



## Physicochemical Characteristics of “Gari” Semolina Enriched with Different Types of Soy-melon Supplements

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### Authors' contributions

*This work was carried out in collaboration between all authors. Authors MOO and IAA designed the study, author MOO performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author MOO managed the analyses of the study. Author MOO managed the literature searches. All authors read and approved the final manuscript.*

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### ABSTRACT

The effects of enrichment of “gari” semolina with three different types of soy-melon protein supplements during toasting of “gari” were studied. Three protein supplements (Full fat, Defatted and Milk residue) were toasted together separately with the grated, dewatered and sifted cassava mash after fermentation (soak-mix method). After toasting and cooling, the samples were subjected to physico-chemical analyses. Results showed that enrichment increased the protein, fat and ash contents, and the pH values, while the hydrocyanic acid content, titratable acidity reduced generally. Enrichment increased the protein content from 2.81% in the control gari to a range of 15.3% - 23.5% in the enriched samples. The fat increased from 3.24% to a range of 4.13% - 13.50%; while the ash content increased from 1.18% to a range of 1.96% to 3.47%. Hydrocyanic acid was significantly ( $P \leq 0.05$ ) reduced from 13.5mg/kg to a range of 6.70mg/kg -12.5mg/kg in the enriched products. The pH increased from 3.62 to a range of 4.86 - 5.25 while the acidity correspondingly reduced from 0.46 in the control gari to a minimum value of 0.36% lactic

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acid in the sample toasted together with defatted soy-melon meal. From the result it could be concluded that enrichment improved the nutrient quality of "gari" especially the protein, fat and ash contents. It also reduced the hydrocyanic acid content, thereby producing "gari" of higher quality and better safety. The acidity of the enriched samples was however reduced thus lowering the sourness of "gari". This may be an advantage for people who are not used to the sour taste of "gari". Of all the three soy-melon "gari" samples, the sample enriched with defatted supplement had been shown to have the highest protein and ash contents, the lowest crude fat and acidity than other enriched gari samples. It had also been shown to have better wettability, water holding capacity, and ability to disperse in water. It also had better swelling and reconstitution indices than "gari" enriched with full fat and milk residue supplements.

**Keywords:** *Enrichment; soy-melon gari; hydrocyanic acid.*

## 1. INTRODUCTION

"Gari" is a fermented, dewatered and toasted starchy granule from cassava which is widely consumed all over West Africa and in Brazil where it is known as 'farinha de mandioca' [1]. "Gari" is one of the most popular forms in which cassava (*Manihot esculenta* Crantz) also known as manioc is consumed in Nigeria and some other parts of West Africa [2]. It is a major component of everyday diet in Nigeria providing about 11.835kJ/person/day [3]. Micronutrient deficiencies in the diet of African countries have been implicated as a national problem which could lead to nutritional insecurity if not adequately tackled. Cassava is therefore recognized as a potential vehicle for micronutrient intervention in Africa [4]. However, Cassava from which this important item of food is produced is low in protein and deficient in essential amino acids. The crude protein content of locally produced "gari" is 1.03% and levels of cyanide are variable (0 – 32mg HCN equivalent Kg<sup>-1</sup>) depending on the processes, method and locality [5,6]. "Gari" has been shown to be a rich source of energy but of poor protein content (1.03%) compared with soy bean (44.08%) [7]. It has low levels of methionine, tryptophan, lysine and phenylalanine [8]. Supplementary protein sources must therefore be provided if cassava is to maintain its role as a major source of calories [4]. Many attempts have been made to enrich cassava products with protein from vegetable sources [9,10]. Oshodi [9] enriched "gari" with combination of soy grits and defatted melon. The protein content was increased from 1.43 to 19.41% dry basis with 40% protein supplement and 60% "gari". However the color and the odor were scored lower than the control. The 'eba' made from the enriched "gari" was darker in color. Collins and Temalilwa [11] increased the Protein Efficiency Ratio (PER) of cassava flour to 1.55 by adding to it 20% soy flour. Sanni and Sobamiwa [10] enriched "gari", after grating, with soybean residue after dewatering and full fat soy flour at 25% before and after fermentation. The protein content was raised from 9 to 11% resulting in a more nutritive and safer "gari". Banjo and Ikenebomeh [12] compared three stages of enriching "gari" with soy protein at the point of grating, before frying and after frying in varying "gari": soy flour ratios. The workers found that ratios 1:1 and 3:2 produced unacceptable soy enriched "gari" while the ratios 7:3 and 4:1 were acceptable. The International Institute of Tropical Agriculture [13] recommended the use of soybean residual to fortify "gari" in a post-fermentation operation and found out that the taste of the soybean fortified "gari" was not different from that of the traditional "gari". Numfor and Noubi [14] studied the effect of full-fat soybean flour on the quality and acceptability of fermented cassava flour. While trying to improve the protein quality level of "gari", it must not be done in such a way as to affect the physicochemical and sensory

