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Preface

We would like to present, with great pleasure, the inaugural volume-11, Issue-3, March 2025, of a scholarly journal, *International Multispeciality Journal of Health*. This journal is part of the AD Publications series *in the field of Medical, Health and Pharmaceutical Research Development*, and is devoted to the gamut of Medical, Health and Pharmaceutical issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

This journal was envisioned and founded to represent the growing needs of Medical, Health and Pharmaceutical as an emerging and increasingly vital field, now widely recognized as an integral part of scientific and technical statistics investigations. Its mission is to become a voice of the Medical, Health and Pharmaceutical community, addressing researchers and practitioners in below areas

Clinical Specialty and Super-specialty Medical Science:

It includes articles related to General Medicine, General Surgery, Gynecology & Obstetrics, Pediatrics, Anesthesia, Ophthalmology, Orthopedics, Otorhinolaryngology (ENT), Physical Medicine & Rehabilitation, Dermatology & Venereology, Psychiatry, Radio Diagnosis, Cardiology Medicine, Cardiothoracic Surgery, Neurology Medicine, Neurosurgery, Pediatric Surgery, Plastic Surgery, Gastroentrology, Gastrointestinal Surgery, Pulmonary Medicine, Immunology & Immunogenetics, Transfusion Medicine (Blood Bank), Hematology, Biomedical Engineering, Biophysics, Biostatistics, Biotechnology, Health Administration, Health Planning and Management, Hospital Management, Nephrology, Urology, Endocrinology, Reproductive Biology, Radiotherapy, Oncology and Geriatric Medicine.

Para-clinical Medical Science:

It includes articles related to Pathology, Microbiology, Forensic Medicine and Toxicology, Community Medicine and Pharmacology.

Basic Medical Science:

It includes articles related to Anatomy, Physiology and Biochemistry.

Spiritual Health Science:

It includes articles related to Yoga, Meditation, Pranayam and Chakra-healing.

Each article in this issue provides an example of a concrete industrial application or a case study of the presented methodology to amplify the impact of the contribution. We are very thankful to everybody within that community who supported the idea of creating a new Research with *IMJ Health*. We are certain that this issue will be followed by many others, reporting new developments in the Medical, Health and Pharmaceutical Research Science field. This issue would not have been possible without the great support of the Reviewer, Editorial Board members and also with our Advisory Board Members, and we would like to express our sincere thanks to all of them. We would also like to express our gratitude to the editorial staff of AD Publications, who supported us at every stage of the project. It is our hope that this fine collection of articles will be a valuable resource for *IMJ Health* readers and will stimulate further research into the vibrant area of Medical, Health and Pharmaceutical Research.

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Dr. Kusum Gaur working as professor Community Medicine and member of Research Review Board of Sawai Man Singh Medical College, Jaipur (Raj) India.

She has awarded with WHO Fellowship for IEC at Bangkok. She has done management course from NIHFW. She has published and present many research paper in India as well as abroad in the field of community medicine and medical education. She has developed Socio-economic Status Scale (Gaur's SES) and Spiritual Health Assessment Scale (SHAS). She is 1st author of a book entitled " Community Medicine: Practical Guide and Logbook.

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He is working as Professor, Department of Surgery, Government Medical College, Chandigarh, India. He has done FMAS, FIMSA and FCLS along with MS (Gen Surgery).

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Research Area: Pediatric Surgery & Laparoscopy.

Table of Content

Volume-11, Issue-3, March 2025

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. $^{a\text{-}d}$ 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. $^{a\text{-}d}$ 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.

REFERENCES

[1] International Institute for Tropical Agriculture (IITA) Cassava (*Manihot esculenta*). https://www.iita.org/cropsnew/cassava/#:~: Accessed 26/02/2025.

[2] Ukwuru, M. U. and Egbonu, S. E. Recent development in cassava-based products research', Academia Journal of Food Research, Vol. 1, no 1, pp. 001-013, 2013.

[3] Achinewhu, S. C., Barber, L. I., Ijeoma, I. O. (1998). Physicochemical properties and garification (gari yield) of selected cassava cultivars in Rivers State, Nigeria. Plant Foods Hum Nutr 52: 133-140.

[4] WHO Facts Sheets Malnutrition – Key facts 2024 https://www.who.int/news-room/fact-sheets/detail/malnutrition Accessed 25/02/2025

[5] Manyike, PC., Chinawa, J., Ubesie, A., Obu, HA., Odetunde, OI., Chinawa, A. Prevalence of malnutrition among pre-school children in, South-east Nigeria. Italian Journal of Pediatrics 2014; 40(1):75

[6] Andy E., Nwachukwu OJ., Oyedele EA., Gotodok KH., Kumzhi RP. Malnutrition and associated factors among under-five in a Nigeria local government area. International Journal of Contemporary Medical Research 2016;3(6):1766-1768.

[7] Qin, P., Wang, T., Luo, Y. A review on plant-based proteins from soybean: Health benefits and soy product development Journal of Agriculture and Food Research Volume 7, March 2022, 100265

[8] Samarajeewa U. Coconut: Nutritional and Industrial Significance In book: Nut Consumption and Usefulness in the Modern World [Working Title] April 2024 DOI:10.5772/intechopen.1004173

[9] Loganathan R., Subramaniam KM., Radhakrishnan AK., Choo Y., Teng K. Health promoting effects of red palm oil: evidence from animal and human studies. Nutrition Reviews. 2017; 75 (2): 98 -113.

[10] International Institute of Tropical Agriculture (IITA) Soybean for good health: how to grow and use soybeans in Nigeria. IITA Publication 1990; 261 -265, 291.

[11] Okafor GI., Usman, OG. Production and evaluation of breakfast cereal from blends of African yam bean (Sphenostylis stenocarpa), maize (Zea mays) and defatted coconut (Cocos nucifera). Journal of Food Processing and Preservation (JFPP). 2014; 38 (3)

[12] AOAC (2016). Official methods of analysis (20th ed.). Association of Official Analytical Chemists.

[13] Ukpabi, UJ., Ndimele C. Evaluation of the quality of Garri produced in Imo State. Nigeria Food Journal. 8; 105 – 110

[14] Nwanekezie EC., Ohagi, NC., Afam-Anene, OC. Nutritional and Organoleptic quality of infant food formulations made from natural and solid-state fermented tubers (cassava, sprouted and unsprouted yam), and soybean flour blends. Nigerian Food Journal. 2001, 19: 55 -62.

