Available: https://doi.org/10.54117/ijnfs.v3i3.61 *Research article*

IPS Journal of Nutrition and Food Science
IPS J Nutr Food Sci, 3(3): 242-247 (2024)
DOI: https://doi.org/10.54117/ijnfs.v3i3.61

Amino Acid Profile, Mineral Composition, *In Vitro* Protein and *In Vitro* Starch Digestibility of Enriched *Gari* Samples

Uche Capulet Anyaiwe [1]* and Taiwo Ayodele Aderinola[2]

[1]Department of Food Science and Technology, Delta State University of Technology, Ozoro.
[2]Department of Food Science and Technology, Federal University of Technology, Akure.

*Corresponding author e-mail: anyaiwecyriano@yahoo.com; Tel.: +2348033106858

Abstract

Amino acids, which act as significant macromolecules for the regulation of critical metabolic pathways, are provided by protein crops (such as soybeans), which are crucial for human nutrition. This study aimed to examine and compare the amino acid profile, mineral composition, and in-vitro protein and starch digestibility of gari enriched with soy curd and soy residue at a 10% substitution level. The amino acid profile results showed a significant increase (p<0.05) in both essential and non-essential amino acids in soy-enriched *gari* compared to the control sample. Specifically, *gari* enriched with soy residue (GMR) and *gari* enriched with soy curd (GMC) had 29.02 and 32.5%, respectively compared to 24.14 for the control sample (GIC). For the non-essential amino acids, GIC, GMR and GMC had 33.39, 33.35 and 39.38%, respectively. The enriched samples had higher mineral contents compared to the control *gari*. During enrichment, the enriched *gari*'s in vitro protein digestibility rose whereas its in vitro starch digestibility declined (p<0.05) sharply. These findings suggest that soy curd or residue can significantly enhance the nutritional quality of gari, particularly by improving its amino acid profile and protein digestibility, though with a trade-off in starch digestibility.

Keywords: *Soy residue; soy curd; gari; amino acid; protein digestibility; starch digestibility*

Article History
Received: 04 Jul 2024
Accepted: 23 Jul 2024
Published: 16 Aug 2024

Scan QR code to view•

How to cite this paper: Anyaiwe, U. C., & Aderinola, T. A. (2024). Amino Acid Profile, Mineral Composition, In Vitro Protein and In Vitro Starch Digestibility of Enriched Gari Samples. *IPS Journal of Nutrition and Food Science*, *3*(3), 242–247. https://doi.org/10.54117/ijnfs.v3i3.61.

This work was previously available as a preprint under the title [Amino Acid Profile, Mineral Composition, In Vitro Protein and In Vitro Starch Digestibility of Enriched Gari Samples, which can be accessed at [https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4661914]. Accessed: 02-08-2024.

1. Introduction

One of the most serious issues in the world is food security, which the accelerating rate of population expansion makes more necessary. This issue is particularly acute in Africa, where 200 million people are currently suffering from starvation and the effects of war (Devaux *et al.*, 2021). Due to the substantial loss of cattle, the latter has resulted in restrictions on the sources of high biological value proteins. In the continued effort to find answers to the problem of malnutrition in its various manifestations, especially among people in developing countries, better processing and fortification have improved the nutritional value of our local food. (Aderinola *et al.*, 2022; Anyaiwe *et al.*, 2022). The cassava plant, *Manihot esculenta Crantz*, is a member of the *Euphobiaceae family*. It is a tropical American native and one of the most significant starchy root tubers in the tropics (Cuenca *et al.*, 2020). The glycosides of hydrocyanic acid (linamarin and loutastralin) found in the tubers and other plant components make them deadly when eaten raw.

Cassava tubers were mostly composed of carbohydrates, 87% starch and 2% protein, ascorbic acid, free sugar, minerals, and other vitamins. In Nigeria, cassava serves as an economical source of carbohydrates for both humans and animals. It is utilized in various forms such as lafun (cassava flour), fufu (cassava mash), cassava starch, kpokpo *gari*, and *gari* (Oluwamukomi et al., 2020). *Gari* is a starchy, fermented food made from cassava that is free-flowing, dry, and granular. However, due to its perishability, low protein content, and probable toxicity, its usage as a food source is constrained. The conventional practice of processing cassava for *gari* includes peeling of the tubers by hand with knife, cleaning grating, dewatering/fermenting (during which microorganisms such as Lactic acid bacteria; *Lactobacillus* spp., *Corynebacterium* spp., and yeast, particularly *Geotrichum* spp., play a crucial role in starch breakdown, pH reduction, cyanide content reduction, and the introduction of flavor compounds that are preserved in the final product. This process involves granulation, sifting, and subsequent roasting to mitigate toxicity. When *gari* is soaked in cold water and sweetened with

