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NUTRITIONAL ENRICHMENT OF YELLOW GARI THROUGH PROCESSING WITH BLENDS OF PALM OIL AND SOYBEAN OIL

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Abstract

This study evaluated the nutritional, functional and sensory characteristics of yellow gari processed with palm oil and soybean oil blends. Six formulations with palm oil-to-soybean oil ratios of 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50 were assessed for proximate composition, functional properties, fatty acid profile and sensory acceptability. Increasing soybean oil inclusion was associated with lower moisture and carbohydrate contents and higher reported protein and fibre concentrations. Moisture ranged from 11.70% to 14.70%, carbohydrate from 72.48% to 77.37%, and estimated energy from 346.10 to 350.30 kcal/100 g. No significant differences occurred in fat, ash, energy, water absorption capacity or taste ($p > 0.05$). Bulk density increased, while swelling capacity increased numerically. The reported fatty acid profile showed declining palmitic and oleic acid proportions alongside increasing linoleic and linolenic acid proportions. The control recorded the highest mean texture, colour and overall acceptability scores. SB10 (90:10) achieved the highest mean overall acceptability among blends and did not differ significantly from the control. SB50 (50:50) recorded the highest aroma score but the lowest colour acceptance. These findings identify SB10 as a candidate for further product development. However, apparent protein and fibre increases and reported long-chain omega-3 fatty acid identities require independent analytical verification.

Keywords: Yellow gari, blended palm and soybean oil, proximate composition, functional properties and fatty acid profile.

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Introduction

Gari is a widely consumed cassava product in West Africa, valued for its affordability, versatility and contribution to household food security (Akpoghelie et al., 2025). It consists of fermented granules produced through peeling, grating, fermentation, dewatering, sieving and roasting, during which starch undergoes partial gelatinisation (Ngoualem Kégah & Ndjouenkeu, 2023). The resulting product typically has a slightly sour taste and characteristic fermented flavour and may be consumed dry, soaked in water or reconstituted with hot water into eba (Adinsi et al., 2019). Its dietary importance is part of the wider dependence on roots, tubers, and fermented cassava products in Nigerian food traditions (Abu et al., 2024). Although gari provides substantial carbohydrate-derived energy, its relatively low protein content creates opportunities to improve its nutritional value, particularly for populations that consume it frequently.

Efforts to improve gari have involved incorporating legumes, oilseeds and other food ingredients at different processing stages. Obinna-Echem and Amgbeye (2021) demonstrated that soybean flour incorporation influenced gari's acidity, hydration characteristics and pasting properties, illustrating how enrichment can alter both composition and functionality. Similarly, Anyaiwe et al. (2022) reported that enrichment with soy curd or residue increased protein, fat and ash while reducing carbohydrate content, although the control received higher sensory acceptance. These findings indicate that formulation changes require consideration of consumer preferences alongside nutritional outcomes, since enriched gari may differ in colour and odour while retaining other familiar characteristics (Adinsi et al., 2019). Furthermore, evidence from biofortified foods shows that nutrient availability depends on processing conditions and the food matrix, emphasising the distinction between greater nutrient content and demonstrated nutritional benefit (Huey et al., 2024).

Red palm oil, obtained from the mesocarp of the oil palm fruit (*Elaeis guineensis*), contributes lipids and carotenoids to foods and contains micronutrients that can influence its oxidative stability (Gao et al., 2023). Its incorporation into gari provides the characteristic yellow appearance and can modify sensory attributes, particularly colour and odour (Adinsi et al., 2019). However, the nutritional contribution of palm oil depends partly on the retention of its carotenoids during processing and storage. Bechoff et al. (2015) showed that carotenoid concentrations in yellow gari declined with longer storage time and higher temperature, although carotenoids were more stable in gari containing red palm oil than in gari made from biofortified cassava. More recently, Van Wayenbergh et al. (2024) found that red palm oil fortification provided better vitamin A retention than the alternative fortification strategies examined under accelerated storage conditions.

