Journal of Food Security, 2017, Vol. 5, No. 5, 162-168
Available online at http://pubs.sciepub.com/jfs/5/5/2

DOI:10.12691/jfs-5-5-2

Evaluation and Developing Simple Techniques for Assessing Gari Adulteration

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Abstract Gari is a major staple food for many West Africans. This study aimed at evaluating the quality parameters of gari, price per quantity in "*Olonka*" (a local measuring container) and develop a nondestructive simple technique for assessing adulteration. A completely randomized design (CRD) was used with three replications. The samples of gari were collected from seven regions of Ghana (from: processors and retailers in each region). The results showed that the mean price per weight in *"Olonka"* was 2.12 kg per Gh₵ 6.4 (0.3313 kg/Gh₵). The physicochemical properties fall within acceptable range; pH was 4.3 to 5.4, moisture content was 4.5- 7.4 %, and ash content was 1.11-1.61 %. Swelling capacity and bulk density were 3.0- 3.2 and 0.52- 0.61 g/cm^3, respectively. Particle size distribution was found to be 0.94-1.69 mm. From this study, bulk density and swelling capacity technique could be used to detect adulteration of gari with sawdust above 10 %. The tests showed that gari produced in Ghana meet the world and local standard, and adulteration of gari with sawdust can easily and simply be detected rapidly using low technology even in rural areas by determining their bulk density and swelling capacity using the developed prediction equations: $Y = 0.0035X + 0.239$ ($R^2 = 0.9827$) where; Y = bulk density and X= percentage pure gari and $Y = 0.0207X + 0.9618$ ($R^2 = 0.9811$) where; Y = swelling capacity and X= percentage pure gari, respectively.

Keywords: *quality, gari, physicochemical properties, adulteration, prediction equation*

Cite This Article: Ernest Teye, Robert Sarpong Amoah, Michael Osei Adu, and Daniel Darko, "Evaluation and Developing Simple Techniques for Assessing Gari Adulteration." *Journal of Food Security*, vol. 5, no. 5 (2017): 162-168. doi: 10.12691/jfs-5-5-2.

1. Introduction

Gari, a popular West African food product, is produced from cassava by grating the roots into a mash, fermenting and de-watering the mash into a wet cake, pulverizing and subsequently dry-frying the pulverized wet material into granular gelatinized particles [1]. Depending on the method of production and the preferences of the targeted consumers, the particle size of gari may range from 0.6 to1.1 mm [1]. Gari is common also in tropical America especially Brazil and is gradually gaining a footing in the international food market [2]. Current data suggests that its exports by Ghana grew by over 23% annually from 2001−2007 [1]. In Ghana and other West African countries, gari is mostly processed by women in local cottage industries, thus offering livelihood and food security to many rural women, the poor and the vulnerable [3].

Due to its availability all year round, long shelf-life and multiplicity of use, gari has become part of the diet for millions of Nigerians and Ghanaians, both rich and poor, as a high energy staple food. The popularity of gari is also based on the fact that the granules are precooked, thus, offering a ready-to-eat food product or with a very short time required to prepare them as main dishes or snacks [4,5].

Gari is a high energy staple food which is rich in carbohydrate, dietary fibre, and contains a significant amount of calcium, phosphorus, and vitamins C, although it is low in protein and deficient in essential amino acids [6]. Gari derivatives are eaten by a lot of people across the world and it is consumed directly in small quantities. It is often soaked in water with either: sugar, milk, or groundnuts as compliments or as a stiff gel made with hot water (as a main meal) and eaten with soup or stew [7]. It is also used as compliment in cowpea with ripe fried plantain which is a popular balanced food for most students and the youth in general [6]. The consumption of gari varies from place to place under different social and economic status.

In Ghana, gari producers operate at cottage industry level and small scale level which make quality assurance and control very challenging [8]. Furthermore, gari is often sold in the local markets without labels with varying quality and quantity attributes making traceability very difficult with a high risk of adulteration. From the standpoint of quality, the rational is to ensure the safety of consumers [1]. The act of adulteration is economically motivated and currently leading as a root cause of public health food risk that needs maximum attention and simple techniques for detection. Therefore, quality control and simple safety detection techniques would be very vital for gari consumers. Gari sold in Ghana are often measured in a localized container popularly called "*Olonka*" or "American tin". The weight per price for each "*Olonka*" is not known. Neither is the particle size distribution available in the literature.