sugar, it can be eaten as a snack or as a main meal (eba) along with roasted nuts, coconut, or dried fish (Awoyale *et al.*, 2021). Numerous attempts have been made to enrich *gari* products with proteins from different vegetable sources in order to address this problem; however the use of soy supplement (curd and residue) has not been extensively employed. (IITA 1990, Oluwamukomi and Adeyemi 2015). The most significant plant proteins in the world are soybeans which is a good source of soy curd and residue. It is widely utilized in confectionary products, baked items, and it is a valuable source of animal feed (Guzeler and Yildirim 2016). Soybean is a great protein complement to other plant proteins because it is regarded as near complete source of protein which includes all the essential amino acids (Fresán *et al.*, 2019). Because soy curd and residue protein is less expensive per unit than other vegetable and animal proteins, it can be used in food enrichment and fortification programs as a low-cost source of high-quality protein. In order to assess the effects of the fortification on the amino acid profile, mineral composition, in-vitro starch digestibility, and in-vitro protein digestibility of the enriched *gari*, this study aimed to enrich "*gari*" by adding soy curd or leftovers.

2. Materials and Methods

2.1. Sources of materials

Manihot esculenta crantz, or cassava roots, were collected from the Federal University of Technology's teaching and research farm in Akure, Ondo State, Nigeria. From Michael Okpara University of Agriculture (UMUDIKE), Oturu, Abia State, Nigeria, soybean seeds (Glycine max (TGX)) were purchased. The Federal University of Technology, Akure, Ondo State, Nigeria's Departments of Crop, Soil, and Pest Management, as well as Forestry and Wood Technology, verified the authenticity of both crops. The rest of the supplies such as chemicals and reagents were bought from Sigma-Aldrich in St. Louis, Missouri, USA.

2.2 Soy curd and residue extraction

According to the previously outlined procedure, 150 g of soy bean seeds were cleaned, sorted, and then soaked for 12 h in 2 L of distilled water containing 0.5 g of $NaHCO_3$ before being heated for 25 minutes (Anyaiwe *et al.*, 2022). The soybean seeds were cooked, dehulled, and then wet processed in a hammer mill. After extracting the milk (pH 6.40) using muslin cloth and adding water in a ratio of 1:8, the pH was brought down to 4.6 by adding 1 M citric acid. The soy milk was left to stand for 6 h before the lower portion (curd) and upper part clear whey was collected. The residue was collected following the extraction and filtering of soy milk from soybean mash. After being oven dried (at 60 ºC for 24 h), the samples of curd and residue were processed into flour, wrapped in high density polythene (HDPE) bags, and kept in the refrigerator for subsequent use.

2.3 *Gari* production and enrichment

A previously published technique was used to create the enriched *gari* samples from cassava tubers (Oluwamukomi and Adeyemi 2015). In a nutshell, cassava tubers were peeled by hand with a sharp knife, cleaned, and grated in a locally constructed mechanical grater that was coupled to a 7 horse power drive engine using a belt. After 72 h of fermentation in Hessian bags, they were then dewatered in a mechanical press owned by Nigeria's Addis Engineering Nig. Ltd. The fibres were manually ground out of the dewatered, wet cassava cakes. One portion of the sifted cassava meal was roasted and kept as the control, while the other was enriched with soy curd and residue at 10% supplementation levels before toasting (Anyaiwe *et al.*, 2018). Then, it was toasted over a wood fire in a large aluminum pan known as a "*gari*fier" at a temperature of more than 250ºC. The iron kettle was then opened, and the toasted soy-enriched *gari* was taken out to cool. Following the cooling process, the *gari* samples were packaged in HDPE plastic and placed in the refrigerator, where they were stored until further examination was conducted.