properties. Oyewole and Asagbra [4] observed that co-fermentation of cassava with 20% cowpea and soy bean was found to increase the protein contents of the fermented cassava product from 1.8% to 5.5% and 8.2% respectively without affecting the organoleptic properties of the product. Past efforts have shown that using soybean, melon or groundnut alone was not sufficient in providing the necessary essential amino acids comparable to the reference protein. The reasons being that adequate amount of these flours cannot be added without strikingly altering the flavors, palatability and appearance of the “gari” product. Also, their biological values are not high enough to compensate for the small amounts in which they have to be added to “gari” and moreover they require further enrichment with Lysine and Methionine [15]. In an attempt to cut down on the amount of legumes used for enriching “gari” at the same time improving the amino acid content of fortified “gari”. Oshodi [9] enriched “gari” with soy grits and defatted melon flour at 25% replacement level, separately and 40% level collectively. The limiting amino acids Lysine and Histidine in melon were provided by soybean while the Methionine lacking in soybean was supplied by melon. The protein content was increased from 1.43 to 19.4% in the enriched sample. The swelling capacity in cold water was retained but the color of the ‘eba’ was darker and the texture was rejected as too soft and lacked cohesiveness. The objective of this current study was to supplement cassava mash with different types of soy-melon protein supplement such as the defatted, full fat and residue after milk extraction from soy-melon milk in order to increase the nutritional and physicochemical qualities of “gari” and also determine the best type of supplement in terms of nutritional and physicochemical qualities.

## **2. MATERIALS AND METHODS**

### **2.1 Source of Materials**

Freshly harvested cassava roots were obtained from the research farm of the Federal University of Technology, Akure, Ondo State, Nigeria. Soybean and melon seeds used to produce the protein supplements were purchased from the Oba market, in Akure, Ondo State, Nigeria. They were sorted, cleaned, packed and kept under refrigeration until use.

### **2.2 Sample Preparation**

#### **2.2.1 Full fat soy flour**

This was developed according to the methods of Sanni and Sobamiwa [10].

#### **2.2.2 Melon flour**

1 kg of melon seeds (*Citrullis vulgaris*) were toasted in an open pan over fire until light brown in color. They were milled in a Moulinex blender (1 single blade, Super Internet, Japan) to a particle size of 450µm.

#### **2.2.3 Defatted Soy-melon flour**

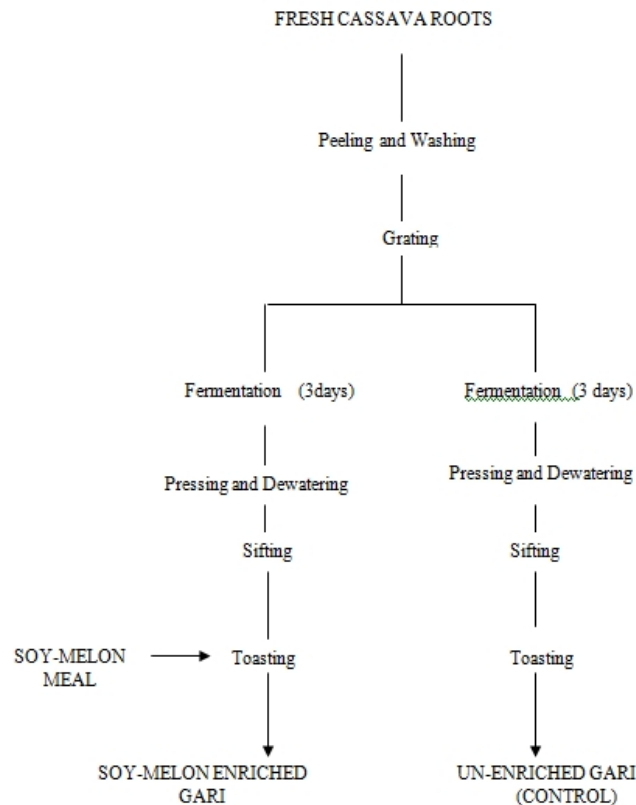
Part of the milled soy and melon flours were defatted separately at room temperature with N-hexane until the residual oil was about 1.5%. These were used to supplement the grated cassava semolina before fermentation, after fermentation and after toasting.

