS COMPOSITION OF THE SOYBEAN-DEFATTED COCONUT-PALM OIL- GARI BLENDS.

Samples	Tannin (mg/100g)	Alkaloid (mg/100g)	Flavonoid (mg/100g)	Saponin (mg/100g)	Phytate (mg/100g)	Hydrogen cyanide (mg/kg)
GSCO1	$0.41^{c} \pm 0.01$	$0.27^{c} \pm 0.01$	$0.61^{c} \pm 0.01$	$0.21^{c} \pm 0.01$	$0.12^{c} \pm 0.01$	$10.12^{b} \pm 0.02$
GSCO2	$0.48^{b} \pm 0.02$	$0.41^{b} \pm 0.01$	$0.66^{b} \pm 0.01$	$0.31^{b} \pm 0.01$	$0.17^{b} \pm 0.02$	$8.25^{c} \pm 0.02$
GSCO3	$0.57^{a} \pm 0.00$	$0.48^{a} \pm 0.02$	$0.72^{a} \pm 0.02$	$0.47^{a} \pm 0.01$	$0.23^{a} \pm 0.01$	$7.32^{c} \pm 0.03$
TG	$0.28^{d} \pm 0.01$	$0.11^{d} \pm 0.00$	$0.41^{d} \pm 0.01$	$0.16^{d} \pm 0.01$	$0.02^{d} \pm 0.01$	$16.44^{a} \pm 0.02$

Values are mean ± standard deviation of duplicate samples determinations. $^{a-d}$ Means with similar superscripts within the same column are not significantly different (p>0.05). GSCO1 = 75% Gari: 15% Soybean flour: 5% coconut flour: 5% palm oil, GSCO2 = 65% Gari: 20% Soybean flour: 10% coconut flour: 5% palm oil; GSCO3 = 55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil; TG = 100% Traditional Gari (control).

The functional properties of the soybean-defatted coconut-palm oil Gari blends shows that the bulk density ranged from 0.72 to 0.84g/ml, WAC 1.07 to 1.56g/g, OAC 1.61 to 2.42g/g, foam capacity 21.66 to 31.61%, foam stability 18.53 to 22.15%, swelling index 2.05 to 4.81%, and gelatinization temperature 70.31 to 78.62^{0}C (table 5)

TABLE 5
FUNCTIONAL PROPERTIES OF SOYBEAN-DEFATTED COCONUT-PALM OIL GARI BLENDS

Samples	Bulk density (g/ml)	Water absorption capacity (g/g)	Oil absorption capacity (g/g)	Foam capacity (%)	Foam stability (%)	Swelling index (%)	Gelatinization temperature (^{0}C)
GSCO1	$0.75^b \pm 0.01$	$1.21^b \pm 0.01$	$1.88^c \pm 0.02$	$28.44^b \pm 0.06$	$18.53^d \pm 0.03$	$2.61^b \pm 0.01$	$72.41^b \pm 0.01$
GSCO2	$0.81^a \pm 0.01$	$1.14^c \pm 0.01$	$2.11^b \pm 0.01$	$24.01^b \pm 0.01$	$19.04^c \pm 0.03$	$2.41^c \pm 0.01$	$71.12^c \pm 0.01$
GSCO3	$0.84^a \pm 0.02$	$1.07^d \pm 0.01$	$2.42^a \pm 0.02$	$21.66^d \pm 0.02$	$21.42^b \pm 0.02$	$2.05^d \pm 0.02$	$70.31^b \pm 0.01$
TG	$0.72^b \pm 0.01$	$1.56^a \pm 0.01$	$1.61^d \pm 0.01$	$31.61^a \pm 0.01$	$22.15^a \pm 0.02$	$4.81^a \pm 0.01$	$78.62^b \pm 0.01$

Values are mean ± standard deviation of duplicate samples determinations. $^{a-d}$ Means with similar superscripts within the same column are not significantly different (p>0.05). GSCO1 = 75% Gari: 15% Soybean flour: 5% coconut flour: 5% palm oil, GSCO2 = 65% Gari: 20% Soybean flour: 10% coconut flour: 5% palm oil; GSCO3 = 55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil; TG = 100% Traditional Gari (control).

The sensory properties scores of the Gari blends shows that sample GSCO3 (55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil) rated highest (7.46) in color (table 6). Sample GSCO2 (65% Gari: 20% Soybean flour: 10% coconut flour: 5% palm oil) rated highest in texture (7.74), taste (7.43), and general acceptability (7.43). Sample GSCO1 (75% Gari: 15% Soybean flour: 5% coconut flour: 5% palm oil) rated highest in Aroma (7.35).