Soybean oil, extracted from the seeds of *Glycine max*, contains substantial proportions of unsaturated fatty acids, particularly linoleic acid and alpha-linolenic acid, which belong to the omega-6 and omega-3 families, respectively (Jokić et al., 2013). These characteristics provide a rationale for blending soybean oil with palm oil to modify the fatty acid composition of the oil incorporated into yellow gari. Nevertheless, blending proportions also influence oil quality during heating, as demonstrated by Memon et al. (2023), who evaluated the thermo-oxidative behaviour of soybean, palm olein and canola oils and their mixtures. El-Badawy et al. (2024) likewise reported

improved oxidative stability when soybean oil was blended with palm oil and identified a 50:50 mixture as a promising formulation within their experiment. Such formulations also require attention to physical behaviour and compatibility because the characteristics of the component fats influence their suitability for food applications (Gao et al., 2023).

Therefore, developing yellow gari containing palm oil and soybean oil blends requires assessment of nutritional composition, processing functionality, and consumer acceptance. Previous research demonstrates that enrichment can modify gari's sensory profile (Adinsi et al., 2019), while soybean flour incorporation can alter hydration and pasting characteristics (Obinna-Echem & Amgbeye, 2021). Investigations of vegetable oil blends further highlight the importance of formulation and heating conditions for lipid quality (Memon et al., 2023), whereas studies of fortified gari establish the relevance of nutrient retention when evaluating enrichment strategies (Van Wayenbergh et al., 2024). However, findings from soybean flour enrichment and isolated oil blends do not directly establish the properties of yellow gari processed with different palm oil–soybean oil ratios. Accordingly, this study, conducted in Abakaliki, Ebonyi State, evaluated yellow gari prepared using palm oil and soybean oil blended at weight ratios of 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50. The blends were incorporated into fermented cassava mash during roasting, and the resulting gari was assessed for proximate composition, functional properties, fatty acid profile and sensory acceptability.

Source of Raw Materials

Freshly harvested cassava roots (Manihot esculenta Crantz), variety TMS 0581, were obtained from Ugwuachara Farm, Abakaliki, Ebonyi State, Nigeria. Fresh oil palm fruits (Elaeis guineensis) used for palm oil extraction were purchased from Lot 2, St. Margaret Umahi International Market, Abakaliki. Golden Penny Pure Soya oil with batch information of 6154000060527, was purchased from the Bakery Line, Lot 1, of the same market.

Preparation of Oil Blends

Palm oil extracted from the purchased fruits was clarified before blending with soybean oil. Five oil blends were formulated at palm oil-to-soybean oil weight ratios of 90:10, 80:20, 70:30, 60:40 and 50:50. Gari prepared using clarified crude palm oil alone served as the control. The formulations and corresponding sample codes are presented below.

Table 1 Sample

Sample code	Palm oil (% w/w of oil blend)	Soybean oil (% w/w of oil blend)
P100	100	0
SB10	90	10
SB20	80	20
SB30	70	30
SB40	60	40
SB50	50	50

Source: Authors' Preparation

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Production of Yellow Gari

The cassava roots were processed into fermented mash, and the respective oil formulations were incorporated during roasting to produce yellow gari. Traditional production of gari procedures was adopted for peeling, washing, grating, fermentation, pressing and sieving. The product was fermented for 72 hours and quantity of oil added measured at 30 ml / 2.5 kg of mash, roasted at temperature of 118 ^{O}C for 18 minutes and cooled at room temperature (37 ^{O}C). The resulting samples were packed in air tight polythene, stored at room temperature for one month prior to analysis.

Proximate Composition

Moisture, crude protein, crude fat, ash and crude fibre contents were determined using the relevant methods in Official Methods of Analysis of AOAC International (Horwitz & Latimer, 2005). Method numbers are: 925.10, 981.10, 996.06, 923.03 and 985.29, standard laboratory conditions were used and nitrogen-to-protein conversion factor used (% N_2 X 6.25).
Carbohydrate content was calculated by difference following Ihekoronye and Ngoddy (1985):

$$Carbohydrate\ (\%) = 100 - (moisture + protein + fat + ash + crude\ fibre)$$

All components were expressed on the same analytical basis. Proximate composition was reported in percentages of sample and on dry-matter basis.