2.4 Amino acid analysis of *gari* samples

The amino acid composition of samples was determined using High-Performance Liquid Chromatography (HPLC) as previously reported (Aderinola and Adeoye, 2022). 10 mg of the sample was weighed into a screw-capped glass hydrolysis tube and placed in ice before adding 0.2 mL of cold performic acid. This was mixed by placing the tube in an ultrasonic bath for 10 min, after which the tubes were capped and left to stand overnight in a refrigerator at 4 ℃. Sodium metabisulphite (50 mg) was added carefully to each tube and mixed using a vortex mixer. Hydrochloric acid (0.8 mL of 7.5 N) was added to the tube and this was mixed again by placing it in an ultrasonic bath for 15 min. The tubes were placed unsealed onto a hot plate previously heated to 110 ℃. After an hour, the tubes were sealed and hydrolyzed for a further 24 hours on the hot plate. After the hydrolysis was complete, the tubes were removed from the hot plate and cooled to room temperature. The contents were transferred to a 5 mL volumetric flask, diluted to volume with distilled water and filtered through filter paper before placing into a rotary evaporator (Buchi, Laboratoriums Technik AG, Switzerland) to dry partially under vacuum at 40 ℃. The residue left after evaporation was dissolved in 0.8 mL of 0.2 M sodium carbonate buffer, pH 9.7 and stored frozen prior to dansylation and analysis. Sodium carbonate (0.2 mL, 0.2 M, pH 9.7), 20 µL of internal standard and 20 µL of samples were added to a 1.5 mL screw-capped reaction vial. Finally, 0.2 mL of dansyl chloride Volume solution (5 mg/mL in acetone) was added before capping and vortexing the tubes. These were incubated overnight in the dark at room temperature. The contents of the reaction vial were transferred to a one mL volumetric tube and diluted to volume with water. This one mL of the dansylated product was used to run in HPLC and the results were expressed as mg amino acid/g dry matter. The predicted biological value (BV) was calculated using previously reported equation (El- Adawy et al., 2001), while whole egg protein was used as the reference protein.

$$BV = 10^{2.15} \times Lys^{0.41} \times (Phe+Tyr)^{0.60} \times (Met+Cys)^{0.77} \times Thr^{0.24} \times Trp^{0.21}$$

The Predicted Protein Efficiency Ratio (P-PER) was calculated using the equation below (Ijarotimi, 2022):

P-PER = = - 0.468 + 0.454 (Leu) - 0.105 (Tyr).

2.5 Mineral analysis of *gari* samples

The mineral contents of the flour samples - sodium, potassium, calcium, magnesium, iron, copper, zinc, manganese, and selenium, were determined using a previously reported method (AOAC, 2012).

2.6 Determination of *in-vitro* protein digestibility of *gari* samples

In vitro protein digestibility was determined with slight modifications using standard method (AOAC, 2012). One tablet of Panzynorm-N (manufactured by M/s German Remedies India, Ltd., Mumbai, India) containing 10,000 units of lipase, 9000 units of α-amylase and 500 units of protease, was dissolved in 5.0 mL sodium phosphate buffer (0.1 M; pH 8.0). One milliliter of the digestive enzyme was added and incubated at 37℃ for 1 h. Enzyme and sample blanks were also simultaneously kept and after the reaction period, the enzyme was heat killed and the total amino acid content in the supernatant was quantified using ninhydrin reagent. In vitro protein digestibility was expressed as mg amino groups (Leucine equivalent) released per h per 100 g sample.

2.7 Statistical analysis

The data were all collected in triplicate. The means and standard deviations of the collected data were computed and reported. Statistical Package for Social Scientists (SPSS) version 17 (SPSS Inc, USA) was then used to do an analysis of variance (ANOVA) on the data and separate the means using the Duncan's Multiple Range Test at (p<0.05).

3. Results and Discussion

3.1 Amino acid profile of *gari* samples

According to Table 1, the amino acid profile of the enriched and control *gari* samples revealed that glutamic acid was the most prevalent amino acid (14.71-16.52%). The result showed that the amount of histidine (2.41-2.43%) and arginine (2.51-2.64%) in the control samples were significantly different from those of the enriched samples (2.00-2.11) and (3.09-3.15%, respectively. The values obtained in this study for arginine (2.51-3.15%) and histidine (2.00-2.43%) are significantly higher than the FAO/WHO (1991) standards for newborns (2%) and (1.9%), respectively. As essential amino acids play a critical role in the growth and development of infants, the inclusion of soy curd and residue in *gari* offers a valuable means to support children's growth. This is particularly significant in developing nations where animal proteins can be very expensive, and *gari*, or its primary derivative (eba), serves as a widespread and cost-effective alternative. As shown in Table 2, the total sulphur content (cystine and methionine, SAA) of *gari* increased as a result of enrichment, going from 3.15% (GIC) to 3.38 and and 3.82% for GMR and GMC, respectively. The production of glutathione, a powerful antioxidant known for its detoxifying properties, is dependent on the presence of sulfur-containing amino acids. These amino acids are essential for synthesizing other amino acids (Colovic *et al*., 2018). Because SAA are said to be involved in the detoxification of hydrogen cyanide, the increase in SAA is advantageous (Ohadoma *et al.*, 2019). In the current investigation, the total amino acids (TAA) of the enriched *gari* samples (67.37 – 71.88%) are considerably greater than those of the control samples (56.87 - 57.53%) (Table 2).