TABLE 6
SENSORY EVALUATION SCORES OF SOYBEAN-DEFATTED COCONUT-PALM OIL-GARI BLENDS

Samples	Color	Texture	Taste	Aroma	General acceptability
GSCO1	$7.39^a \pm 0.99$	$7.61^a \pm 0.94$	$7.35^a \pm 1.11$	$7.35^a \pm 1.15$	$7.42^a \pm 0.72$
GSCO2	$7.39^a \pm 0.94$	$7.74^a \pm 1.01$	$7.43^c \pm 0.70$	$7.13^a \pm 1.14$	$7.43^a \pm 0.75$
GSCO3	$7.46^a \pm 1.02$	$6.63^b \pm 1.69$	$7.25^a \pm 1.22$	$6.92^a \pm 1.28$	$7.06^a \pm 0.88$
TG	$6.18^b \pm 2.36$	$6.50^b \pm 1.44$	$5.89^b \pm 2.17$	$5.91^b \pm 1.51$	$6.10^b \pm 1.66$

Values are mean ± standard deviation of duplicate samples determinations. $^{a-d}$ Means with similar superscripts within the same column are not significantly different (p>0.05). GSCO1 = 75% Gari: 15% Soybean flour: 5% coconut flour: 5% palm oil, GSCO2 = 65% Gari: 20% Soybean flour: 10% coconut flour: 5% palm oil; GSCO3 = 55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil; TG = 100% Traditional Gari (control).