Functional Properties

The functional properties evaluated were bulk density, swelling capacity and water absorption capacity, according to Sanni et al., (2001) and Onwuka (2018).

Bulk density determination

The method described by Onwuka (2018), was adopted. Three grammes of sample was weighed into a 10 ml graduated cylinder and tapped ten times against the palm of hand. The volume of the gari after tapping was recorded and bulk density expressed as:

$$\text{Bulk density (g/ml)} = \frac{Mass\ of\ Sample}{Volume\ of\ Sample\ after\ tapping} \quad (2)$$

Swelling capacity determination

The swelling capacity was determined using Sanni *et al.*,(2001) method . Sample was added to measuring cylinder until the 10 ml threshold was reached. 50 milliliters of distilled water were added. The cylinder was inverted and its top securely sealed, allowing the contents to be mingled. Two minutes later, the cylinder was inverted once again, after three more minutes of standing, the cylinder was checked to determine the ultimate volume that the gari has occupied.

$$Swelling\ Capacity = \frac{Volume\ of\ Sample\ in\ Water}{Initial\ Volume\ of\ Sample} \quad (3)$$

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Water absorption capacity

The method described by Onwuka (2018) was used. 15 ml centrifuge tube was filled with 2 g of gari sample, which was then suspended in 10 ml of water. It was Shaked for one minute at room temperature on a platform tube rocker, after being left to stand for half an hour, sample was centrifuge for 30 minutes at 1200 x.g, the volume of free water was measured;

$$WAC(\%) = \frac{Mass\ of\ Sample}{Initial\ Volume - Final\ Volume} \times 100 \quad (4)$$

Energy Content

Energy content was estimated using the general Atwater conversion factors of 4 kcal/g for protein, 9 kcal/g for fat and 4 kcal/g for carbohydrate (Food and Agriculture Organization of the United Nations [FAO], 2003) using the equation below:

$$E = 4P + 9F + 4C$$

where E represents estimated energy content in kcal/100 g, and P, F and C represent protein, fat and carbohydrate contents, respectively, in g/100 g of sample.

Fatty Acid Profile

Fatty acid profiling was performed on extracted lipid blends (palm oil + soyabean oil) from finished gari, determined by Gas chromatography – electron capture detector (Buck 530 automatic injector series) using a column (RESTEX15 Meter MXT-1) of HP88 capillary (100 m x 0.25 µm film thickness) and Helium at PSI carrier. The reported operating conditions comprised an oven temperature of 210 °C, an injector temperature of 250 °C and a detector temperature of 280 °C. Helium was used as the carrier gas at a reported pressure of 5 psi, while the integrator chart speed was 2 cm/min, AOAC (2010). Cold extraction method using n-hexane as solvent was used for lipid extraction. 200 g of gari samples was weighed into 500 ml beaker, 400 ml of n-hexane was added and stirred using a stirrer, the extraction period lasted for exactly 24 hours with periodic stirring. At the end of extraction period, the extract was filtered into 500 ml beaker using filter paper (Whatman no. 1) and placed in hot air oven at temperature of 105 ^{O}C for 5 minutes to evaporate n-hexane and the oil obtained was stored in airtight bottle prior to analysis and the results represented fatty acid mass fractions.

Sensory Evaluation

A total of 24 semi-trained panelists, drawn from students of the Department of Food Science and Technology, Ebonyi State University, Abakaliki, participated in the sensory evaluation. Panelists were familiar with gari products and were selected based on their willingness to participate, absence of allergies to gari foods and non-smoking status. Ten grams (10 g) of dried gari sample were coded with random two-digit numbers and presented in identical odor-free plates and cleaned after each participant, under standardized laboratory conditions with adequate lighting. Panelists assessed texture, taste, aroma, colour and overall acceptability using a seven-point hedonic scale, where 1 = dislike extremely and 7 = like extremely. Each evaluation was conducted in duplicate and results were averaged for analysis.