#### **2.2.4 Soy-melon milk residue**

The sorted and cleaned soybean and melon seeds were boiled in water at 100°C for about 25 minutes. The boiled soybean seeds were dehulled manually and both were wet milled separately in a hammer mill. Water was added in ratio 1:8 and a muslin cloth was used to extract the milk. The residues obtained were oven dried at 65°C for 24 hrs [16]. The flours obtained were similarly used to supplement the cassava semolina before fermentation, after fermentation and after toasting.

#### **2.2.5 Soy-melon “gari”**

This was produced according to the methods of Banjo and Ikenebomeh [12]. The Cassava tubers were peeled manually with a sharp knife, washed and grated in a locally fabricated mechanical grater (Fig. 1).



**Fig. 1. Flow chart for the processing of soy-melon enriched and control gari.**

The grater was made of a flat galvanized sheet punctured with holes with a big nail with opening of 0.75cm diameter and fixed round a drum-like plank. This was connected through a belt to a 7 hp driving motor [17]. The grated wet mash was then allowed to ferment for 72 hours after which it was dewatered in a mechanical press( Addis Engineering Nig. Ltd, Nigeria). The dewatered wet cassava cakes were pulverized with hands and sifted on a local raffia made sieve of mesh (0.3cm x 0.3cm) mounted on a rectangular wooden frame 40cm<sup>2</sup> to remove the fibers. The sifted meal was divided into four portions. Different types of soy-

melon supplements (i) full fat soy-melon (ii) defatted soy-melon and (iii) soy-melon residue; were used to enrich the cassava meal during toasting (soak mix method) using 15% enrichment level and taking into consideration the water content of the mash of 65% [18]. The remaining batch was used as the control, containing no supplement. The white and fluffy meal was introduced into a wide aluminum pan (garifier) supported and being heated over wood fire. It was continuously stirred using a self insulating manual baffle made of calabash from gourd. This operation fairly distributes the heat to prevent or limit dextrization of "gari". The wet semolina fluffy meal was introduced into the garifier piecemeal, amidst continuous stirring, until a full manageable batch is subjectively determined as done. The time taken to get the batch toasted to dryness depends on the experience of the processor. From past studies, 1.5-2.2 kg of "gari" semolina was satisfactorily toasted over fire between 13-20 minutes, with high intensity of heat [17]. The toasted "gari" was removed from the wide aluminum pan, spread over a large spread of clean surface of woven Hessian sack and allowed to cool. The cooled "gari" samples were then packaged in High Density Polyethylene (HDPE) film and kept under refrigerated storage until ready for further analysis.

## **2.3 Analysis**

### **2.3.1 Chemical analysis**

The proximate compositions were determined according to the standard methods of AOAC [19]. The crude protein was determined by multiplying the total nitrogen by 6.25. The carbohydrate content was obtained by difference. The pH was measured with a pH meter. The total cyanide (mg/100g) was determined by the method of Rao and Hahn [20]. The phytic acid was determined by the method of Wheeler and Ferrel [21].

### **2.3.2 Physical analysis**

The Bulk density was determined by the method of AOAC [19]. The density calculated here was referred to as Loosed density. The same container was used to determine the packed density after compacting by tapping the cylinder gently unto the wooden surface by dropping it from a height of 1.2cm once per second, adding more flour until the cylinder was full and the top was scrapped off with a spatula to obtain uniform volumes. The Swelling capacity was determined by the method of Ukpabi and Ndimele [22]. The Reconstitution Index was determined by the method of Banigo and Akpapunam [23]. The Wettability was determined by the method of Armstrong et al. [24].