Table 1: Amino acid composition of enriched ''*gari*'' and control samples (%)

Amino acids	GIC	GEC	GMC	GMR	*RDA
Alanine	2.26±0.00^{c}	2.06±0.00^{d}	3.44±0.00^{a}	3.62±0.06^{a}	-
Aspartic	5.44±0.00^{c}	5.33±0.01^{c}	6.26±0.15^{a}	5.67±1.13^{b}	-
Serine	2.61±0.01^{cd}	2.53±0.00^{c}	3.53±0.02^{a}	3.23±0.01^{b}	-
Glutamic	14.87±0.01^{c}	14.71±0.06^{d}	16.26±0.00^{ab}	16.52±1.51^{a}	-
Proline	2.28±0.00^{c}	2.61±1.55^{b}	3.21±0.01^{a}	3.11±0.04^{a}	-
Glycine	2.13±0.01^{c}	2.09±0.01^{cd}	2.41±0.00^{a}	2.45±0.01^{a}	-
Arginine	2.64±0.01^{c}	2.51±0.00^{d}	3.09±0.02^{ab}	3.15±0.01^{a}	-
Cysteine	2.00±0.00^{b}	2.14±0.04^{a}	1.86±0.01^{c}	1.85±0.10^{c}	-
Tyrosine	1.80±0.01^{c}	1.61±0.01^{d}	2.41±0.06^{a}	1.90±0.01^{b}	-
Lysine	2.37±0.01^{d}	2.63±0.01^{bc}	3.71±0.00^{a}	3.01±0.01^{b}	5.2
Threonine	3.44±1.49^{ab}	3.36±0.01^{b}	3.59±0.01^{d}	3.00±0.01^{c}	2.70
Valine	2.59±0.00^{b}	2.42±0.01^{c}	3.10±0.01^{b}	3.21±0.29^{a}	4.20
Methionine	1.15±0.02^{d}	1.08±0.01^{c}	1.96±0.00^{a}	1.53±0.06^{b}	2.2
Isoleucine	2.68±0.01^{c}	2.51±0.00^{d}	3.71±0.00^{a}	3.51±0.03^{b}	3.10
Leucine	4.41±0.00^{cd}	4.48±0.00^{c}	6.84±0.00^{a}	5.49±0.01^{b}	6.30
Phenylalanine	1.11±0.01^{c}	1.15±.0.01^{c}	2.89±0.01^{a}	2.71±0.01^{b}	2.8
Histidine	2.41±0.01^{a}	2.43±0.00^{a}	2.11±0.00^{b}	2.00±0.02^{c}	1.80
Tryptophan	1.34±0.10^{c}	1.23±0.01^{cd}	1.50±0.00^{a}	1.41±0.00^{b}	0.74

Data represent mean ± standard deviation of three replicates, values with different superscripts along the same column are significantly different (p<0.05)
KEY: GIC = Control sample, GEC= commercial sample GMC, = '*gari*' enriched with 10% curd, GMR= '*gari*' enriched with 10% residue *RDA – recommended daily allowance (FAO/WHO 2000).

The improved samples included more essential amino acids overall than the control samples, indicating that the enriched samples will provide consumers with more nutritional advantages (Table 2). The current total amino acid profiles of GMR (67.37%) and GMC (71.88%) were higher than the respective values reported by Adeyina *et al.* (2008) for melon, pumpkins, gourd seed, soybean, and pigeon peas which were 53.40, 38.30, 53.60, 44.40, and 45.20%, respectively. There is no question that the additional soy supplements are responsible for the rise in the amino acid values of the enriched samples. This implies that the protein components of legume seeds and their seed flour may be used as food supplements.

In terms of nutrition (protein efficiency ratio, PER), the value for cowpea (1.21), millet (1.62), and pigeon pea (1.82) (Adeyeye, 2006) are comparable to *gari* enhanced with soy residue (1.82) and soy curd (2.38). As opposed to fermented African locust bean (Adeyeye, 2006) and casein (Oyarekua and Eleyinmi, 2004) samples, the PER of *gari* samples in the current investigation is less than 2.0 and 2.5, respectively except for sample with soy curd. Notably, PER is a metric that calculates the quality-based nutritional importance of foods high in protein. In comparison to other samples like the control sample (48.98%) and commercial sample (54.25 samples enriched with soy residue and curd had a higher biological value (BV) of 75.77 and 79.39%, respectively. The BV provides an estimate of the amount of protein consumed that would be absorbed and used during bodily metabolism. When a protein-based dietary source has a PER of 2.7 and a BV of greater than 70%, it is considered to have good nutritional quality (Mensah and Tomkins, 2003). As an alternate source of protein and energy for consumers, the usage of food based on cassava and legumes is therefore encouraged.