Numerous studies have investigated the quality of gari such as nutritional evaluation [9], effect of the duration of fermentation on the quality [10], influence of roasting methods on quality characteristics [11], quality of gari produced from a conductive rotary dryer [12], optimizing quality attributes [13], feasibility of using sealed polyethylene film to prolong storage [14], effect of cassava processing equipment on quality [8], evaluation of quantity and quality from three cultivar [15], quality assessment of gari produced by using microwave energy [16], quality characteristic as affected by fermentation [17] comparative study on quality attributes [18] and quality of gari from selected processing zones [19].

It is evident from the foregoing that adulteration of gari has not received much attention. At present, quality management systems to manage the processes and activities that transform cassava roots into gari, to meet processors' objectives while satisfying the customer's quality requirements, complying with regulations, and meeting environmental and public health objectives are non-existent and/or not enforceable in Ghana. Quality examination and simple safety detection techniques would be very vital for the gari industry. The aim of the present study was therefore to evaluate the quality and quantity parameters of gari selected from seven geographical regions in Ghana and to develop a nondestructive and simple technique for detecting adulterated gari.

2. Materials and Methods

2.1. Materials

Samples of gari were collected from seven geographical regions in Ghana, which comprised: Ashanti, Brong-Ahafo, Central, Eastern, Greater Accra, Western, and Volta regions. Five samples were collected from processors and five from retailers in each region. The samples collected were put into polythlene bags sealed with a heat sealer, labeled and transported to the Technology Village laboratory of the School of Agriculture, University of Cape Coast, Cape Coast, Ghana and stored at room temperature (25±3°C) for subsequent laboratory analyses.

2.2. Methods

Physicochemical properties measured included moisture content, and ash content, pH, swelling capacity, bulk density, and particle size distribution. These were determined using standard procedures [8,11,19].

2.3. pH

Ten grams of gari was taken into 50 ml beaker with distilled water and homogenized. The mixture was filtered through Whatman No.4 filter paper. The pH of the filtrate was taken using digital pH meter (model PHS-3C, China) after the recommended calibrations with buffer solution of 4.0 and 7.0.

2.4. Moisture content

The moisture content of the gari was determined on a 10g sample using hot air oven dry method at 105°C overnight. The container with its content was removed and cooled in a desiccator at room temperature, weighed and the moisture content calculated on a dry basis per cent [8].

2.5. Ash Content

Ash content was determined by the method described by standard method [20]. Five grams of gari sample was measured into a crucible and placed into a muffle furnace at 600°C for 6 hours

2.6. Swelling Capacity

The swelling capacity was determined by the method described by Ukpabi and Ndimele [21]. Fifty grams of gari sample was placed into a 500-ml measuring cylinder and 300 ml distilled water was added and shaken for 5 min. The mixture was allowed to stand for 30 min and the swelling capacity was calculated by dividing the volume of gari in water by the initial volume/ original volume [19].

2.7. Bulk Density

Ten grams of gari was measured into 50 ml measuring cylinder and tapped repeatedly for 5 min. The bulk density of the gari was calculated as the mass over the volume [22,23].

2.8. Particle Size Distribution

Hundred grams (100 g) of gari was sieved through a set of known aperture size Tyler sieves with the aid of mechanical shaker set at frequency of 50 Hz for 10 min. Fractions retained on each were then weighed and the particle size distribution calculated as done by other researchers [19].

2.9. Price Per Weight of "*Olonka*"

Seventy samples (70) were collected; the weight and price of each "*Olonka*" of gari were determined. A digital weighing scale (0.01 g) was used and price of gari in "*Olonka*" in Ghana cedis (3.85 Gh₵/US dollars) was also taken.

2.10. Measurement of Adulteration

Samples of adulterated gari were prepared by us in the lab, from pure samples of gari. We opted for an adulterant that was analogous in granular size and colour to the pure gari such that an uneducated eye could not at a first glance identify the contamination. The adulterant was sawdust from a local woodwork shop. Six sawdust/gari preparations were made on weight-by-weight (w/w) basis. These ranged from10 – 50% w/w adulterant. Thus, there were 100% pure, 90, 80, 70, 60 and 50% pure labeled A to F, respectively. Similar measurements as previously done on the pure samples, pH, ash content, bulk density and swelling capacity were made on the adulterated mixtures.

2.11. Statistical Analysis

Data obtained from the parameters studied were analyzed by Analysis of Variance (ANOVA) and the least significant difference (LSD) test at significant level P<0.05 was performed using Minitab 16 software for windows to compare the difference between means.