[15] Wang N., Maximiuk, L., Fenn D., Nickerson MT., Hou, A. Development of a method for determining oil absorption capacity in pulse flours and protein materials. Cereal Chemistry. 2020; 97(6)

[16] Onwuka, GI. Food analysis and Instrumentation. Theory, and practice. Naphtali prints, Lagos Nigeria. pp 177 – 180.

[17] Iwe, MO. Handbook of Sensory method and analysis Rejoint Communication Science Ltd. Enugu Nigeria 2010. Pp. 75 -78.

[18] Ajani AO., Alade, OA., Olagbaju AR., Fasoyiro SB., Arowora KA., Oyelakin, MO. Chemical and sensory qualities of stored Gari fortified with soybeans and groundnut flour. Applied Tropical Agriculture 21 (2): 79 – 100.

[19] Abu, JO., Achagh, E., Iyordye-Abiem E. Quality evaluation of white and yellow Gari sold in Makurdi Metropolis. 34th Annual Conference and General Meetings of the Institute of Food Science and Technology (NIFST). Port Harcourt. 2010, PP 155 -156.

[20] Odebunmi, EO., Oluwaniyi, OO., Sanda, AM., Kolade, BO. Nutritional composition of selected tubers and root crops used in Nigerian food preparations. International Journal of Chemistry 2007, 17; 37 – 43.

[21] Oluwamukomi, MO., Adeyemi, IA. Effect of stages of enrichment on the chemical composition of soy-melon Gari- A protein enriched cassava semolina. Journal of Scientific Research and Reports. 2014; 4 (3):1 - 9.

[22] Arisa NU., Omosaiye, AO., Adelekan, AO., Alabi-Macfoy, A. Chemical and sensory qualities of Gari fortified with groundnut flour. African Journal of Food Science and Technology. 2011; 2 (5): 116 – 119.

[23] Adeleke, RO., Odedeji JO. Functional properties of wheat and sweet potatoes flour blends. Pakistan Journal of Nutrition. 2010; 9(6): 535

[24] Udensi JU., Anyanwu CO., Opara MC., Egwuogu GC., Duru CC., Anyanwu EC., Nwanaforo EO. Proximate and Microbial Analysis of Yellow, White and Spoilt Garri Sold in Owerri, Imo State, Nigeria. Archives of Current Research International. 2024; 24 (3):138-45.

[25] Codex Standard. CODEX Standard for Gari CODEX STAN 151 - 1989

[26] Trinidad, PT., Divinagracia, HV., Aida, CM., Faaridah, CA., Angelica SM., Modesto TC., Askali CA., Loyola, AS., Masa DB. Coconut flour from residues: A good source of dietary fiber. Indian Coconut Journal. 2001; 32 (6): 9 – 13.

[27] Ibe, DC. Semi mechanized Gari processing for the rural communities in Nigeria. In: Terry ER., Oduro, KA., Caveness E. (Ed). Tropical Root Crops: Research strategies, for the 1980s. International Society for Tropical Root Crops. African Branch, Ibadan. 1981 pp: 159

[28] Parmar, PT., Singh AK., Borad SG. Coconut (Cocos nucifera) In: Oilseeds: Health Attributes and Food Applications. Tanwar B., Goyal A. (Ed.) Springer Nature Link: https://link.springer.com/book/10.1007/978-981-15-4194-0 2021; 163 - 189

[29] Jonathan HT., Priscilla, JN. Examination of constituents of coconut natural product for dietary and therapeutic purposes Advances in Agronomy, Plant Breeding and Horticulture, Prime Scholars Library. 2019; 7 (3): 35 - 39,

[30] Udeze, SO., Ishola IA., Nnaemeka CN., Austine I. Mineral composition of Bambara nut-tigernut-coconut milk beverage blends. Journal of Food and Nutrition Sciences. 2014; 2 (5) : 231 – 235.

[31] Samuel, FO., Otegbayo, BO., Alalade T. Nutrient and Anti-Nutrient Content of Soy-Enriched Tapioca. Food and Nutrition Sciences. 2012; 3: 784-789.

[32] Thomas, GA., Olaiya, COO. Nutritional and Chemical Properties of Fermented Soybean-supplemented Cassava Flour Journal of Advances in Biology & Biotechnology. 2017; 12(3): 1-10.

[33] Page, MJ., Di Cera E. Role of Na+ and K+ in enzyme function. Physiological Reviews. 2006; 86 (4): 1049 – 92.

[34] Bamidele, OP., Ogundele, FG., Ojunbanire, BA., Fasogbon, MB., Bello, OW. Nutritional composition of Gari analog produced from cassava (Manihot esculenta) and cocoyam (Colocasia esculenta) tuber. Food Science and Nutrition. 2014; 2(6): 706 – 711.

[35] Bradbury, JH., Holloway, WD. Chemistry of tropical root crops: significance for nutrition and Agriculture in Pacific. ACIAR Monograph. No 6

[36] Okigbo, BN. Nutritional implications of projects giving high priority to the production of staples of low nutritive quality, In the case for cassava (Manihot esculenta, Crantz) in the humid tropics of the West Africa, Food and Nutrition Bulletin 2, pp 1 -10.

[37] Twum, LA., Ocloo, FCK., Duah-Bisiw D., Odai, BT. Determining the effect of heat treatment on iron fortified soybean *gari* blend and its potential bioavailability. Scientific Africa. 2021; 12, e00763

[38] Ojo, A., Akande EA. Quality evaluation of Gari produced from cassava and potatoes tuber mixes. African Journal of Biotechnology. 2013; 12: 4920 -4924

[39] Guado, I., Mawamba, AD., Ouambo, RSM., Some, IT., Felicite, TM. Provitamin A carotenoids of dried fermented cassava flour: The effect of palm oil addition during processing. International Journal of Food Engineering. 2008; 4(4); 1556 – 3758.