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Statistical Design and Analysis

A completely randomized design comprising six oil formulations was adopted, based on twelve (12) independent production batches. Data from chemical analyses and sensory evaluation were analyzed using IBM SPSS Statistics, version 26.0. Means separation was done using Duncan's multiple range test and analysis of variance was used to determine significant differences between samples at 5 % level ($p < 0.05$) of significance. Results were expressed as means and standard deviations where significant formulation effects were detected (Steel et al., 1997).

Proximate Composition of Yellow Gari through Processing with Blends of Palm Oil and Soybean Oil

The proximate composition of the yellow gari formulations is presented in Table 2. Moisture content ranged from 11.70% to 14.70%, with the control recording the highest mean. Among the blended formulations, moisture decreased progressively from 14.60% in SB10 to 11.70% in SB50. According to the reported mean separation, SB50 had significantly lower moisture content than all other formulations ($p < 0.05$), whereas P100 and SB10–SB40 did not differ significantly. Differences in drying during roasting may contribute to moisture variation, as discussed by Ndife et al. (2019). Only SB50 had a reported mean below the Codex maximum moisture content of 12.0%. Although this lower value may favour storage performance, a specific shelf life cannot be established without storage trials examining water activity, packaging conditions and microbiological quality.

Crude protein content increased from 1.84% in P100 to 4.54% in SB50. SB30, SB40 and SB50 contained significantly more protein than the control ($p < 0.05$), while SB10 and SB20 did not differ significantly from P100. Crude fibre similarly increased from 1.50% to 5.00%, with SB40 and SB50 recording significantly higher values than P100 and SB10; SB20 and SB30 occupied intermediate significance groups. These fibre values were lower than the approximately 8.02% and 9.12% reported for white and yellow gari, respectively, by Udensi et al. (2024). Protein increases following gari enrichment have also been documented by Anyaiwe et al. (2022) and Henry-Unaeze and Ibeaka (2025), although their formulations incorporated protein-containing soy products or flour mixtures. Soybean oil contains negligible protein and essentially no crude fibre, so oil substitution alone does not explain the present increases. Confirmation of sample composition, analytical calculations and reporting basis is therefore necessary. These findings also do not establish improved amino acid composition, protein digestibility, total dietary fibre or disease-prevention benefits.

Fat content ranged from 3.70% in P100 to 4.70% in SB50, with blended formulations recording 4.00–4.70%. Despite the numerical increase, no statistically significant differences were detected among formulations ($p > 0.05$). The values exceeded the 0.31–3.55% reported by Ndife et al. (2019), although differences in oil addition rates and processing conditions limit direct comparison. Total fat content alone cannot establish resistance to rancidity; Memon et al. (2023) demonstrated changes in oxidation indicators during heating of vegetable oils and their blends, highlighting the need for direct stability measurements. Ash content increased numerically from 0.90% to 1.60%, but the differences were also statistically insignificant ($p > 0.05$). These values were broadly comparable with the 1.27% and 1.70% reported for yellow and white gari, respectively, by Udensi et

al. (2024). Nevertheless, the results do not demonstrate significant mineral enrichment, and changes in individual minerals would require elemental analysis.

Carbohydrate content decreased from 77.37% in P100 to 72.48% in SB50. Only SB50 differed significantly from the control ($p < 0.05$), while SB10–SB40 shared significance letters with both formulations. Anyaiwe et al. (2022) also reported lower carbohydrate concentrations following enrichment with soy curd or residue. However, carbohydrate was calculated by difference in the present study, so its decline is mathematically linked to changes in the other proximate components and does not represent an independently measured reduction in starch. Estimated energy content ranged from 346.10 to 350.30 kcal/100 g, compared with 350.10 kcal/100 g in P100, with no significant differences among formulations ($p > 0.05$). Energy declined between SB10 and SB40 but increased in SB50, indicating no consistently decreasing response to soybean oil inclusion. The values were lower than the 360.98–413.41 kcal/100 g reported by Henry-Unaeze and Ibeaka (2025), whose formulations contained soybean flour, defatted coconut flour and palm oil. Differences in ingredient composition should therefore be considered when interpreting this comparison.