IV. DISCUSSION

The moisture content of the formulated blends (10.13 to 10.83%) was more than the control (9.25%) and 7.97 to 8.93% obtained in Gari-soybean-groundnut flour reported by Ajani et al., [18]. The moisture content of the study blends was below the 12% recommended for shelf stable Gari, an indication of good keeping quality as reported [19]. The crude protein content of the Gari blends (6.31 to 11.52%) varied significantly due to the different constitutions and was higher than 1.27% in the control (Traditional Gari). The fat contents of the soybean-coconut-palm oil blended Gari was higher than 1.06 to 14.29% reported for cassava and other tubers [20]. The addition of palm oil to Gari adds flavor, color, as well as health effect of reducing the cyanide content of the product amongst other factors. The higher crude proteins obtained in this study was as the high protein Gari reported when traditional Gari was supplemented with legumes [21, 22]. The ash content of the soybean-coconut-palm oil blended Gari was significantly higher than the ash content of the traditional Gari. Ash content of a food product is an indication of the mineral composition. It was reported that values close to 0.5% ash is a good representation of the mineral contents [23]. This study ash range (1.74 to 2.47%) could be compared to 1.70% reported for white Gari [24]. The ash content of the study soybean-coconut-palm oil blended Gari was lower than the 2.75% stipulated by Codex Standard [25]. There was significant increase in the fiber content of the blends compared to the control. The increase in fiber was more in the sample with more defatted coconuts flour. This was expected as coconut was reported to contain up to 69.8% total dietary fiber [26]. The study fiber value was higher than 1.55 to 1.80% reported for Gari-soybean-groundnut flour reported [18]. The difference in fiber could be due to the different processing method employed. The fiber value of the study samples was within the expected nutritional maximum. A fiber level of Gari was recommended to be not more than 2% or a maximum of 3% respectively [27, 25]. The carbohydrate content of the blended soybean-coconut-palm oil blended Gari was significantly lower than the traditional Gari due to the addition of soybean, and coconuts. This addition implies more protein and fiber composition which are very necessary in improving good health. The energy value of the blends was significantly more than the traditional Gari. This is a plus to the new products as energy is a basic requirement for life. The soybean-coconut-palm oil blended Gari had higher mineral (calcium, sodium, phosphorus, potassium, iron, and zinc) values than the control. Sample GSCO3 (55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil) was more superior in mineral values than the other blends. This is attributed to the higher quantity of coconuts reported to be very rich in minerals like calcium, [28, 29]. A study that used coconuts in beverages showed increase in calcium value of the beverage [30]. The calcium value of the study samples varied significantly due to composition, and processing methods; and was lower than 8.9 to 61.35mg reported for soy-enriched Tapioca [31], and higher than 0.00 to 0.12mg soybean-supplemented cassava flour [32]. The high sodium value of Sample GSCO3 (55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil) is noteworthy as some consumers as reducing their sodium intake. Sodium is very important in protein function, enzymatic reactions and in blood clothing [33]. The magnesium content of the study blends was more than 1.25mg and 0.05 to 0.25mg reported for dried cassava, and fermented soybean supplemented cassava flour respectively [31, 20]. The phosphorus content of the study blends was inferior to 23.35 to 625.45mg, and 1.20 to 18.46mg reported for soy-enriched cassava tapioca and iron-fortified Cassava Gari, respectively [31, 34]. The iron value of the soybean-coconut-palm oil blended Gari was higher than previous reports of 0.23mg, 0.7mg, and 1.76mg in similar products [35, 36, 37]. The zinc value of the study blends is comparable to 14.00 to 41.00 reported for cassava-potato Gari [38]. The vitamin contents of the study soybean-coconut-palm oil blended Gari varied significantly from the traditional Gari. The addition of palm oil significantly increased the beta-carotene value of the blends over traditional Gari. It was reported that the addition of palm oil to Gari also reduces mold growth, improve aesthetic value, and reduce vitamin A deficiency [39]. The beta-carotene value of the study samples was much higher than 0.23 to 0.34 in traditional fermented bio-fortified cassava [40]. The B vitamins in the study samples were appreciably higher than 0.03 to 0.28mg thiamin, 0.33mg niacin, 0.01 to 0.19mg vitamin E, and lower than 18mg riboflavin reported for cassava staple [41]. The study vitamin C value was appreciable, but it was reported that up to 21% of the vitamin C will be lost during storage [42]. The antinutrients contents of the soybean-coconut-palm oil blended Gari varied considerably. The tannin, alkaloids, flavonoids and saponin, were lower than the permissible levels 10% or 4 to 9mg respectively [16, 43]. The flavonoid content could be due to the inclusion of soybean. Higher levels of antinutrients are known to chelate certain nutrients and irritate the mouth. The antinutrients obtained in this study could be compared to those reported in soy-enriched cassava tapioca [34, 44]. Soybean is documented to be high in. The phytate content of the study blends could be beneficial to health. The hydrogen cyanide content of the soybean-coconut-palm oil blended Gari is significantly lower than the traditional Gari (control). This could be the effect of constitution and with other constituents. The cyanide values were comparable to 4.13 to 21.47ppm reported for cassava products sold in Lafia Nigeria [45].The sensory evaluation scores of the study samples showed sample that GSCO3 (55% Gari: 25% Soybean flour: 15% coconut flour: 5% palm oil) was rated higher in color, sample GSCO2 (65% Gari: 20% Soybean flour: 10% coconut flour: 5% palm oil) rated highest in texture, taste, and general acceptability, while sample GSCO1 (75% Gari: 15% Soybean flour: 5% coconut flour: 5% palm oil) rated highest in Aroma. Processing methods, and composition are among the major determinants in acceptability scores. The study samples sensory scores were comparable with those reported for soybean-groundnut-Garri flour [22]. The bulk density is an indication of particle size and a determining factor in packaging raw materials, handling, and industrial application [46, 47]. The bulk density of the study soybean-coconut-palm oil blended Gari was significantly higher than the control. This is a plus to the product since higher bulk density will mean the Gari will not float but will soak adequately while a lower bulk density will mean that the product will float on top of water without proper soaking, a quality that will lead to rejection of the Gari. The soybean-coconut-palm oil blended Gari bulk density could be compared to 0.82 to 0.84g/ml reported on Gari processed in the South-West Nigeria [48]. The water absorption capacity of the soybean-coconut-palm oil blended Gari was lower than 1.27 to 156.5g/g reported for cassava flour fortified with soybeans [49]. High water absorption capacity means higher water uptake, a value related to the structure of the starch polymers. Lose structure is associated with high water uptake, while low values are associated with the compactness of the structure [50]. The oil absorption capacity of the samples suggest that they may be useful in in bakery products. The foaming stability of the samples was higher that 0.98 to 14.07% reported for cassava, wheat, rice, and potatoes flours [51]. The swelling index of the soybean-coconut-palm oil blended Gari was more than the control and indication of good quality Gari. A good quality Gari could swell three times its original volume [52]. High swelling index gives a greater volume and increased satiety per unit weight [53]. The gelatinization temperature of the study samples compared favorably with that of tapioca seeds (Kpokpo gari) reported [54]. The study samples functional properties are indicative of a good product with high industrial applicability.

V. CONCLUSION

Soybean-defatted coconut-palm oil-Garri blends have good storage stability, high protein value, considerable mineral, and vitamin composition and permissible antinutrients levels. The high fiber content of the blends will aid waste removal and reduction in diet-related non-communicable diseases. The acceptability scores of 7^+ on a nine-point hedonic scale was very encouraging. The functional profile of the samples is indicative of a good product. Nutritional diversification is encouraged to improve nutrients intake and reduce malnutrition.

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