### **2.3.3 Statistical analysis**

Means and standard errors of the mean (SEM) of replicate scores were determined and subjected to analysis of variance (ANOVA) using the Statistical Package for Social Statistics (SPSS version 16). Means were separated using The Duncan's New Multiple Range (DNMR) Test [25].

### 3. RESULTS AND DISCUSSION

#### 3.1 Chemical Composition of Soy-Melon Enriched “Gari”

##### 3.1.1 Protein content

Enrichment significantly increased the protein content from 2.81% in the control sample to 15.27% for “gari” enriched with soy-melon milk residue; 19.92% for “gari” with full fat supplement and 23.54% for “gari” with defatted supplement (Table 1). This means that the defatted samples had the highest mean protein content followed by those with full fat supplements while those with soy melon milk residue were the lowest ( $p < 0.05$ ). The highest values for the “gari” with defatted supplements might have been due to the removal of the oil in the supplement thus increasing the values of the protein contents [26]. Addition of soy meal into low protein foods such as sweet potato meal has been known to increase the protein content of such foods [27]. According to the recommendations of the Protein Advisory Group (PAG) guidelines [28] for weaning foods, protein content should be at least 20% (on a dry weight basis), fat levels up to 10%, moisture 5% to 10%, and total ash not more than 5%. The results for the composition of the enriched samples fall within these acceptable ranges of recommendations. The increase in protein content is attributable to the incorporation of soy meal in the blend. Therefore enrichment of “gari” with soy-melon meal produced “gari” of higher nutritional value. The protein contents of the blends (15.27 – 23.54%) were higher than the range of 11-14% recommended for growth by Beaton and Swiss [29] and still within the range of Protein Advisory Group (PAG) [28] guidelines. Therefore, the blends of soy-melon “gari” may be inferred as capable of supporting growth in school age children who often consume “gari” as a convenience food. To meet the Recommended Daily Allowance (RDA) of 34g/day for protein for a child of school age (11-14 years) consuming gari as a staple diet; he will need to consume about 1.209kg of normal control gari per day but with this protein enrichment he will need to consume less amount of about 0.222kg for gari enriched with soy melon residue, 0.170kg for gari enriched with full fat supplement and 0.144kg for gari enriched with defatted soy-melon supplement.

**Table 1. Chemical composition of soy-melon enriched and un-enriched (control) “gari” samples**

Parameter	Control	Defatted	Fullfat	Residue
Protein(%db)	2.81 <sup>d</sup> ±0.01	23.5 <sup>a</sup> ±0.02	19.9 <sup>b</sup> ±0.01	15.3 <sup>c</sup> ±0.01
Ash (%db)	1.18 <sup>d</sup> ±0.01	3.47 <sup>a</sup> ±0.01	2.36 <sup>b</sup> ±0.01	1.96 <sup>c</sup> ±0.01
Fat (%db)	3.24 <sup>c</sup> ±0.01	4.13 <sup>c</sup> ±0.01	13.5 <sup>a</sup> ±0.02	7.02 <sup>b</sup> ±0.01
Crude fiber (%db)	6.31 <sup>a</sup> ±0.01	4.79 <sup>d</sup> ±0.01	5.92 <sup>b</sup> ±0.01	5.16 <sup>c</sup> ±0.01
Carbohydrate(%db)	86.5 <sup>a</sup> ±0.01	64.1 <sup>c</sup> ±0.67	58.3 <sup>d</sup> ±0.01	70.6 <sup>b</sup> ±0.01
Total Energy (MJ/g)	1.62 <sup>c</sup> ±0.03	1.62 <sup>c</sup> ±0.09	1.82 <sup>a</sup> ±0.04	1.70 <sup>b</sup> ±0.02
pH	3.62 <sup>c</sup> ±0.02	5.25 <sup>a</sup> ±0.01	4.94 <sup>b</sup> ±0.01	4.86 <sup>b</sup> ±0.01
HCN (mg/kg)	13.4 <sup>a</sup> ±0.07	6.72 <sup>b</sup> ±0.01	6.72 <sup>b</sup> ±0.00	6.70 <sup>b</sup> ±0.09
Acidity (%)	0.465 <sup>a</sup> ±0.060	0.363 <sup>c</sup> ±0.010	0.413 <sup>b</sup> ±0.010	0.384 <sup>c</sup> ±0.090
Phytate (mg/kg)	16.9 <sup>d</sup> ±0.02	22.4 <sup>a</sup> ±0.15	22.0 <sup>a</sup> ±0.41	19.2 <sup>c</sup> ±0.31