[40] Phorbee, OO., Olayiwola, IO., Sanni SA. Bioavailability of beta-carotene in traditional fermented, roasted granules, Gari from bio-fortified cassava roots. Food Nutrition Science 2013; 4(12):1247

[41] Montagnac, JA., Davis CR., Tanumihardjo SA. Nutritional Value of Cassava for Use as a Staple Food and Recent Advances for Improvement. Comprehensive Reviews in Food Science and Food Safety. 2009. https://doi.org/10.1111/j.1541-4337.2009.00077.x

[42] Ukhun, ME., Dibie EN. The ascorbic acid contents of selected marketed foods and influence of water activity (a_w) during storage. Food Chemistry. 1991; 41(3): 277 -283.

[43] Siddhuraju, P., Becker, K. Effect of various domestic processing methods on antinutrients and in-vitro protein and starch digestibility of two indigenous varieties of Indian tribal pulse, Mucuna pruriens Var. Utilis. Journal of Agriculture and Food Chemistry. 2001; 49: 3058.

[44] Folake, O. Samuel, F. A., Bolanle, O. Otegbayo, T. and Titilope, A. (2012). Nutrient and anti-nutrient content of soy-enriched tapioca. Food and nutrition science. 3:784-789.

[45] Akpomie, TM., Edet, IV., Augustine AU. Assessment of hydrogen cyanide levels in processed cassava products in Lafia Town Nigeria during January to March 2023. International Journal of New Chemistry. 2024; 11(2):133 -155

[46] Adebowale AA., Sanni LO., Onitilo MO. Chemical composition, and pasting properties of Tapioca grits from different cassava varieties and roasting methods. African Journal of Food Science. 2008; 2(7): 077 – 082.

[47] Ajanaku, KO., Ajanaku, CO., Edobor-osoh A., Nwinyi, OC. Nutritive value of sorghum ogi fortified with groundnut seed (*Arachis hypogeal*). American Journal of Food Technology. 2012; 79:82 -288

[48] Makanjuola, OM., Ogunmodede, AS., Makanjuola, JO., Awonorin, SO. *Comparative Study on Quality Attributes of Gari Obtained from Some Processing Centers in Southwest, Nigeria.* Advance Journal of Food Science and Technology. 2012; 4 (3): 135-140.

[49] Bankole YO., Tanimola, AO., Odunukan, RO., Samuel, DO. Functional and Nutritional Characteristics of Cassava Flour (Lafun) Fortified with Soybeans.Journal of Education and Social Research. 2013; 3(8):

[50] Yusuf, MI, Ejie, DD. Production of Bambara groundnut substituted whole wheat bread: Functional properties and quality characteristics. Journal of Nutrition and Food Science. 2018; 8:73

[51] Chandra, S., Samsher Assessment of functional properties of different flours African Journal of Agricultural Research . 2013; 8(38): 4849-4852

[52] Sanni, LO., Adebowale, AA., Awoyale, W., Fetuga, GO. Quality of Gari (roasted cassava mash) in Lagos State, Nigeria. Nigeria Food Journal. 2008; 26(1):125 134.

[53] Udensi, EA., Oselebe, HO., Iweala OO. The investigation of chemical composition and functional properties of water yam (Dioscorea alata): Effect of varietal differences. Pakistan Journal of Nutrition. 2008; 7(2): 342 -344.

[54] Onwuvariri, OK. Cassava toxixcity and food security. Tyrch Kontakt, Uppsala Dichester P. 91.

Effect of Stunning Methods on the Proximate Composition and Organoleptic Properties of Fresh and Smoke-Dried Catfish (*Clarias gariepinus*)

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Abstract— *Stunning is a critical step in fish processing that immobilizes fish before slaughter. This study investigated the effect of different stunning methods on the proximate composition and organoleptic properties of fresh and smoke-dried catfish. A total number of 20 live catfish (Clarias gariepinus) with a mean weight of 0.84±0.03 kg were obtained from a fish farm and were stunned by salting, icing, hammering, and exsanguination methods. Proximate analysis was carried out on parts of the freshly stunned fish. The rest of the fish samples were smoked dried, and then subjected to proximate analysis and organoleptic properties evaluation. The result of the organoleptic properties evaluation revealed that fish stunned by Salting (9.4±0.52) were the most preferred, while those stunned by icing (8.8±0.79) were the least preferred with no significant difference in overall acceptability among the stunning methods. The proximate analysis of fish samples showed that stunning methods had varying impacts on the proximate composition of fresh and smoke-dried fish samples. Fresh fish samples stunned by icing had the highest protein content (33.95±0.49) with the lowest moisture content (39.48±3.97), while the hammering method had the lowest protein content (19.25±0.49) with the highest moisture content (51.11±0.77). Smoke-dried fish samples stunned by icing method had the highest protein content (64.23±0.74), fat content (17.91±3.01) with a moisture content of 4.01±0.55, while the Salting method had the lowest protein content (54.78±0.74), and highest fat content (19.44±3.08) with a moisture content of 4.21±0.66. This study revealed that smoke drying improved the nutritional composition of catfish across all stunning methods.*

Keywords— Stunning methods, Proximate composition, Organoleptic properties, Clarias gariepinus.

I. INTRODUCTION

Fish is consistently among the most used and cheap dietary sources of animal protein for most people worldwide (Allam *et al.*, 2020; Maulu *et al.*, 2020). It is a valuable source of essential nutrients, especially high-quality protein and fats (macronutrients), vitamins, and minerals (micronutrients) that make a vital contribution to the world's food and nutrition security (FAO, 2020). As a food product, fish is of greater importance in developing countries where it accounts for 75% of the daily animal protein, referred to as "rich and poor food" as an important companion (Willett *et al.*, 2019; Mansour, 2021). It is readily available even in poorer communities at a relatively cheaper price than other animal protein sources. Furthermore, fish production through aquaculture is considered sustainable and the most efficient way to produce high-quality proteins for human consumption (Ali *et al.*, 2021; Khalil *et al.*, 2021).

The African catfish (*Clarias gariepinus*) is a significant fish species cultured in Africa. It has also been introduced into aquaculture in different parts of the world. It is primarily freshwater fish that are well adapted to confined environments and are resistant to manipulation and disease. Catfish are highly nutritious, containing a high concentration of unsaturated fatty acids, vitamins, proteins, and minerals (Nelson *et al.*, 2016). Since dietary composition is a significant determinant of the nutritional quality of fish flesh, numerous reports are available on African catfish slaughter traits and fillet quality (Sándor *et al.*, 2022). Recently, farmed fish have been subjected to various stunning techniques while processing. Many of these methods are assumed to present welfare problems since they expose fish to prolonged suffering and pain before death (WOAH, 2022).