Table 2: Estimated protein quality of ''*gari*'' products (**%**)

Parameters	GIC	GEC	GMR	GMC	REF
TAA	57.53	56.87	67.37	71.88	
TEAA	21.50	22.29	25.87	29.41	30.1
NEAA	36.03	35.58	41.5	42.47	
TNEAA/TAA	0.59	0.59	0.62	0.69	
TSAA [Meth+Cys]	3.15	3.22	3.38	3.82	2.6s
TArAA [Phe+Tyr+Trp]	4.25	3.99	6.02	6.8	4.6-
TEAA/TNEAA	0.72	0.72	0.77	0.83	
PER	1.35	1.40	1.82	2.38	
BV	48.98	54.25	75.77	79.39	100

Data represent mean ± standard deviation of three replicates, values with different superscripts along the same column are significantly different (p<0.05)
KEY: GIC = Control sample, GEC = commercial sample, GMC = '*gari*' enriched with 10% curd, GMR = '*gari*' enriched with 10% residue *REC - FAO/WHO 2000. TAA= Total amino acid, TEAA= Total essential amino acids (arginine, lysine, threonine, valine, methionine, isoleucine, leucine, phenylalanine, histidine and tryptophan), TNEAA= Total non-essential amino acid, TSAA=Total sulphur containing amino acid (cysteine and methionine), TArAA-=Total aromatic amino acids (Tyrosine, phenylalanine and tryptophan), PER= Protein efficieny ratio, BV=Biological value, RDA=Required dietary allowance.

3.2 Mineral compositions of *gari* samples

According to Table 3 mineral composition of formulated food samples, potassium was the most prevalent mineral in enriched and control samples, which was in line with earlier research (Manning 2010, Ahmad *et al.*, 2016) that found potassium to be the most prevalent mineral in agricultural products. Potassium supported healthy kidney function and blood pressure regulation (Omoyeni *et al.*, 2015). The results for iron and copper ranged between 0.21 - 3.16 mg/100 g and 0.34 – 0.85 mg/100 g, respectively. In the control samples, the calcium levels ranged from 9.18 to 9.78 mg/100g, whereas in the enhanced samples GMR and GMC, they ranged from 46.24 to 66.54 mg/100g. These differences in calcium concentrations were significant (p<0.05). This was consistent with earlier research (Samuel *et al.*, 2012), which showed that enriched samples are a better supplier of minerals than commercial and control samples. The current findings support previous research (Goyal *et al.*, 2012), which identified soybean as a nutrient-dense source of vitamins and minerals. According to Goyal *et al.* (2012), the increased calcium content of enriched samples would encourage healthy bone and teeth development in both adults and children.

Table 3: Mineral composition of *gari* enriched with soy curd and residue (mg/100 g)

Sample	GIC	GEC	GMR	GMC	*REF
Ca	9.78 ± 0.06^{c}	9.18 ± 0.19^{d}	46.24 ± 1.11^{b}	66.54 ± 0.40^{a}	
Mg	17.75 ± 0.11^{d}	17.53 ± 0.05^{c}	74.09 ± 0.19^{b}	84.63 ± 0.01^{a}	
Na	11.24 ± 0.03^{b}	11.26 ± 0.00^{b}	13.28 ± 0.01^{a}	8.82 ± 0.05^{c}	
K	182.66 ± 2.74^{d}	188.57 ± 0.17^{c}	195.27 ± 1.01^{b}	625.10 ± 2.07^{a}	
Fe	0.21 ± 0.01^{c}	0.23 ± 0.06^{c}	1.45 ± 0.01^{b}	3.16 ± 0.00^{a}	
Zn	0.28 ± 0.01^{c}	0.26 ± 0.01^{c}	0.64 ± 0.02^{b}	1.39 ± 0.01^{a}	
Mn	0.36 ± 0.00^{c}	0.30 ± 0.01^{c}	0.48 ± 0.00^{b}	1.17 ± 0.05^{a}	
Cu	0.46 ± 0.00^{b}	0.34 ± 0.00^{b}	0.85 ± 0.01^{a}	0.82 ± 0.00^{a}	
P	105.02 ± 1.06^{d}	107.94 ± 1.6^{c}	136.87 ± 0.35^{b}	186.25 ± 5.14^{a}	
Pb	ND	ND	ND	ND	< 0.1
Cd	ND	ND	ND	ND	< 0.1
Ca/P	2.00	2.09	3.24	4.64	> 1
Na/K	0.03	0.04	0.07	0.08	< 1