Values are means of triplicate determinations.

Means in the same row bearing different superscript are significantly different.  $P < 0.05$ .

± are Standard error of Mean

### 3.1.2 Fat content

The fat content increased from 3.24% in the control sample to 4.13% in “gari” with defatted supplement, 7.02% in “gari” with milk residue and 13.50% in “gari” with full fat supplement. Expectedly, full fat enriched “gari” samples had the highest fat contents, followed by those enriched with milk residue and finally by “gari” enriched with defatted supplements. This increase in the fat content in “gari” enriched with full fat supplement might have been as a result of the contribution of the oil in the full fat soy-melon supplement [30].

**Table 2. Physical properties of soy-melon enriched and un-enriched (control) “gari” samples.**

Parameter	Control	Defatted	Fullfat	Residue
Swelling Index(v/v)	4.80 <sup>a</sup> ±0.05	4.02 <sup>b</sup> ±0.04	4.01 <sup>b</sup> ±0.03	4.00 <sup>b</sup> ±0.05
Reconstitution Index (v/v)	4.50 <sup>a</sup> ±0.04	4.30 <sup>b</sup> ±0.09	4.35 <sup>b</sup> ±0.03	4.23 <sup>c</sup> ±0.03
Wettability (seconds)	30 <sup>c</sup> ±0	120 <sup>b</sup> ±2	120 <sup>b</sup> ±1	150 <sup>a</sup> ±1
Packed Bulk Density (g/dm <sup>3</sup> )	0.610 <sup>b</sup> ±0.031	0.670 <sup>a</sup> ±0.021	0.660 <sup>a</sup> ±0.023	0.620 <sup>c</sup> ±0.031
Loosed Bulk Density (g/dm <sup>3</sup> )	0.530 <sup>b</sup> ±0.022	0.580 <sup>a</sup> ±0.022	0.520 <sup>c</sup> ±0.032	0.500 <sup>d</sup> ±0.021

*Values are means of triplicate determinations.*

*Means in the same row bearing different superscript are significantly different. P < 0.05.*

*± are Standard error of Mean*

### 3.1.3 Ash content

Enrichment with soy-melon meals resulted in higher ash contents. Enrichment increased the ash content significantly (P < 0.05) from 1.18% in the control “gari” to a minimum of 1.96% in “gari” enriched with residue from soy-melon milk to a maximum of 3.47% in “gari” enriched with defatted meal. This shows that the ash contents of “gari” with defatted residues were higher than those of “gari” enriched with either milk residue or full fat supplements. This is similar to the findings of Edem et al. [31], who increased the ash content of “gari” to 5.17% and 5.58% by fortifying with 10% and 15% soy meal respectively. This is also true of some food products other than “gari”. Iwe and Onadipe [32] increased the ash contents of sweet potato from 2.2% to 2.5% - 4% by supplementing it with soy meal up to 25% level.

### 3.1.4 Crude fibre

Crude fibre decreased from a value of 6.31% to 4.79%, 5.16% and 5.92% for “gari” with defatted supplement, milk residue and full fat supplement respectively. This showed that enrichment with soy-melon supplement reduced the fibre content of “gari”. This reduction of the fibre content might have been due to the dilution effect of the supplement on the fibre content of “gari”.

### 3.1.5 Carbohydrate content

The carbohydrate content was reduced from 86.5% (db) to a minimum value of 58.3% in the sample enriched with full fat soy-melon meal, 64.1% in sample with defatted supplement and the maximum value of 70.6%(db) in the sample enriched with soy-melon milk residue. Similar decrease with increase in protein enrichment was reported in “Ugali”, a Kenyan soy-

enriched maize meal [30], soy-enriched rice [34], soy-sweet potato meal mixtures [27] and soy-sweet potato meal cookie [35].