3. Results and Discussion

3.1. Physicochemical Analysis

The moisture content of the samples ranged from 4.70 - 7.71 % with samples from Volta Region having the highest moisture content while those from the Brong-Ahafo region recorded the lowest (Table 1). The moisture content recorded was not different from others given by other researchers [19]. Compared to acceptable limits though, it does appear that the moisture content of Ghana's gari is lower. This is perhaps intentional to allow for longer travelling distances and storability since the centres of gari processing are often distant from the major marketing centres. Abass et al. [1] suggested that following roasting; the final moisture content of gari should be 8 – 10 % with a maximum limit of 12 %. The authors further indicated that for the purposes of export or long-distance marketing, lower moisture limits may be required for certain destinations depending on the climate, packaging method, duration of transport, and storage. The result here, therefore, suggests that Ghana's gari is of the right moisture content for good storage and marketing and could thus be passed off as good quality product [10]

The ash content observed was between 1.11-1.61% (Table 1) and this was comparable to others previously reported. [24]. For example, Oluwamukomi and Adeyemi [25] reported 1.18 % ash content of Nigeria gari. Generally, ash should not exceed 2.7 % [1], suggesting that the percentage ash in the present study falls within the range. Indeed, Ghana standard board recommends that ash should be 1.5 %.

The pH was between 5.2-5.5 (Table 1). These values were different from that observed by Oduro et al. [19] and did not also fall within the recommended range of 3.5 - 4.5 for acid fermented products [14]. But results are consistent with the suggestion of [1] that reported that fermented mash of pH range 4.0 to 5.5 will produce gari with sourness liked by different categories of consumers. Variation in the pH values with others reported elsewhere may thus be linked to differences in fermentation processes. For example, non-optimal duration at the fermentation stage may account for inadequate or excessive acidic gari which poses a significant hazard or quality defect [1]. Fermentation for the appropriate duration is also vital as it produces the level of sourness acceptable to the target consumer. Meanwhile, the results showed no significant differences in the pH of the samples from the seven regions. This shows that the processing methods are uniform across Ghana and could be attributed to the nationwide training of local gari processors.

The particle size of the samples ranged from 0.96 to 1.69 mm a bit higher than the common particle size (0.6 to1.1 mm) reported by Adebayo et al., [1]. Normally, about 80% of the particle should range between 0.25 mm to 2.0 mm and on visual examination, may be described as extra fine, fine, medium or coarse gari [1]. Our results suggest that majority of the gari in Ghana could be described as medium size (1 mm to 1.25 mm) or coarse gari (1.25 to 2.0 mm), for the Ghanaian consumers taste, as many people do not prefer the dust (<0.25 mm), the extra fine (0.25 to 0.5 mm), the fine (0.5 to 1 mm) or the lumps (>2.0 mm). However, the results pointed to a significant variation in particle size among the regions. These differences could be attributed to the grating procedure, the extent of fermentation and the treatment of the gari after roasting [19].

The bulk density recorded ranged between 0.517 - 0.627 gcm^{-3} (Table 1). The values obtained is comparable to gari samples sold in Lagos Metropolis [24]. More so, Oluwamukoni and Aeyemi [25] recorded loosed and packed bulk density of gari between 0.53 - 0.61 gcm^{-3}. Ukpadi and Ndimele [21] suggested that the bulk density of good quality ranges between 0.56 - 0.908 g cm^{-3}. Given that different materials are characterized by different bulk densities, this parameter is one of the physical properties of gari that can easily deviate from normal, should there be the presence of impurities or foreign materials.

The swelling capacity of the samples used in this study range from 3.0-3.2 (Table 1). There were no significant differences between the swelling capacities of gari from various regions (Table 1). Our results were consistent with the values reported by others [8,19,26]. The swelling capacity is a very important attribute for a good quality gari as it indicates the degree of gelatinization of the gari sample [19]. The implication, therefore, is that there is a consistency ingari processing procedures across various regions in Ghana. This could be attributed to the nationwide training offered to gari processor or the good dose of indigenous knowledge accrued over time through experience.