Table 2: proximate composition of yellow garri samples

Sample	Moisture %	Protein %	Fat %	Fibre %	Ash %	Carbohydr-ate %	Energy (kcal)
P100	14.70^{b}±0.70	1.84^{d}±0.21	3.70^{a}±0.71	1.50^{b}±0.00	0.90^{a}±0.42	77.37^{a} ±0.79	350.10^{a}±2.40
SB10	14.60^{b} ±0.85	2.05^{d}±0.10	4.00^{a}±0.57	2.00^{b}±0.71	1.00^{a}±0.28	76.35^{ab}±0.33	349.60^{a}±3.39
SB20	13.90^{b} ± 0.14	2.26^{cd}±0.20	4.20^{a}±0.28	2.75^{ab}±0.35	1.20^{a}±0.00	75.69^{ab} ±0.41	349.60^{a}±3.39
SB30	13.50^{b} ± 0.14	2.54^{c} ±0.20	4.40^{a} ±0.28	3.75^{ab}±0.35	1.30^{a}±0.42	74.51^{ab}±0.69	347.90^{a}±0.42
SB40	13.20^{b} ± 0.00	3.60^{b}±0.11	4.50^{a} ±0.14	4.50^{a}±0.00	1.40^{a}±0.28	72.81^{ab}±0.53	346.10^{a}±0.42
SB50	11.70^{a} ± 0.99	4.54^{a} ±0.20	4.70^{a} ±0.99	5.00^{a} ±2.12	1.60^{a}±0.00	72.48^{b} ± 4.30	350.30^{a}±7.50

Values are means ± standard deviation of duplicate determination. Means with the same superscript within the same columns are not significantly difference ($p > 0.05$).

Functional Properties of yellow gari through processing with blends of palm oil and soybean oil.

The functional properties of the yellow gari formulations are presented in Table 3. Swelling capacity increased numerically from 3.70 in the control to 4.50 in SB50, while values for the blended formulations ranged from 3.85 to 4.50. SB40 and SB50 recorded the highest mean values, suggesting greater measured swelling responses at higher soybean oil proportions. Swelling behaviour is relevant to the reconstitution of gari in water and its preparation into eba. Adinsi et al. (2019) reported relationships between swelling capacity, perceived water absorption and texture, demonstrating the importance of hydration characteristics to product quality. Their study expressed swelling capacity as the ratio of hydrated volume to initial volume. Accordingly,

comparisons with the present results require confirmation that equivalent measurement procedures and units were used. The observed numerical increase does not, by itself, establish improved sensory quality, which requires separate assessment.

Bulk density ranged from 0.51 to 0.59 g/mL. P100, SB10 and SB20 had identical reported mean values of 0.51 g/mL and did not differ significantly ($p > 0.05$). According to the supplied superscripts, SB30 and SB40 had significantly higher bulk densities than these three formulations ($p < 0.05$), but did not differ significantly from each other. SB50 recorded the highest bulk density and differed significantly from the remaining formulations. The present range partially overlapped the 0.56–0.65 g/mL reported by Ndife et al. (2019), who also observed changes in bulk density following palm oil incorporation during gari production. Higher bulk density indicates that a greater mass of gari occupies a given bulk volume, which has implications for packaging and portion measurement. However, bulk density alone does not establish whether a product will wet more readily or receive higher consumer acceptance.