### **3.1.6 Total energy value**

The energy values increased significantly ( $P < 0.0.5$ ) from 1.62MJ/g in the control sample to a maximum value of 1.82MJ/g in the sample enriched with full fat meal. The increase and the higher values of energy in the “gari” with full fat supplement might have been due to its oil content since oil has twice the energy for the same quantities for both protein and carbohydrate [36]. It could be inferred that “gari” enriched with defatted soy-melon meal was the richest in terms of the protein and ash contents, while “gari” enriched with full fat supplement was highest in fat content and total energy values while “gari” enriched with milk residue was high in crude fibre. Un-enriched “gari” (control) was highest in crude fibre and carbohydrate contents. These shows that “gari” enriched with defatted meal seem to be the best sample in terms of the proximate composition.

### **3.1.7 Hydrocyanic acid (HCN)**

The hydrocyanic acid content was consistently lower in all the enriched samples than the control “gari”. HCN was reduced from 13.5mg/kg in the control “gari” to a range of 6.72mg/kg – 12.5mg/kg for sample toasted together with full fat soy-melon meal. These values were lower than the recommended standard value of 20.0mg/kg [37,38,39]. They were also lower than a range of values reported in earlier studies [5,40,41]. This decrease in value might have been due to the dilution effect of the soybean protein in the supplements as observed by earlier workers [10,42]. Sanni [43] observed that after 3days of fermenting cassava, “gari” had a total cyanide content of 20.0 and 7.0mg/kg during the dry and wet seasons respectively. Sanni and Sobamiwa [10] also observed that the cyanide content of soy-“gari” was reduced with increasing protein content. The type of supplement added did not have any significant effect on the hydrocyanic acid content ( $P < 0.05$ ).

### **3.1.8 pH/Acidity**

The pH of “gari” was increased by enrichment with soy-melon meal. It increased from 3.62 in the control sample to the maximum value of 5.25 in the sample toasted together with defatted meal. The acidity was correspondingly reduced from 0.46% in the control “gari” to a minimum value of 0.36% lactic acid in the sample toasted together with defatted soy-melon meal. This showed that enrichment with soy meal tended to make the “gari” less acidic by the dilution effect of the supplements. This general increase in pH and the corresponding decrease in the acidity with enrichment might have been due to the dilution effect of the soy-melon supplement which indirectly responsible for the reduced sourness in the enriched “gari” samples [12]. This reduction by enrichment made the acidity to be much lower than the recommended range values of 0.9 - 1.2% [44] and 0.6% - 1.0% [38]. This was noticed in the reduction of the sour taste of the soy-melon “gari” which was an important parameter of sensory quality of “gari”. This reduction might have been due to the differences in the number of days of fermentation and the dilution effect of the soy-melon meal supplements. This had also been observed to be due to the production of ammonia from the soy-melon protein degradation [12,45].

## 3.2 Physical Properties of Soy-Melon Enriched “Gari”

### 3.2.1 Swelling index

Data showed that the swelling index of the enriched “gari” was lower than that of the control “gari” (Table 2). The swelling index decreased with enrichment ( $p < 0.05$ ). Swelling index was reduced from 4.80 (v/v) to a range of minimum value of 4.00 (v/v) in the sample enriched with milk residue to a maximum value of 4.02 (v/v) in sample enriched with defatted supplement. This is a confirmation of the findings of Banjo and Ikenebomeh [12] who also reported a reduced swelling with enrichment. It is also similar to the findings of Afoakwa, et al. [46] that swelling capacity decreased slightly with increasing soy meal concentration in “gari” from 10% to 30% enrichment level. The lower values in the enriched samples must have been due to the presence of lipids in the soy and melon flour which must have reduced the swelling capacities of the “gari” granules [47]. High swelling capacity has been shown to give a greater volume and more feeling of satiety per unit weight of “gari” [48].