Data represent mean ± standard deviation of three replicates, values with different superscripts along the same column are significantly different (p<0.05).
KEY: GIC = Control sample, GEC= commercial sample GMC, = '*gari*' enriched with 10% curd, GMR= '*gari*' enriched with 10% residue *REF - FAO/WHO (2000).

In comparison to the control and commercial samples, the samples supplemented with soy curd and residue displayed a comparable trend on copper, magnesium, zinc, manganese, and phosphorus. Overall, the Ca/P ratios of all the dietary samples were good. The two micronutrients are necessary for a number of body physiological activities. While potassium is necessary for maintaining a proper fluid balance in the cell and controlling blood pressure, calcium is crucial for bone health,

muscular function, and tissue health. When compared to the control samples, the enrichment with soy curd or residue dramatically enhances this ratio. Due to the higher C/P ratio (>1) than the recommended value, incorporating soy curd or residue into *gari* could potentially enhance the availability and absorption of specific micronutrients (Isaac-Bamgboye et al., 2020). Although the sodium/potassium (Na/K) ratios of the enriched products (0.07–0.08) were higher than the values (0.03–0.04) found in the control samples, these values are comparable to the suggested value (1) in the literature (Olagunju *et al*., 2018). Because of the low value Na/K in this investigation, these food samples may be good for hypertensive customers who eat "*gari*" as their main meal. According to Aburto *et al*. (2013), a high potassium diet can help prevent blood pressure spikes and other cardiovascular concerns. Evidently, foods with a Ca/P ratio more than 1.0 are seen as good, while those with a ratio lower than 0.5 are regarded as inferior. (Goyal *et al*., 2012; Loughrill *et al*., 2017). They also stated that soy enrichment increased the Ca/P and Fe concentration of wheat rotis, which is consistent with the current study.

3.3 *In-vitro* protein digestibility of *gari* samples

Table 4 displays the in-vitro protein digestibility (IVPD) results for the *gari* samples. The enriched *gari* had an IVPD that was considerably (p<0.05) greater than the control, ranging from 6.91 (GIC) to 71.41% (GMC) in the *gari* samples. The addition of soy curd and residue improved the IVPD of supplemented *gari* samples. The pattern of this result indicated that the supplementation with soy residue and curd, which increased the protein quality (amino acid profile), indeed imply greater protein digestibility. The IVPD showed how much protein was absorbed by the body in relation to how much was taken or swallowed. In addition, the IVPD assessed the bioavailability of nutrients after ingestion because the protein content is insufficient to do so. The addition of soy curd and residue to *gari* seems to have enhanced protein bioavailability, according to the results. This outcome is consistent with other research (Acevedo-Pacheco and Serna-Saldivar 2016, Montemayor-Mora *et al*., 2018), which found out that diet samples supplemented with soybean had higher protein digestibility. Due to the inclusion of starch and other non-protein constituents, the control samples were more resistant to enzymatic hydrolysis, which is why there were discrepancies in the IVPD values between the enriched and control samples.

Table 4: *In-vitro* protein digestibility (IVPD) of "*gari*" samples **(%)**

Sample	IVPD
GIC	6.91 ± 0.21^{d}
GEC	7.28 ± 0.08^{c}
GMC	71.41 ± 0.61^{a}
GMR	50.33 ± 0.44^{b}

Data represent mean ± standard deviation of three replicates, values with different superscripts along the same row are significantly different (p<0.05)
KEY: GIC = Control sample, GEC= commercial sample GMC, = "*gari*" enriched with 10% curd, GMR= "*gari*" enriched with 10% residue.

4. Conclusion

In this study, the nutritional and digestibility qualities of *gari* that had been enhanced with soy curd or residue were assessed. This outcome demonstrated that nutritional profiles, including the amounts of minerals and amino acids, had greatly improved. Additionally, the enhanced samples had better protein digestibility, indicating a larger likelihood that consumers may profit from the enrichment.

Declarations

Funding

This research/authors did not receive any support, specific grant from funding agencies, organization, in the public, commercial, or not-for-profit sectors for the submitted work. No funding was received for the conducting of the study.