Table 1. Physicochemical properties of gari in seven regions in Ghana

Samples	% Mc	% Ash	pH	Particle size (mm)	Bulk density (g/cm^3)	Swelling capacity
Ashanti	5.27^{ab}	1.11^{a}	5.4^{ab}	1.20^{bc}	0.607^{bc}	3.2^{b}
Brong Ahafo	4.70^{a}	1.15^{a}	5.3^{a}	1.30^{b}	0.542^{ab}	3.1^{b}
Central	6.85^{b}	1.54^{bc}	5.3^{a}	0.94^{c}	0.627^{c}	3.0^{ab}
Eastern	6.12^{ab}	1.61^{c}	5.2^{a}	1.69^{a}	0.607^{bc}	3.0^{ab}
GT. Accra	4.85^{a}	1.36^{abc}	5.3^{a}	1.10^{c}	0.598^{bc}	3.0^{ab}
Volta	7.71^{b}	1.31^{bc}	5.5^{b}	1.40^{ab}	0.610^{bc}	3.0^{ab}
Western	5.83^{ab}	1.11^{a}	5.3^{a}	1.10^{b}	0.517^{a}	3.0^{ab}
Mean	**1.945**	**1.15**	**0.167**	**1.24**	**0.587**	**3.04**

Values with different superscript within a column are significantly different (p<0.05).

3.2. Weight per Price of Gari in "*Olonka*"

The weight of gari in "*Olonka*", a local measuring container was found to be between 2.0-2.19 kg and the price range of Gh₵6.0 to 7.5 at the time of sampling in March, 2017 (Table 2). Until now the weight of gari in "Olonka" as used by local traders is not known. This study revealed that the local measuring containers used in the market were similar across various markets as there were no significant differences among them. The unit price of gari was 0.284-0.3312 Kg/1 Gh₵. Though the weights were almost the same across regions, there were significant differences in the price per '*Olonka*' across regions. The price of gari from Brong-Ahafo for example was the lowest (5 Gh₵ per '*Olonka*') while, the highest price was recorded in the Greater Accra and Central region (7.5 Gh₵ per ''*Olonka*'). The price variations across regions is however not surprising because the markets were just responding to the principles of supply and demand. Brong Ahafo region is among the major food baskets of Ghana, producing a lot of cassava, many of which gets rotten at the farm gates. More gari is thus processed in the region and subsequently sold in the markets. Besides, the inhabitants of this region are likely to have access to diverse range of fresh food sources and would only patronize gari in the lean season. There is therefore, likely to be more supply than demand in this area. In contrast, the Greater Accra and the Central regions have limited cassava production and hence few gari processing industries. Whilst majority of gari in the markets of Accra and Cape Coast (the capitals of the two regions) had been transported from remote places, there is also high demand, especially from students in the numerous second cycle schools and tertiary institutions in these regions. Demand exceeding supply pushes the prices up.

3.3. Adulteration of Gari with Sawdust

There was a reduction of bulk density, swelling capacity and ash content following the adulteration of pure gari samples with various amounts of foreign material (10-50% of sawdust) as listed in Table 3. This phenomenon suggested that bulk density and swelling capacity could be used to detect adulteration of gari with impurities. We proceeded to develop a simple prediction equation that would detect the presence of impurities and quantify the amount in each gari sample. The coefficient of determination to predict adulteration and to quantify the amount of adulterant were high ($R^2 > 0.98$) as seen in Figure 1 and Figure 2. With these equations developed, bulk density or swelling capacity or both (for surety) could be used to determine adulteration (quality and quantity) of gari with sawdust and for that matter, similar impurities. For a known bulk density or swelling capacity, the purity of gari could be determined using $Y = 0.0035X + 0.239$ ($R^2 = 0.9827$) where; Y = bulk density and X= percentage purity while for swelling capacity, $Y = 0.0207X + 0.9618$ ($R^2 = 0.9811$) where; Y = swelling capacity and X= percentage purity. These equations were further used to test 30 different samples. The prediction equations derived for detecting adulteration was consistent and very stable in the prediction of other samples of adulterated gari. A chi-square analysis as shown in Table 4 & Table 5, revealed that there was no significant difference between values obtained by standard method (bulk density & swelling capacity) for the determination and the prediction equations developed using bulk density and swelling capacity of gari respectively. Hence the prediction equation could be used for the rapid estimation of the bulk density and swelling capacity of gari to determine its purity or levels of adulteration. This approach is similar to the determination of dry mater content of cassava using specific gravity method [27].

Table 2. Weight and price of "Olonka" of gari from seven regions in Ghana

Region	Price Gh₵	Weight of *Olonka* (kg)	Weight/price (Kg/ Gh₵)
Ashanti	7.0	2.05	0.292857
Brong Ahafo	5.0	2.02	0.404
Central	7.5	2.13	0.284
Eastern	6.0	2.17	0.361667
Greater Accra	7.5	2.21	0.294667
Volta	6.0	2.07	0.345
Western	6.0	2.19	0.365
Mean	**6.4**	**2.12**	**0.33125**

Gh₵/USD= 3.85.