The physiological response to pain is to release oxidizing substances that negatively impact the quality of the flesh, not to mention the implications regarding animal welfare (Alves *et al.*, 2015).

For a slaughter method to be considered humane, effective stunning that lasts until death, as well as the reduction of pain and fear throughout all procedures, is essential. (Coelho *et al*., 2022). The stunning method was adequate if the fish had no movement or behavioral reaction to a painful stimulus. It was assumed that a fish in that condition would not be able to feel pain or would feel it less intensely. The severity of the stunning and slaughter stresses is recognized to affect many quality traits such as the fish and fillet appearance promoting physical injuries, flesh gaping and changes in colour, rigor evolution, texture (firmness, cohesiveness, elasticity), water holding capacity, sensorial freshness indicators and, finally, in the shelf life. To date, although several recommendations have been proposed to reduce stress before and during fish slaughtering (WOAH, 2022), no specific Regulations are available about the procedure to be adopted (Bermejo-Poza *et al*., 2021). Thus, this study aimed to examine the effect of stunning methods on the proximate composition and organoleptic properties of fresh and smoke-dried catfish samples.

II. MATERIAL AND METHODS

2.1 Sample Collection and Preparation:

Twenty mature *Clarias gariepinus* with a mean weight of 0.84±0.03 kg and a mean length of 32.91±0.77 cm were purchased from a commercial fish farm (HouseTully fish farm) in the Awka metropolis for this study. The fish were harvested from the same rearing tank and taken to the slaughter slab on the farm, where fish stunning and slaughtering processes took place. The pre-stunning procedures were the same for all the fish samples. The weight, length, and number of fish used for each stunning method were recorded before the stunning procedures.

2.2 Fish Stunning/Killing Procedures:

The fish stunning was carried out at the House Tully fish farm, where it was purchased. Immediately after the contemporary catch and pre-stunning procedure, the fish were subjected in parallel to the following stunning/killing methods:

a) **Salting:** Fish were placed in a bowl and sprinkled with salt (100 g of salt per 1kg), after which the bowl was covered to prevent the fish from escaping.

b) **Ice block:** Fish were placed in a cooler made from Polyethylene terephthalate (plastic) containing ice flakes and 3 liters of water.

c) **Hammering:** Fish were hit on its head using a small wooden hammer.

d) **Exsanguination without stunning method:** The fish were cut alive with a knife without allowing the fish to lose consciousness, and the fish bled to death.

2.3 Fish Processing Procedures:

The fish were taken to the processing house of the House Tully fish farm after stunning, where they were gutted, washed, and brined. The fish samples were cut into fillets before being subjected to smoking processing method. Fish smoking was done using a metallic oven smoking kiln with charcoal as its heat source. The fish were occasionally turned to achieve even drying and smoking of the fish lasted for about 2 days.

2.4 Physical and Organoleptic Analysis:

Sensory evaluation was performed by a 10 man-trained committee panel using a 9-point Hedonic scale. The following grades were allotted depending on the condition of the fish. 9-10 = very good, 7-8 = good, 5-6 = fair, 3-4 = bad and <2 = worst. Panelists were instructed to assess the fish by feeling and tasting it. Fish product samples were served in clean dishes alongside questionnaires to the panelists. The fish aroma, flavor/taste, appearance/color, acceptance, and texture were examined in a ranking test, a form of discriminating test aimed at evaluating specific attributes of the processed fish. The characteristics of the Smoke-dried fish products tested include taste, texture, aroma, and color acceptance. The questionnaires were returned and analyzed for each parameter.

2.5 Proximate Analysis:

The crude protein, moisture, ash, fiber, carbohydrate, and fat contents of the fresh and smoke-dried fish samples were determined.

2.5.1 Determination of Total Ash Content:

This was done using the furnace incineration gravimetric method described by AOAC (2005). The empty platinum crucible was washed and dried, and the weight was noted. 2 g of the sample was weighed into the platinum crucible and placed in a muffle furnace at 500ºC for 3 hours. The sample was cooled in a desiccator after burning and weighed and calculated using Equation 1:

$$\% \text{ Ash content} = \frac{\text{Weight lost}}{\text{Weight of sample}} \times 100 \quad (1)$$

2.5.2 Determination of Moisture Contents:

This was done using the gravimetric method described by the AOAC (2005). A crucible was washed and dried in the oven. 2 g of the sample was weighed into the crucible. The weight of the crucible and sample were noted before drying. The crucible and sample were put in the oven for 2 hours at 105ºC. The drying procedure continued until a constant weight was obtained. Moisture content was calculated using Equation 2:

$$\% \text{ Moisture content} = \frac{\text{Weight lost}}{\text{Weight of sample}} \times 100 \quad (2)$$

2.5.3 Determination of Crude Protein:

This was done using the Kjeldahl method described by AOAC (2005). A 2 g sample was weighed into a 300 ml kjehdal flask (gently to prevent the sample from touching the walls of each side, and then the flasks were stopped and shaken. Then, 0.5 g of the kjedahl catalyst mixture was added. The mixture was heated cautiously in a digestion rack on an electric hot plate until a clear solution appeared. The clear solution was then allowed to stand for 30 minutes and cool. After cooling, about 100 ml of distilled water was added to avoid caking, and then 5 ml of the filtrate and 5 ml of 40% Na0H were transferred to the Kjedahl distillation apparatus. A 250 ml receiver beaker containing 10 ml of 10% boric acid and an indicator mixture containing five drops of Bromocresol blue and one drop of methylene blue was placed under a condenser of the distillation apparatus so that the tap was about 20 cm inside the solution. Then 5 ml of 40% sodium hydroxide was added to the digested sample in the apparatus, and distillation commenced immediately until 50 drops got into the beaker, after which it was titrated to pink color using 0.01N hydrochloric acid. Percentage Nitrogen was calculated using equation 3.