Competing Interests

No competing Interests or conflict of interest. The authors have no relevant financial or non-financial interest to disclose.

Authors' Contributions

Anyaiwe was responsible for the conceptualization, project administration, writing of original draft, reviewing and provision of resources for the research, formal analysis while Aderinola was involved with methodology, writing, editing and reviewing of the manuscript. All authors read and approved the final copy.

References

Aburto, N. J., S. Hanson, H. Gutierrez, et al., 2013. Effect of increased potassium intake on cardiovascular risk factors and disease: systematic review and meta-analyses. BMJ. 346, f1378. https://doi.org/10.1136/bmj.f1378

Acevedo-Pacheco, L. and S. O. Serna-Saldivar, 2016. In vivo protein quality of selected cereal-based staple foods enriched with soybean proteins. Food Nutr Res. 60, 31382. https://doi.org/10.3402/fnr.v60.31382

Aderinola, T. A., annd Adeoye, A. D. (2022). Proximate, Amino Acid Compositions and Functional Properties of Maize-Beans Composite Flours. Food Science and Engineering, 4(1), 9–19.

Aderinola, T. A., I. A. Akinola, O. E. Babalola, et al., 2022. Supplementation of Biscuit with Moringa Oleifera Seed Protein Enhanced Its in-vitro Antioxidative, Antidiabetic and anti-inflammatory Properties. Journal of Culinary Science & Technology. 1-17. https://doi.org/10.1080/15428052.2022.2073933

Adeyeye, E., 2006. Amino acids composition offermented African locust bean (Parkia biglobosa). Journal of Applied and Environmental Sciences December. 2, 154-158.

Adeyina, A. O., S. O. Oguntoye, O. A. Olatunde, et al., 2008. Comparative effects of theobromine and Cocoa Bean Shell (CBS) extract on the performance, serum constituent profile and physiological parameters in rabbits. Global Journal of Pure and Applied Sciences. 14, https://doi.org/10.4314/gjpas.v14i3.16604

Ahmad, M., S. M. Nadeem, M. Naveed, et al., 2016. Potassium-Solubilizing Bacteria and Their Application in Agriculture. Potassium Solubilizing Microorganisms for Sustainable Agriculture: 293-313.

Anyaiwe, U., M. Oluwamukomi, T. Aderinola, et al., 2022. Effects of Enrichment on Amino Acid Profile, Mineral Composition and Anti-Nutritional Factors of Lafun Powder. Turkish Journal of Agriculture - Food Science and Technology. 10, 1515-1523. https://doi.org/10.24925/turjaf.v10i8.1515-1523.5133

Anyaiwe, U. C., M. O. Oluwamukomi and T. N. Fagbemi, 2018. Effect of protein enrichment on proximate composition, functional and pasting characteristics of cassava "Lafun". Annals Food Science and Technology. 19, 39-50.

AOAC, 2012. Official Method of Analysis: Association of Analytical Chemists. Washington DC.

Awoyale, W., E. O. Alamu, U. Chijioke, et al., 2021. A review of cassava semolina (*gari* and eba) end-user preferences and implications for varietal trait evaluation. Int J Food Sci Technol. 56, 1206-1222. https://doi.org/10.1111/ijfs.14867

Biancarosa, I., M. Espe, C. G. Bruckner, et al., 2016. Amino acid composition, protein content, and nitrogen-to-protein conversion factors of 21 seaweed

species from Norwegian waters. Journal of Applied Phycology. 29, 1001-1009. https://doi.org/10.1007/s10811-016-0984-3

Colovic, M. B., V. M. Vasic, D. M. Djuric, et al., 2018. Sulphur-containing Amino Acids: Protective Role Against Free Radicals and Heavy Metals. Curr Med Chem. 25, 324-335. https://doi.org/10.2174/0929867324666170609075434

Cuenca, P., S. Ferrero and O. Albani, 2020. Preparation and characterization of cassava starch acetate with high substitution degree. Food Hydrocolloids. 100, https://doi.org/10.1016/j.foodhyd.2019.105430

Devaux, A., J. P. Goffart, P. Kromann, et al., 2021. The Potato of the Future: Opportunities and Challenges in Sustainable Agri-food Systems. Potato Res. 64, 681-720. https://doi.org/10.1007/s11540-021-09501-4

Fresán, U., M. A. Mejia, W. J. Craig, et al., 2019. Meat Analogs from Different Protein Sources: A Comparison of Their Sustainability and Nutritional Content. Sustainability. 11, https://doi.org/10.3390/su11123231

Goyal, M., D. Sasmal and B. Nagori, 2012. Review on Ethnomedicinal uses, Pharmacological activity and Phytochemical constituents of <i>Ziziphus mauritiana</i> (<i>Z. jujuba</i> Lam., non Mill). Spatula DD - Peer Reviewed Journal on Complementary Medicine and Drug Discovery. 2, https://doi.org/10.5455/spatula.20120422080614

Guzeler, N. and C. Yildirim, 2016. The utilization and processing of soybean and soybean products. Journal of Agricultural Faculty of Uludag University. 30, 546-553.