Table 3. Some properties of pure and adulterated gari with saw dust

Samples (% pure)	pH	Ash content	Bulk density	Swelling index
100	5.467^{c}	1.1267^{c}	0.6467^{c}	3.067^{d}
90	5.300^{b}	1.0933^{abc}	0.5667^{b}	2.767^{c}
80	5.207^{a}	1.0800^{ab}	0.5033^{b}	2.467^{b}
70	5.194^{b}	1.0733^{a}	0.4867^{a}	2.400^{ab}
60	5.167^{a}	1.0633^{c}	0.4667^{a}	2.333^{a}
50	5.100^{a}	1.0500^{ab}	0.4133^{a}	1.933^{a}

Values with different superscript within a column are significantly different ($p<0.05$).

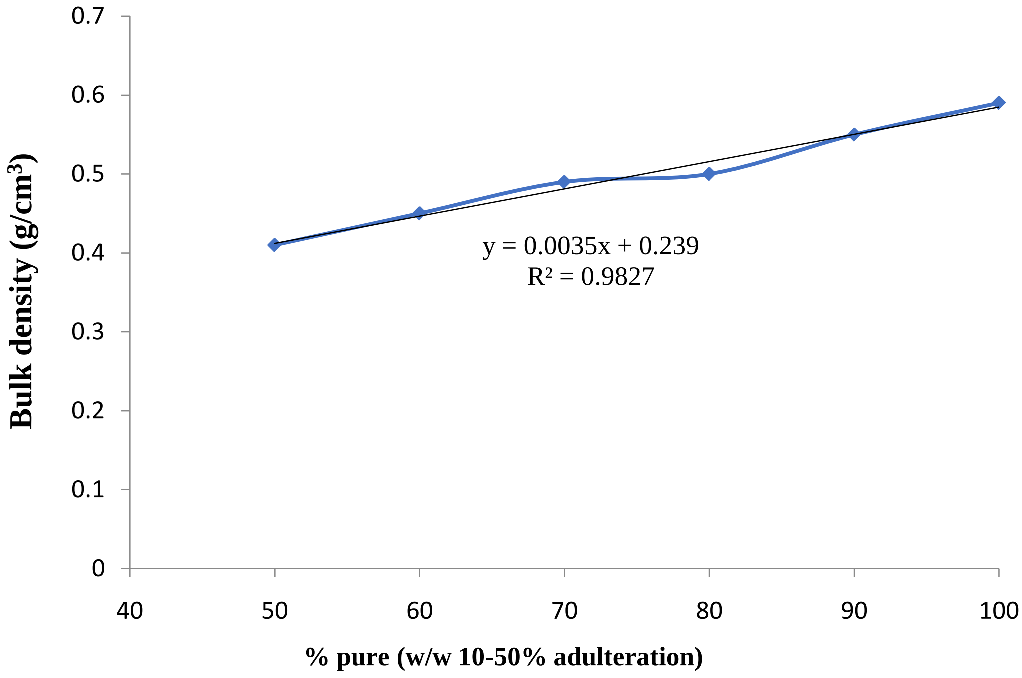

Figure 1. Bulk density of gari samples against percentage purity

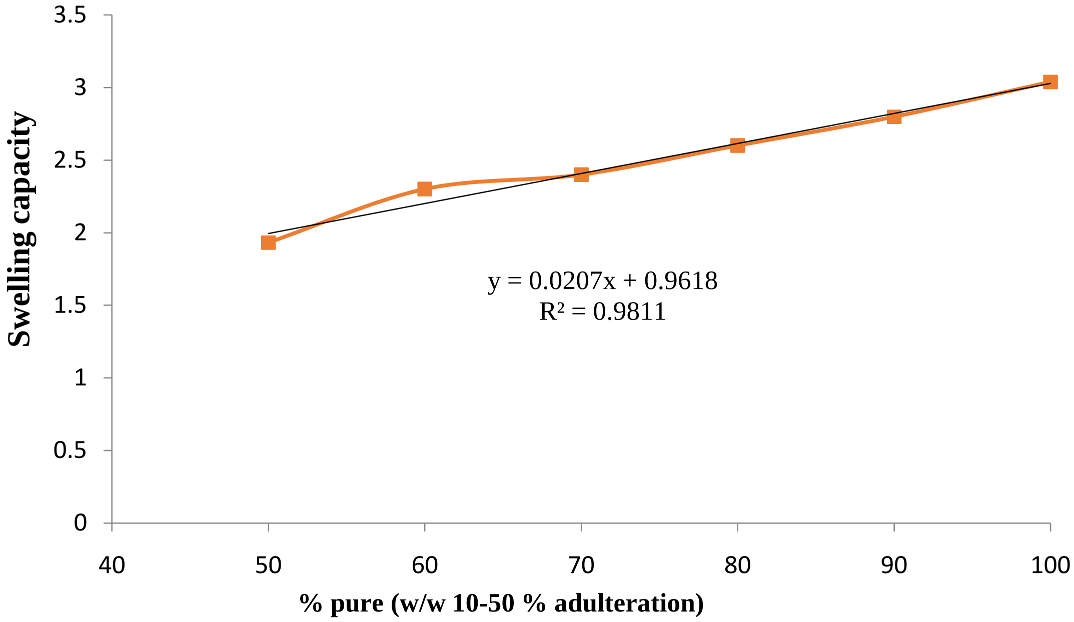

Figure 2. Swelling capacity of gari against percentage purity

Table 4. Verification of prediction equation for % purity of gari based on bulk density

Samples (% pure)	DF	Percentage pure		Chi-square χ^2	Probability of greater value	
		Standard method	Prediction equation		0.05	0.001
100	3	0.6467	0.589	0.005652	7.81473	11.3449
90	3	0.5667	0.554	0.000291	7.81473	11.3449
80	3	0.5033	0.519	0.000475	7.81473	11.3449
70	3	0.4867	0.484	0.000015	7.81473	11.3449
60	3	0.4667	0.449	0.000698	7.81473	11.3449
50	3	0.4133	0.414	0.00000118	7.81473	11.3449

(Y = 0.0035X + 0.239; R^2 = 0.9827); Y = bulk density and X= percentage pure.

Table 5. Verification of prediction equation for percentage purity of gari samples based on swelling capacity

Samples (% pure)	DF	Percentage pure		Chi-square χ^2	Probability of greater value	
		Standard method	Prediction equation		0.05	0.001
100	3	3.067	3.0318	0.000409	7.81473	11.3449
90	3	2.767	2.8248	0.001183	7.81473	11.3449
80	3	2.467	2.6178	0.008687	7.81473	11.3449
70	3	2.400	2.4108	0.0000484	7.81473	11.3449
60	3	2.333	2.2038	0.007574	7.81473	11.3449
50	3	1.933	1.9618	0.000423	7.81473	11.3449

(Y = 0.0207X + 0.9618; R^2 = 0.9811); Y= Y = swelling capacity and X= percentage pure.