% Nitrogen = Titre value x 0.01 x 14 x 4 (3)

% Protein = % Nitrogen x 6.25

2.5.4 Determination of Crude Fat:

The solvent extraction gravimetric method described by AOAC (2005) determined this—dry 250 ml clean boiling flasks in the oven at 105-110ºC for about 30 minutes. Transfer into a desiccator and allow to cool. Weigh about 2 g of samples accurately into labeled thimbles. Weigh correspondingly labeled, cooled boiling flasks. Fill the boiling flasks with about 300 ml of petroleum ether (boiling point 40-60ºc). Plug the extraction thimble lightly with cotton wool. Assemble the soxhlet apparatus and allow it to reflux for about 6 hours. Remove the thimble carefully, collect petroleum ether in the top container of the set-up, and drain into a container for re-use. Remove and dry at 105ºC - 110ºC for 1 hour when the flask is almost petroleum-free. Transfer from the oven into a desiccator, cool, and weigh. The percentage of fat was calculated using Equation 4:

$$\% \text{ Fat} = \frac{\text{Weight lost}}{\text{Weight of sample}} \times 100 \quad (4)$$

2.5.5 Determination of carbohydrates:

In the determination of carbohydrates, the carbohydrate content of a sample was regarded as a nitrogen-free extract. This was determined by adding up the percentages of moisture, Ash, protein, and Fat and subtracting the sum from 100. The Percentage of Carbohydrates was calculated using Equation 5.

% Carbohydrate = 100- (% Protein + % Ash + % Moisture + % Fat + % Fibre) (5)

2.5.6 Determination of Crude Fibre:

Weigh 2 g of the plant sample into a conical flask containing 200 ml of 1.25 g of H_2SO_4 solution per 100 ml. Boil under reflux for 30 minutes. Filter the solution through linen or several layers of cheese cloth on a fluted funnel. Wash with boiling water until the washings are no longer acidic at pH 7.0. Transfer the residue to a beaker and boil for 30 minutes with 200 ml of a solution containing 1.25 g of carbonate-free NaOH per 100 ml. Filter the final residue through a thin but close pad of washed and ignited asbestos in a crucible. Dry in an electric oven at a temperature of 105ºC and weigh. Incinerate in a muffle furnace at a temperature of 300ºC for 2 hours, cool, and weigh. The loss in weight after incineration x 100 is the percentage of crude fibre:

$$\%\ \text{Crude fibre} = \frac{\text{Weight lost}}{\text{Weight of sample}} \times 100 \qquad (6)$$

2.6 Data analysis:

All analyses were repeated in triplicate, and the results were presented as mean ± standard deviation (SD). Analysis of variance (ANOVA) was carried out using F-test to determine the treatment's significance level. Treatments were separated using the Duncan Multiple Range Test (DMRT) at a 95% confidence value ($p < 0.05$). All statistical analysis was performed using SPSS version 20.

III. RESULTS AND DISCUSSION

3.1 Organoleptic/Sensory Evaluation of the Fish Samples:

The result of the organoleptic assessment of smoke-dried fish samples stunned differently is presented in Table 1. The appearance of the fish samples ranged from 7.7 to 8.5, with no significant difference observed across the various stunning methods ($p > 0.05$). In terms of taste, the samples ranged from 8.1 to 9.4, and a significant difference was observed among the samples ($p < 0.05$), indicating that the taste of the smoke-dried fish varied depending on the stunning method used. The aroma of the samples ranged from 8.8 to 9.1, with no significant difference observed among the samples ($p > 0.05$). Similarly, the texture of the samples ranged from 8.2 to 8.5, with no significant difference observed among the samples ($p > 0.05$). Overall acceptability scores ranged from 8.8 to 9.4, with no significant difference observed among the samples ($p > 0.05$).

TABLE 1
ORGANOLEPTIC EVALUATION OF SMOKE-DRIED FISH SAMPLES STUNNED DIFFERENTLY

Stunning methods	Appearance	Taste	Aroma	Texture	Overall acceptability
Salting	8.4±0.97^a	9.4 0.52^a	9.1±0.57^a	8.5±0.85^a	9.4±0.52^a
Icing	7.7±0.82^a	8.1 0.88^c	9.0±0.67^a	8.2±0.92^a	8.8±0.79^a
Hammering	8.3±0.82^a	8.6 0.97^b	8.8±0.63^a	8.2±0.63^a	9.0±0.67^a
Exsanguination	8.2±1.03^a	8.4 0.84^b	8.8±0.63^a	8.3±0.95^a	8.9±0.74^a

Attribute in mean ± standard deviation of 10 committee panel responses on a 9-Hedonic scale (very good=9-10, good=7-8, fair=5-6, bad=3-4, worst=1-2). The means in rows with different superscripts are significantly different (p<0.05).

The organoleptic properties of the fish samples were assessed to identify the most preferred stunning method based on sensory characteristics. The acceptance of aroma, texture, tenderness, colour, appearance and general acceptability, vary among the smoked fish samples that were subjected to different stunning methods. The results of the study revealed that fish stunned by salting was significantly higher and most preferred in terms of all the parameters used in assessing the organoleptic properties. This finding revealed that salting has a positive impact on the sensory characteristics of fish products. Salting is known to enhance the flavor and aroma of fish (Hafez *et al*., 2019) by enhancing the natural taste of the fish and drawing out excess moisture. Additionally, salting serves as a cleansing agent for removing slime from the fish samples, which can improve the overall appearance of the product. The texture of fish is also improved by salting, leading to a firmer and clearer appearance after smoke-drying. Fish stunned by icing was found to be the least preferred in terms of appearance, taste, texture, and overall acceptability. This finding may be attributed to the stunning effect and smoke-drying process on the flesh quality of the fish samples. Alves *et al*. (2015) reported that immersion in ice water during stunning process causes low temperatures that decrease metabolism, immobilize fish, and negatively impact the quality of the fish flesh. Similarly, Bermejo-Poza *et al*. (2021) also noted that immersion in ice water (live chilling) is still commonly used as a stunning method in fish, but can have negative effects on the stress response and flesh quality. Fish stunned by hammering and exsanguination were the least preferred in terms of aroma. This could be due to the stress and struggle experienced by the fish during stunning, which may have affected the aroma of the fish. Alves *et al*. (2015) noted that if stunning occurs without loss of conscience, the fish may feel pain during slaughtering, leading to the release of oxidizing substances that can negatively impact the quality of the flesh. Additionally, other organoleptic parameters for hammering and exsanguination were observed to be moderate between salting and icing. The effect of stunning methods on the organoleptic properties of smoke-dried fish samples varied slightly, with taste being the most affected, especially in the salting method.