Water absorption capacity ranged from 26.88% in P100 to 28.18% in SB50, with the blended formulations recording values between 27.03% and 28.18%. Although mean values increased progressively with soybean oil inclusion, all formulations shared the same significance letter, indicating that no statistically significant differences were detected ($p > 0.05$). The maximum increase over the control was 1.30 percentage points; therefore, the results provide insufficient evidence that oil substitution improved water absorption capacity. Anyaiwe et al. (2022) reported increased water absorption following enrichment with soy curd or residue, while Obinna-Echem and Amgbeye (2021) documented changes in the functional properties of gari containing soybean flour. These studies involved different enrichment materials, limiting direct comparison with oil blending. Under the conditions examined here, water absorption capacity showed a small numerical increase without a statistically detectable formulation effect.

Table 3: Functional properties of yellow

Sample	Swelling capacity	Bulk density g/ml	Water absorption capacity %
P100	3.70^{d} ± 1.41	0.51^{c} ± 0.01	26.88^{a} ± 1.28
SB10	3.85^{cd} ± 0.71	0.51^{c} ± 0.01	27.03^{a} ± 0.51
SB20	3.95^{c} ± 0.71	0.51^{c} ± 0.01	27.53^{a} ± 2.27
SB30	4.15^{b} ± 0.71	0.54^{b} ± 0.00	27.65^{a} ± 3.75
SB40	4.45^{a} ± 0.71	0.56^{b} ± 0.00	27.70^{a} ± 2.44
SB50	4.50^{a} ± 0.00	0.59^{a} ± 0.01	28.18^{a} ± 0.56

Values are means ± standard deviation of duplicate determination. Means with the same superscript within the same columns are not significantly difference ($p > 0.05$).

Fatty acid Composition of yellow gari through processing with blends of palm oil and soybean oil

The reported fatty acid composition of the yellow gari formulations is presented in Table 4. Palmitic and oleic acids predominated in the control, accounting for 45.0% and 40.1%, respectively. Among the saturated fatty acids, lauric and myristic acids remained at 0.2% and 1.1% across all formulations, while stearic acid increased slightly from 4.0% in P100 to 4.3% in the blends. Palmitic acid declined progressively to 33.5% in SB50, consistent with replacing a palmitic acid-rich oil with soybean oil.

Jokić et al. (2013) similarly identified relatively low palmitic acid proportions alongside higher unsaturated fatty acid proportions in soybean oil extracts. Linoleic acid and alpha-linolenic acid (ALA) are essential fatty acids, whereas palmitic and oleic acids are not classified as essential (Office of Dietary Supplements [ODS], 2025). Because Table 4 provides no replicate variation or statistical test results, these differences are interpreted descriptively.

Oleic acid decreased from 40.1% in P100 to 30.7% in SB50, while linoleic acid increased from 9.7% to 27.7%, representing an increase of 18.0 percentage points. These opposing trends indicate a redistribution of monounsaturated and polyunsaturated fatty acids within the reported profile. The increasing linoleic acid proportion agrees with Jokić et al. (2013), who identified it as the predominant fatty acid in soybean oil extracts. The fraction reported as linolenic acid also increased from 0.5% in SB10 to 1.1% in SB50, with SB30 and SB40 both recording 1.0%. This pattern is compatible with soybean oil contributing ALA, although identification of the C18:3 peak as C18:3n-3 requires confirmation using appropriate standards. No numerical value was provided for P100; the dash should therefore be defined rather than interpreted automatically as complete absence. These compositional changes also require consideration of oxidative stability. Memon et al. (2023) demonstrated changes in peroxide value, free fatty acids and other quality indicators during heating of vegetable oils and their blends, highlighting the need for oxidation measurements when evaluating formulations intended for gari production.