4. Conclusion

The study has shown that the entire gari samples in the seven regions of Ghana had standard moisture content that ranged between 4.48 to 7.4 % and therefore could store favourable. Ash content ranged between 1.11 to 1.61% while, pH was 4.3 to 5.4. The swelling capacity and bulk density falls within acceptable range (3.0-3.2 %), and (0.52-0.61%) respectively. The average particle size distribution also ranges from 8.7 x 10^{-3}- 9.2 x 10^{-3}. Eastern region has the highest particle sizes in terms of it classifications according to codex regional standard for gari classification whiles Western region has the lowest particle size. The weight per unit price of gari "*Olonka*" in Ghana was found to be 0.331 kg/ Gh₵. The investigations from some producers of gari in Ghana revealed that, some level of sawdust (adulterant) is added to gari for financial gains. From this study, bulk density and swelling capacity of gari can be used to check adulteration of gari with sawdust from 10% upwards. The prediction equation for percentage adulteration using bulk density and swelling capacity (as Y) is Y = 0.0035X + 0.239 (R^2 = 0.9827) and Y = 0.0207X + 0.9618 (R^2 = 0.9811) respectively. Pure gari sample from different locations all have bulk density above 6.4 kg/m^3 and swelling capacity above 3.0 while, adulterated gari (10-90%) showed bulk density and swelling capacity between 0.56-0.41 kg/m^3 and 2.76-1.93, respectively.

Acknowledgments

This work has been financially supported by the Department of Agricultural Engineering, School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast, Ghana. Mrs. Winifred Akpene Teye is acknowledged for proof reading this manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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