3.2 The Proximate Composition of the Fish Samples:

In recent years, concerns about fish welfare have increased in aquaculture, particularly in relation to the slaughter process (Bermejo-Poza *et al.*, 2021). The stunning methods used during slaughter can have a significant impact on the proximate composition of fresh and smoke-dried catfish. This is primarily due to the effect of stress hormones released during the stunning process, which can lead to changes in muscle breakdown and fat distribution. The results of the stunning methods, including Salting, Icing, Hammering, and Exsanguination, showed varying impacts on the proximate composition of fresh and smoke-dried catfish samples. Ajibare *et al.* (2023) reported that proximate composition of fish not only help in identifying the nutritional components of the fish but also ascertain the quality of the fish product. According to the proximate analysis of the fresh fish samples, the different stunning methods had varying effects on the moisture, protein, ash, and fiber content of the fish. The results revealed that the fish stunned by hammering had the highest moisture content of 51.11%, salting at 50.35%, exsanguination at 49.46%, while icing recorded the lowest moisture content at 39.48% as shown in Table 2. The moisture content of fresh fish samples of the stunning methods is significantly different ($p < 0.05$). Addo *et al.* (2023) reported moisture content of 77.4 ± 1.94% in fresh *Clarias gariepinus* which is higher than the result of this study. For ash content, exsanguination recorded the highest value at 13.37%, followed by hammering at 12.23%, icing at 10.83%, and the lowest value was salting at 7.46%. There is a significant difference between the ash content of the fresh fish samples of the stunning methods ($p < 0.05$). These findings recorded higher ash content than those reported by Umar *et al.* (2024). For fiber content, fish stunned by icing had the highest value at 2.10%, followed by salting at 1.86%, hammering at 1.61%, and exsanguination at 1.56%. The fiber content of the fresh fish samples from the different stunning methods is significantly the same ($p > 0.05$). Namaga *et al.* (2020) observed a higher level of fibre in fresh *Clarias gariepinus*. The results also revealed that for fat content, fish stunned by exsanguination had the highest value of 15.24%, followed by salting at 15.14%, hammering at 14.78%, and icing with the lowest value of 9.76%. However, there was no significant difference ($p > 0.05$) between the fat content of the fresh fish samples of the different stunning methods. Umar *et al.* (2024) reported a higher value (27.01±0.40%) of fat content in *Clarias gariepinus* in their study. In terms of protein content, fish stunned by icing recorded the highest value of 33.95%, followed by salting at 22.40%, exsanguination at 20.13%, and hammering at 19.25%. The protein content of the fresh fish samples of the stunning methods was found to be significantly different ($p < 0.05$). The finding of this result was higher than those of Addo *et al.* (2023) but lower that those reported by Namaga *et al,* (2020). Lastly, for carbohydrates, fish stunned by Icing has the highest value of 3.88%, Salting at 3.34%, Hammering at 1.02%, and then Exsanguination with the lowest value of 0.24%. The carbohydrate content of the stunning methods is significantly the same ($p > 0.05$). Addo *et al.* (2023) reported total carbohydrate of 4.45 ± 1.55% which is higher than this study.

TABLE 2
THE PROXIMATE COMPOSITION OF FRESH CATFISH SAMPLES STUNNED DIFFERENTLY

Stunning methods	Moisture (%)	Ash (%)	Fibre (%)	Fat (%)	Protein (%)	Carbohydrate (%)
Salting	$50.35±1.01^{a}$	$7.46±1.96^{c}$	$1.86±0.59^{a}$	$15.14±6.81^{a}$	$22.40±2.47^{b}$	$3.34±1.18^{a}$
Icing	$39.48±3.97^{b}$	$10.83±1.23^{bc}$	$2.10±0.24^{a}$	$9.76±0.79^{a}$	$33.95±0.49^{a}$	$3.88±1.20^{a}$
Hammering	$51.11±0.77^{a}$	$12.23±0.55^{ab}$	$1.61±0.46^{a}$	$14.78±0.42^{a}$	$19.25±0.49^{b}$	$1.02±0.60^{a}$
Exsanguination	$49.46±0.31^{a}$	$13.37±0.52^{a}$	$1.56±0.59^{a}$	$15.24±0.76^{a}$	$20.13±0.25^{b}$	$0.24±0.06^{a}$

M±SD = Mean±Standard deviation, Mean with different superscript within the same column are significantly different ($p < 0.05$); SM= Salting method, IM= Icing method, HM= Hammering method, EM= Exsanguination method.

Fresh fish samples stunned by salting resulted in relatively high moisture (50.35%) and protein (22.40%) content. The ash content was moderate at 7.46%, while fat content was 15.14% and carbohydrate content was 3.34%, falling within typical ranges. The Salting method may be effective in preserving the quality of fresh fish (Hafez *et al.*, 2019) and maintaining essential nutrients like protein. Fish stunned by the Icing method led to lower moisture (39.48%) but relatively higher ash (10.83%), and protein (33.95%) content in the fresh fish sample. Fat (9.76%) and carbohydrate (3.88%) were moderate. The Icing method may play a role in reducing the moisture content while preserving protein levels, making it suitable for specific applications.

Fish samples stunned by Hammering method resulted in high moisture (51.11%) and ash (12.23%) content, with moderate fat (14.78%) and protein (19.25%) levels. The carbohydrate content (1.02%) was lower compared to other methods. Hammering may positively impact moisture retention and maintain higher ash and protein content in the fish quality. The Exsanguination method showed moderate levels of moisture (49.46%), ash (13.37%), fat (15.24%), and protein (20.13%) content. The fiber content (1.56%) was relatively low, and the carbohydrate content (0.24%) was the lowest among the methods. Exsanguination may help retain essential nutrients like protein and fat while reducing carbohydrate content. It was also observed from the result that high moisture content lowers the protein content of the fish. The Hammering method recorded the highest moisture content (51.11%) and the lowest protein content (19.25%) while the Icing method recorded the lowest moisture content (39.48%) and the highest protein content (33.95%). This finding is in agreement with the work of Ajibare *et al.* (2023) who reported that the crude protein of fish samples increased as the moisture reduces.