### 3.2.2 Reconstitution Index

The reconstitution index was reduced with enrichment from 4.50 (v/v) in the control sample to a range of 4.23 (v/v) in the sample enriched with the milk residue to 4.35 (v/v) in sample enriched with full fat soy-melon supplement. These lower values of reconstitution index with the enriched samples must have been due to the presence of oil in the soy and melon flours. This behavior is similar to that of swelling index which was also found to decrease with soy flour enrichment. It has been shown that the presence of lipids acted as a buffer thus lowering the swelling power of starch granules [47].

### 3.2.3 Wettability

This was measured as the time taken in seconds by soy-melon “gari” granules to sink in water when dropped from a distance of 13cm from above the surface of the water. This is an indication whether “gari” will float as particles over the water or sink to the bottom [24]. The smaller the value in seconds the faster the ability of the “gari” to sink and the faster the better the “gari”. The wettability was found to increase significantly from 30seconds in the control sample to a range of 120seconds in the defatted and full fat samples to 150seconds in the sample enriched with milk residue. High wettability values means that it will require more time for the enriched “gari” samples to sink in water and will float for more time on the surface of the cold water than the control sample. The samples enriched with milk residue had higher wettability values than the rest of the samples. This is a bit surprising because one would have expected the sample with full fat supplement to behave this way. This might have been due to the processing method. The residue was not milled to fine particles after drying before being incorporated into the wet mass and the toasted “gari”. This might have been responsible for the higher values for wettability. When this finding was compared with previous findings it was found that the wettability values ranging from 120 – 150 (seconds) for soy-melon enriched “gari” were higher than those of 27-35 (seconds) reported for un-enriched *D. alata* yam flour [49] and 42.5 (seconds) reported for un-enriched *D. rotundata* yam flour [50]. This was an indication that the un-enriched yam flours had similar wettability values with un-enriched “gari” but were denser and will sink faster than soy-melon enriched “gari” granules.

### **3.2.4 Bulk densities**

The packed bulk densities increased generally with enrichment ( $P < 0.05\%$ ). The packed densities increased from  $0.061\text{g/cm}^3$  to values ranging from a minimum value of  $0.620\text{g/cm}^3$  in sample enriched with milk residue supplement to a maximum of  $0.670\text{g/cm}^3$  for the sample enriched with defatted supplement. Loose bulk density reduced slightly from  $0.53\text{g/dm}^3$  in the un-enriched sample to 0.50 and 0.52 in the sample enriched with full fat and milk residue respectively; while it increased to a maximum value of  $0.580\text{g/dm}^3$  in samples enriched with defatted supplement. Udensi *et al.* [49] observed that high bulk density increases the rate of dispersion of granules in water, which is important in the reconstitution of “gari” in hot water to produce reconstituted “gari” (‘eba’) dough. Udensi and Okaka [50] further observed that a slight increase in bulk density was paralleled by a progressive increase in wettability and water holding capacity. Brennan *et al.* (1976) also reported an increase in bulk density with an increase in the sinkability of powdered particles. From the above observations, it could be inferred that “gari” enriched with defatted supplement had the best wettability values, better swelling and reconstitution indices than “gari” enriched with full fat and milk residue supplements. The packed densities in all the samples were however consistently and significantly higher than the loosed bulk densities, which means that more quantity of “gari” can be packed for the enriched products than the control “gari” for the same specific volume [51].

## **4. CONCLUSION**

From the results it could be concluded that enrichment with soy-melon protein supplement, improved the nutrient quality of “gari” especially the protein, fat and the ash contents. It also reduced the hydrocyanic acid content, thereby producing “gari” of higher quality and better safety. The acidity of the enriched samples was however reduced thus lowering the sourness of “gari”. This may be an advantage for people who are not used to the sour taste of “gari”. However, enrichment reduced the swelling and the reconstitution indices and also reduced the sink ability of “gari”; while it increased the packed bulk densities. Soy-melon “gari” enriched with defatted supplement had therefore been shown to have the highest protein and ash contents, lowest crude fat and acidity than other enriched gari samples. It had also been shown from this study to have better wettability, water holding capacity, and ability to disperse in water. It also had better swelling and reconstitution indices than “gari” enriched with full fat and milk residue supplements.

## **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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