The fractions labelled eicosatetraenoic acid, EPA and DHA were reported at identical values of 0.9%, 0.6% and 0.8%, respectively, in every blend, while no values were provided for the control. These findings require verification because conventional soybean oil supplies omega-3 principally as ALA, whereas EPA and DHA are associated primarily with marine and algal sources (ODS, 2025). Their reported occurrence and uniform concentrations across five blending ratios warrant examination of chromatograms, peak assignments, calibration and reference standards. Furthermore, before assigning a nutritional interpretation, the double-bond positions and omega family of C20:4 must be specified. Identical reported values do not establish a statistically insignificant treatment effect when variability estimates and statistical tests are unavailable. Consequently, claims of EPA and DHA enrichment should remain provisional pending analytical confirmation. Nutritional interpretation also requires clarification of the percentage basis and, preferably, reporting individual fatty acids per 100 g of finished gari. The present compositional measurements do not establish extended shelf life, improved learning ability or other clinical benefits.

Table 4: Fatty acid composition of yellow gari.

Fatty Acid (% w/w)	**Samples**					
	P100	**SB10**	**SB20**	**SB30**	**SB40**	**SB50**
Lauric acid (C12:0)	0.2	0.2	0.2	0.2	0.2	0.2
Myristic acid (C14:0)	1.1	1.1	1.1	1.1	1.1	1.1
Palmitic acid (C16:0)	45.0	40.9	40.2	38.8	36.8	33.5
Stearic acid (C18:0)	4.0	4.3	4.3	4.3	4.3	4.3
Oleic acid (C18:1)	40.1	37.0	34.1	33.0	31.2	30.7
Linoleic acid (C18:2)	9.7	13.8	17.4	19.6	23.1	27.7

Fatty Acid (% w/w)	Samples					
	P100	SB10	SB20	SB30	SB40	SB50
Linolenic acid (C18:3)	-	0.5	0.8	1.0	1.0	1.1
Eicosatetraenoic acid (C20:4)	-	0.9	0.9	0.9	0.9	0.9
Eicosapentaenoic acid (EPA) (C20:5)	-	0.6	0.6	0.6	0.6	0.6
Docosahexaenoic acid (DHA) (C22:6)	-	0.8	0.8	0.8	0.8	0.8

Sensory attributes of yellow gari processed using blends of palm oil and soybean oil.

The sensory scores in Table 5 indicated differences in texture, colour, aroma and overall acceptability, while taste scores did not differ significantly. Texture liking ranged from 5.92 in SB30 to 6.71 in P100. Although all blends recorded numerically lower scores than the control, SB40 (6.54) did not differ significantly from P100 ($p > 0.05$), whereas the remaining blends had significantly lower scores ($p < 0.05$). Colour liking ranged from 5.00 in SB50 to 6.92 in P100. The control received significantly higher scores than all blends, while SB50 scored significantly below every other formulation. SB10–SB40 did not differ significantly from one another. These findings indicate that colour acceptance was particularly affected at the highest soybean oil proportion. However, colour preference scores do not establish differences in carotenoid concentration or measured yellow colour intensity. Taste scores ranged from 5.75 in SB50 to 6.21 in SB30, compared with 6.08 in P100, with no significant differences among formulations ($p > 0.05$). Adinsi et al. (2019), using descriptive sensory profiling, similarly identified colour differences between traditional and enriched gari while reporting comparable lightly sour taste characteristics.

Aroma liking ranged from 5.71 in SB40 to 6.38 in SB50. SB50 received significantly higher scores than P100 and SB40 ($p < 0.05$), while SB10–SB30 occupied intermediate groups and did not differ significantly from either group. This indicates that SB50's lower colour acceptance was accompanied by greater aroma acceptance relative to the control. Ingredient-related odour differences were also reported by Adinsi et al. (2019), although the compounds responsible for the present responses cannot be identified from hedonic ratings alone. Overall acceptability ranged from 5.90 in SB50 to 6.37 in P100. SB10 recorded the highest mean among the blends (6.11), followed numerically by SB40 (6.10). SB10 did not differ significantly from the control, whereas SB20–SB50 received significantly lower overall acceptability scores than P100 ($p < 0.05$). Nevertheless, all blends shared a significance letter, so their numerical ranking does not demonstrate significant preference among them. The higher mean acceptance of the control agrees with Anyaiwe et al. (2022), who reported greater acceptance of conventional gari than products enriched with soy curd or residue. All overall acceptability means exceeded the neutral midpoint of four, indicating positive average ratings within the study panel, with SB10 providing the closest overall acceptance to the control.