Table 3 presents the proximate composition of smoke-dried catfish samples stunned differently. The result revealed that the moisture content of fish stunned by Exsanguination had the highest value at 4.41%, followed by Salting at 4.21%, icing at 4.01%, and Hammering with the lowest value of 3.64%. There is a significant difference between the moisture content of the smoke-dried fish samples of the stunning methods ($p < 0.05$). The values of the moisture content across the stunning methods of the smoked dried fish was much lower than the findings of Ajibare *et al.* (2023) who noted that the degree of moisture content in smoked fish could be as a result of the extent of dryness, smoking duration as well as the type of smoking kiln used. For ash content, fish stunned by Hammering recorded the highest value of 16. 37%, followed by Exsanguination at 13.49%, Salting at 13.41%, and then Icing with the lowest value of 11.68%. The ash content of the smoke-dried fish samples showed a significant difference across the stunning methods ($p < 0.05$). The ash content recorded in this study was higher than those reported by Addo *et al.* (2023) and Umar *et al.* (2024). However, no significant difference ($p > 0.05$) was observed in the fiber content of the smoke-dried fish samples stunned using different methods. The Exsanguination method had the highest fiber content at 2.17%, followed by Hammering at 2.17%, Salting at 1.76%, and Icing at 1.43%. This present study recorded higher fibre content than those reported by Umar *et al.* (2024). The fat content of the smoke-dried fish samples of the stunning methods is significantly different ($p < 0.05$). Among the stunning methods, the Salting method has the highest fat content of 19.44%, followed by the Exsanguination method at 18.68%, followed by the Icing method at 17.91%, and then Hammering with the lowest value of 14.98%. Umar *et al.* (2024) reported higher fat content but lower protein content than this study. For protein content, fish stunned by Icing recorded the highest value of 64.23%, followed by the Hammering method at 59.68%, followed by Exsanguination at 54.96%, and Salt with the lowest value of 54.78%. There is a significant difference between the protein content of the smoke-dried fish samples of the stunning methods ($p < 0.05$). The protein content and fat content obtained in this present study were within the range reported by Emre *et al*., (2018) who opined that the total protein content in fish ranged from 63.80 % - 78.15%, and total fat content varied from 4.57% - 21.29% in different seasons. Lastly, for carbohydrate content, fish samples stunned by Hammering had the highest value of 6.61%, followed by the Salting method with 6.40%, the Exsanguination method with 6.29%, and then the Icing method with the lowest value of 0.73%. The carbohydrate content of the smoke-dried fish samples of the stunning methods is significantly different ($p < 0.05$). Addo *et al.* (2023) reported a lower fat and protein content than this study but higher carbohydrate content in smoked *C. gariepinus.*

TABLE 3
THE PROXIMATE COMPOSITION OF SMOKE-DRIED CATFISH SAMPLES STUNNED DIFFERENTLY

Stunning methods	Moisture (%)	Ash (%)	Fibre (%)	Fat (%)	Protein (%)	Carbohydrate (%)
Salting	4.21 ± 0.66^{a}	13.41 ± 2.59^{b}	1.76 ± 1.02^{a}	19.44 ± 3.08^{a}	54.78 ± 0.74^{c}	6.40 ± 3.25^{a}
Icing	4.01 ± 0.55^{a}	11.68 ± 1.71^{c}	1.43 ± 0.34^{a}	17.91 ± 3.01^{b}	64.23 ± 0.74^{a}	0.73 ± 0.34^{b}
Hammering	3.64 ± 0.64^{b}	16.37 ± 1.08^{a}	2.17 ± 0.73^{a}	14.98 ± 1.28^{c}	59.68 ± 3.71^{b}	6.61 ± 0.78^{a}
Exsanguination	4.41 ± 0.14^{a}	13.49 ± 1.58^{b}	2.19 ± 0.24^{a}	18.68 ± 0.46^{b}	54.96 ± 0.59^{c}	6.29 ± 0.63^{a}

The effect of processing or smoke-drying on the proximate composition of fresh fish samples was observed in this study. The nutritional composition the fish samples improved after smoke-drying. There was a great variation between the moisture content of fresh and smoke-dried fish samples across the stunning methods. The moisture content of the fresh fish samples

(39.48 - 51.11%) were higher than those of the smoke-dried fish samples (3.64 - 4.41%). The ash, fat and protein content of the fish samples increased across the stunning methods after smoke-drying. The findings is in agreement with the work of Famurewa *et al.* (2017) who observed an increasing protein content at a level of 5.5% and crude ash at 14% in their study after fish smoking. Addo *et al.* (2023) also recorded higher nutritional composition in smoked fish samples and recommended that farmed catfish should be smoked before consumption to obtain maximum nutritional benefit.

IV. CONCLUSION AND RECOMMENDATIONS

In conclusion, this study evaluated the effect of different stunning methods on catfish's nutritional composition and organoleptic properties. The findings showed that each stunning method had unique effects on the nutritional composition of fish. Stunning methods of Hammering may be considered effective and humane since they exert little stress, pain, and struggle on the fish. In organoleptic evaluation, the salting method may be considered the best stunning method compared to other methods. Smoking may be a means of improving the nutritional composition of catfish since the proximate composition of the fish was improved after smoke-drying. The impact of stunning methods on fish quality highlighted the importance of considering nutritional factors, food safety concerns, and consumer preferences in fish stunning, processing, and storage. By understanding the effects of different stunning and processing techniques on fish quality, producers can make proper decisions to meet consumers' diverse needs and expectations. The choice of stunning method should be considered based on the desired nutritional profile and the intended use of fish products because of its significant impact on the quality and freshness of fish samples.

Further research and evaluation of stunning methods are important for ensuring fish quality and safety throughout the supply chain. Fish producers should avoid stunning methods that are considered inhumane since they affect the quality and safety of the fish's final product. Fish producers should also consider fish quality and safety, nutritional composition, and consumer preference before choosing the stunning, processing, and storage methods to maintain the quality of fish products. Using salt to stun catfish is highly recommended since it improves the fish's organoleptic properties (it adds to its taste and serves as a cleansing agent) and is a preservative. It is also recommended that farmed catfish should be smoked before consumption to obtain maximum nutritional benefit.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any conflict of interest.

AUTHOR'S CONTRIBUTION

ORC and OOR designed the study and collection of fish samples from the commercial fish farm in Awka metropolis. OPA and ICF performed the laboratory analysis. ORC and NCG were responsible for data analysis and writing of the manuscript. All authors reviewed and approved the manuscript for submission.