IITA, 1990. Cassava in tropical Africa: a reference manual, IITA.

Ijarotimi, O. S. (2022). Macronutrient composition, amino acid profiles and acceptability of maize-based complementary foods enriched with defatted white melon seed and Moringa oleifera leaf powder. Croatian Journal of Food Science and Technology, 14(1), 63–73. https://doi.org/10.17508/CJFST.2022.14.1.07

Isaac-Bamgboye, F. J., V. N. Enujiugha and M. O. Oluwamukomi, 2020. Chemical and Sensory Evaluation of African Yam Bean (Sphenostylis Sternocarpa) Seed-Enriched Cassava (Manihot esculenta) Product (Pupuru).

Loughrill, E., D. Wray, T. Christides, et al., 2017. Calcium to phosphorus ratio, essential elements and vitamin D content of infant foods in the UK: Possible implications for bone health. Maternal & Child Nutrition. 13, https://doi.org/10.1111/mcn.12368

Manning, D. A. C., 2010. Mineral sources of potassium for plant nutrition. A review. Agronomy for Sustainable Development. 30, 281-294. https://doi.org/10.1051/agro/2009023

Mensah, P. and A. Tomkins, 2003. Household-level technologies to improve the availability and preparation of adequate and safe complementary foods. Food and Nutrition Bulletin. 24, 104-125.

Montemayor-Mora, G., K. E. Hernandez-Reyes, E. Heredia-Olea, et al., 2018. Rheology, acceptability and texture of wheat flour tortillas supplemented with soybean residue. J Food Sci Technol. 55, 4964-4972. https://doi.org/10.1007/s13197-018-3432-3

Ohadoma, S., G. Akuodor, F. Osuala, et al., 2019. Manihot utilissima and the challenges and implications of nutritional toxicity towards Nigeria agricultural revolution.

Olagunju, A. I., O. S. Omoba, V. N. Enujiugha, et al., 2018. Development of value-added nutritious crackers with high antidiabetic properties from blends of Acha (Digitaria exilis) and blanched Pigeon pea (Cajanus cajan). Food Sci Nutr. 6, 1791-1802. https://doi.org/10.1002/fsn3.748

Oluwamukomi, M. and I. Adeyemi, 2015. Influence of Temperature and Packaging Materials on the Storage Qualities of Soy-Melon "*Gari*" - A Protein Enriched Cassava Product. American Journal of Advanced Food Science and Technology. https://doi.org/10.7726/ajafst.2015.1004

Oluwamukomi, M. O., V. N. Enujiugha and F. J. Isaac-Bamgboye, 2020. In-vitro Antioxidant Capacity, Phytochemical Characterisation, Toxic and Functional Properties of African Yam Bean (Sphenostylis stenocarpa) Seed-Enriched Cassava (Manihot esculenta) Product (Pupuru). European Journal of Nutrition & Food Safety. 84-98. https://doi.org/10.9734/ejnfs/2020/v12i330212

Omoyeni, O. A., O. Olaofe and R. O. Akinyeye, 2015. Amino acid composition of ten commonly eaten indigenous leafy vegetables of South-West Nigeria. World J Nutr Health. 3, 16-21.

Oyarekua, M. and A. Eleyinmi, 2004. Comparative evaluation of the nutritional quality of corn, sorghum and millet ogi prepared by a modified traditional technique. Journal of Food Agriculture and environment. 2, 94-99.

Samuel, F. O., B. O. Otegbayo and T. Alalade, 2012. Nutrient and Anti-Nutrient Content of Soy-Enriched Tapioca. Food and Nutrition Sciences. 03, 784-789. https://doi.org/10.4236/fns.2012.36105

Sandhu, K. S. and S.-T. Lim, 2008. Digestibility of legume starches as influenced by their physical and structural properties. Carbohydrate Polymers. 71, 245-252. https://doi.org/10.1016/j.carbpol.2007.05.036

Wang, L. and Y. J. Wang, 2001. Structures and physicochemical properties of acid-thinned corn, potato and rice starches. Starch-stärke. 53, 570-576.