Table 5: Sensory attributes of yellow garri

Sample	Texture	Colour	Taste	Aroma	General acceptability
P100	$6.71^{a} \pm 0.46$	$6.92^{a} \pm 0.71$	$6.08^{a} \pm 0.78$	$5.75^{b} \pm 0.94$	$6.37^{a} \pm 0.42$
SB10	$6.21^{bc} \pm 0.66$	$6.13^{b} \pm 0.45$	$6.17^{a} \pm 0.87$	$5.92^{ab} \pm 0.88$	$6.11^{ab} \pm 0.65$
SB20	$6.04^{c} \pm 0.81$	$6.13^{b} \pm 0.61$	$6.08^{a} \pm 0.78$	$6.00^{ab} \pm 0.89$	$6.06^{b} \pm 0.74$

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Sample	Texture	Colour	Taste	Aroma	General acceptability
SB30	$5.92^{c} \pm 0.78$	$6.13^{b} \pm 0.74$	$6.21^{a} \pm 0.78$	$6.00^{ab} \pm 0.78$	$6.08^{b} \pm 0.61$
SB40	$6.54^{ab} \pm 0.59$	$5.96^{b} \pm 0.75$	$6.00^{a} \pm 0.83$	$5.71^{b} \pm 0.96$	$6.10^{b} \pm 0.82$
SB50	$6.25^{bc} \pm 0.68$	$5.00^{c} \pm 1.18$	$5.75^{a} \pm 0.99$	$6.38^{a} \pm 0.77$	$5.90^{b} \pm 0.97$

Values are means ± standard deviation of duplicate determination. Means with the same superscript within the same columns are not significantly difference ($p > 0.05$).

Conclusion

The reported results indicate that replacing part of the palm oil with soybean oil modified the composition and sensory characteristics of yellow gari. Increasing soybean oil inclusion was associated with lower moisture and carbohydrate contents, reduced proportions of palmitic and oleic acids, and higher reported proportions of linoleic and linolenic acids. No statistically significant differences were reported in total fat, ash, estimated energy content or water absorption capacity. The apparent increases in protein and crude fibre require analytical verification before they can be attributed to oil blending. Similarly, the reported identification of EPA and DHA requires confirmation.

Sensory acceptance varied across attributes. The control recorded the highest mean scores for texture, colour and overall acceptability, while taste scores did not differ significantly among formulations. SB10, containing 90% palm oil and 10% soybean oil, had the highest mean overall acceptability among the blends and did not differ significantly from the control. SB50 received the highest aroma score but the lowest colour and overall acceptability scores among the blends. These findings identify SB10 as a candidate for further product development, although significant preference over the other blends was not established. The results do not establish improved health outcomes or extended shelf life.

Recommendations

Further formulation trials should prioritise the 90:10 palm oil-to-soybean oil blend while retaining other ratios for comparison. Production should use a clearly specified total oil addition rate and controlled fermentation, roasting and cooling conditions. Final moisture content should meet the Codex maximum of 12.0%, with particular attention to formulations whose reported means exceeded this limit. www.fao.org

The protein, crude fibre and fatty acid results should be checked against the original laboratory records. Future analyses should examine both the component oils and lipids extracted from finished gari using validated procedures and authentic fatty acid standards. Particular attention should be given to confirming the reported EPA, DHA and C20:4 peaks. Fatty acid concentrations should also be expressed per 100 g of finished product to clarify their dietary contribution.

Further experiments should include independent production batches, distinguish production replication from analytical duplicates, and analyse sensory ratings while accounting for repeated assessments by each panellist. Larger and more diverse consumer panels would help establish the consistency of acceptance. Storage studies should evaluate water activity, microbiological quality, lipid oxidation and carotenoid retention before commercial storage recommendations or broader nutritional claims are made.

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