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REFERENCES

[1] Addo, S., Sowah, W., Amonsah, S.K.K., Issifu, K. and Asamoah, E.K. (2023). 'Nutritional composition, Bacterial load and organoleptic quality of farm-raised Catfish (*Clarias gariepinus*, Burchell 1822) from the Dormaa Municipality Ghana'. *Ghana J. Sci*., 64 (2), 2023, 12 - 22 Original scientific article https://dx.doi.org/10.4314/gjs.v64i2.2.

[2] Ajibare, A.O., Ayeku, P.O. and Udoh, F.E. (2023). Proximate Composition and Sensory Evaluation of Catfish (Clarias gariepinus) Smoked with Different Materials. *Aquatic Food Studies*, 3(2), AFS193. https://doi.org/10.4194/AFS193.

[3] Ali, A., El Sherif, S., Abd All,a J., Maulu, S., Tantawy, A.A. and Soliman, M. F. K. (2021). Morphometric, histochemical, and ultrastructural analysis of male blue crab's reproductive system and spermatogenic stages (Callinectessapidus Rathbun, 1896). *J Mar Sci Eng.* (2021) 9:1105. doi: 10.3390/jmse9101105.

[4] Allam, B.W., Khalil, H.S., Mansour, A.T., Srour, T.M., Omar E.A. and Nour A.A.M., (2020). The impact of substitution of fish meal by high protein distillers dried grains on growth performance, plasma protein and economic benefit of striped catfish (Pangasianodon hypophthalmus). *Aquaculture,* 517, 734792. doi: 10.1016/ j. aquaculture.2019.73479.

[5] AOAC (2005). Association of Analytical Chemistry. Methods for chemical Analysis. 2217 – 2280.

[6] Bermejo-Poza, R., Fernández-Muela, M., De la Fuente, J., Pérez, C., González de Chavarri, E., Díaz, M.T., Torrent, F. and Villarroel, M., (2021). "Effect of ice stunning versus electronarcosis on stress response and flesh quality of rainbow trout. Aquaculture, 538, Article 736586, 10.1016/j.aquaculture.2021.736586

[7] Coelho, M.E.G, Pedrazzani, A.S, Quintiliano, M.H, Bolfe F, and Molento, C.F.M. (2022). Fish slaughter practices in Brazilian aquaculture and their consequences for animal welfare. *Anim Welf.,* 31, 18792. doi: 10.7120/09627286.312003.

[8] Famurewa, J.A.V., Akise, O.G. and Ogunbodede, T. (2017). Effect of storage methods on the nutritional qualities of African Catfish Clarias gariepinus (Burchell, 1822) Afr. J. Food Sci. 2017;11:223–233.

[9] FAO (2020). The State of World Fisheries and Aquaculture 2020.

[10] Hafez, N.E., Awad, A.M., Ibrahim, S.M., Mohamed, H.R. and El-Lahamy, A.A. (2019). Effect of Salting Process on Fish Quality. *Nutrition and Food Processing*, 2(1); Doi:10.31579/2637-8876/011.

[11] Khalil, H.S., Momoh, T., Al-Kenawy, D., Yossa R., Badreldin A. and Roem, A. (2021). Nitrogen retention, nutrient digestibility, and growth efficiency of Nile tilapia (*Oreochromis niloticus*) fed dietary lysine and reared in fertilized ponds. *Aquac Nutr*., 00, 1–13. doi: 10.1111/ anu.13365.

[12] Maulu, S., Hasimuna, O.J., Monde, C. and Mweemba, M. (2020). An assessment of post-harvest fish losses and preservation practices in Siavonga district, Southern Zambia. *Fish Aquatic Sci.,* 23, 1–9. doi: 10.1186/s41240-020-00170-x.

[13] Mansour, A.T., Allam, B.W., Srour, T.M., Omar, E.A., Nour, A.M., Khalil, H.S. (2021). The feasibility of monoculture and polyculture of striped catfish and nile tilapia in different proportions and their effects on growth performance, productivity, and financial revenue. *J Mar Sci Eng*., 9, 586. doi: 10.3390/jmse9060586.

[14] Namaga, W.M., Yahaya, B. and Salam, M.A. (2020). Proximate composition of male and female African catfish (*Clarias gariepinus*) and tilapia (*Tilapia zilli*) in Jega river, Kebbi state, *Nigeria. Journal of Fisheries, Livestock and Veterinary Science*, 01(02), 28-35.

[15] Nelson, J.S, Grande T.C. and Wilson M.V.H. (2016). Fishes of the world. Animal Science and Zoology. John Wiley and Sons Inc. 5th Edition.

[16] Alves, R.C.P., Tech, A.R.B., Natori, MM., de Oliveira, A.B.S and Viegas, E.M.M. (2015). Health & Welfare; Stunning methods for fish published in the January/February 2015 print edition of the Global Aquaculture Advocate.

[17] Sándor, Z. J., Bíró, J., Adányiné Kisbocskói, N., Perjéssy, J., Lengyel-Kónya, É., and Gyalog, G. (2022). "DDGS tartalmú táp tesztelése afrikai harcsa növendéken üzemi halnevelő rendszerben/Investigation of DDGS containing diet in feeding of African catfish in industrial condition," *Halászatfejlesztés/Fisheries & Aquaculture Development*, vol. 39, pp. 57–60, 2022.

[18] Umar, S. G. Anyekema, M., Umar, A. and Osesua, B.A. (2024). Proximate analysis and Minerals Evaluation of Fresh and Smoked Catfish (*Clarias Gariepinus*). *International Journal of Chemistry and Chemical Processes*,10, 65-74,

DOI: 10.56201/ijccp.v10.no6.2024.pg65.74.

[19] Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T. and Vermeulen, S. (2019). Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from Sustainable Food systems. *Lancet*., 393:447–92. doi:10.1016/ S0140-6736(18)31788-4.

[20] WOAH (2022). "Welfare aspects of stunning and killing of farmed fish for human consumption", *Aquatic Animal Health Code* (2022) p 14. Available at:

https://www. woah.org/fileadmin/Home/eng/Healthstandards/aahc/current/chapitrewelfare stunningkilling.pdf.

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