Assessment of Quality of Garri Produced from a Conductive Rotary Dryer

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Abstract
The quality of *garri* produced from a Conductive Rotary Dryer (CRD) was assessed with a view to optimizing the use of the CRD for the production of high quality *garri.* Cassava tubers were pre- processed into mash which was divided into two portions; one portion was roasted using a traditional fryer while the other was roasted using the CDR. The mash roasted using the CRD was subjected to varying parameters (batch quantity, drum temperature, vapour extraction rate, drum speed, number of flights and number of breakers) to produce seven *garri* samples using a Taguchi design. The quality of *garri* produced using the traditional fryer and CDR was determined by analysing samples for some physiochemical properties and proximate composition. Results showed that the quality of samples produced using the CDR agreed with standards given for *garri* in literature. In conclusion, this study showed that using the right operating parameters, the CDR could produce high quality *garri* that is acceptable not only in local markets but also at regional and international markets.
Keywords: mash, standards, properties, roasted, traditional fryer

1. Introduction

Cassava *(Manihot esculenta crantz)* is a major food crop in Nigeria, supplying about 70 % of the daily calorie of over 50 million people (Oluwole *et al.,* 2004).). Nigeria's cassava production is by far the largest in the world, a third more than production in Brazil and almost double the production of Indonesia and Thailand (FAO, 2006). Cassava is a perishable commodity with a shelf life of less than 3 days after harvest. Processing cassava tubers into other products provides a means of producing shelf stable products; thus reducing post-harvest losses, adding value at a local rural level and reducing the bulk to be marketed. *Garri,* is one of the numerous products derived from cassava is a major staple food for many countries in West Africa and Latin American countries (Agbetoye and Oyedele, 2007), it is also the most popular form in which cassava is consumed in Nigeria. *Garri* is a granular product which is creamy white or yellow in color, it also has a slightly sour taste due to fermentation and gelatinization during processing.

Although efforts have been made in mechanizing some of the unit operations in *Garri* production, processing cassava tubers into *garri* is carried out by traditional (mostly manual) methods in Nigeria. The traditional method of producing *garri* is however associated with a lot of difficulties and short comings especially during roasting/frying of cassava mash. *Garri* frying/garification (a combination of simultaneous cooking and drying operation) is the most critical step in processing cassava tubers to *garri* (Adetife and Samuel, 2012). Most of the women that roast *garri* spend several hours close to the heat in order to produce few kilograms of *garri*. The quality of *garri* produced is not guaranteed, as it all depends on the skill and experience of the operator. Additionally, the process is not environmentally friendly as trees used for fuel produces carbon which is released to atmosphere due to burning.

In order to minimise the challenges associated with traditional method of roasting, a conductive rotary dryer (CDR) was developed in the Department of Agricultural and Environmental Engineering, Faculty of Technology, Obafemi Awolowo University, Ile-Ife. The objective of this study was, therefore, to investigate the quality of *garri* produced by the conductive rotary dryer. This is in a bid to determine the operating parameters of the CDR that would produce high quality *garri* based on standards available in literature.

2. Materials and Methods

2.1 The Conductive Rotary Dryer (CDR)

The Conductive Rotary Dryer is an electro-mechanical system, specifically designed and fabricated in the Department of Agricultural and Environmental Engineering, Faculty of Technology, Obafemi Awolowo University, Ile-Ife for drying or roasting of pulverized and sifted cassava mash. The design of the conductive rotary dryer is based on the principle of a metallic cylindrical shell of diameter (0.56m) and length (0.90m) whose external surface is heated directly by electrical heating elements placed around it. The cylinder (shell) which is horizontal rotates slowly at a speed range of 5rpm to 15rpm while its internal surface simultaneously heats up to specific temperature ranges (90ºC≤T_d≤190ºC). Three equidistant flights each with length (0.90m) is located 120 degree from each other on the inner surface of the shell for lifting and dispersion of the material (Fig. 1).

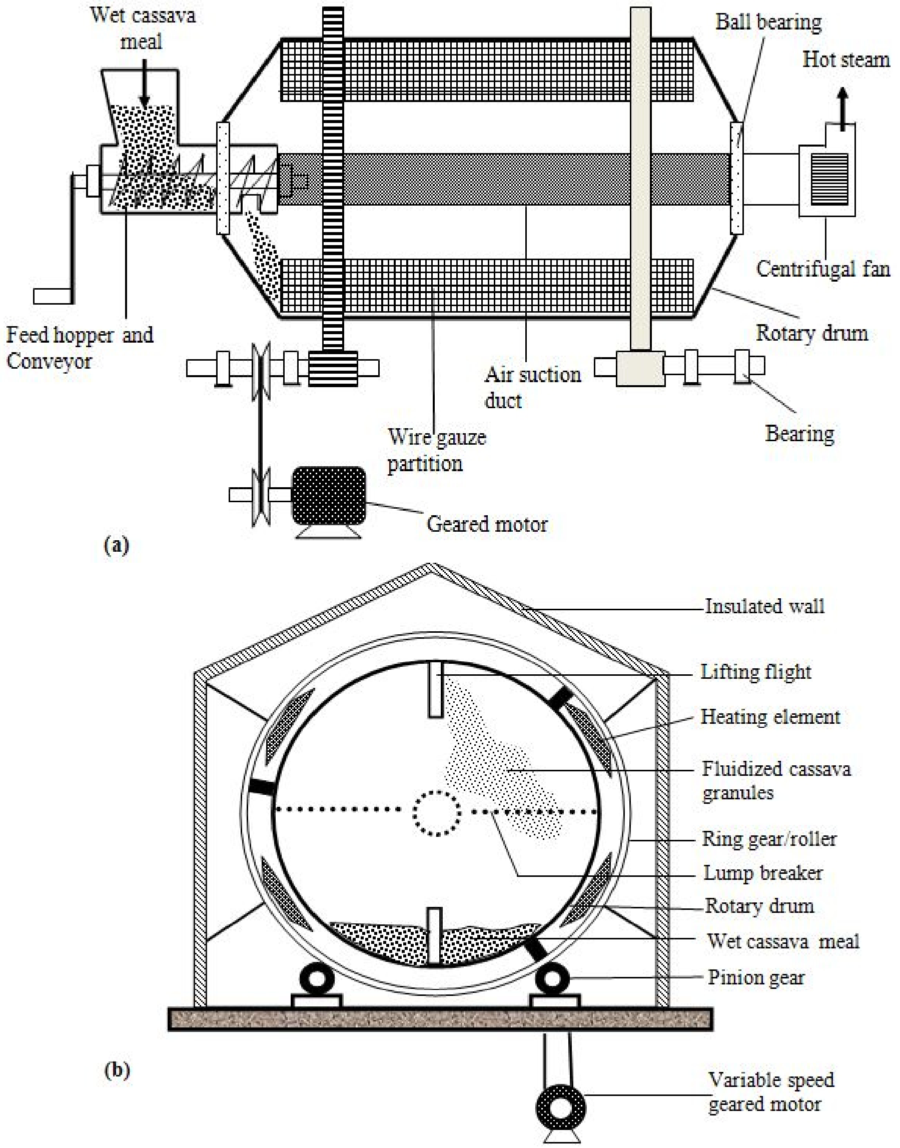

Figure 1: Schematic diagram of the conductive rotary dryer

The rotating drum is entirely enclosed by an insulating wall lagged with glass fiber to conserve the heat generated from the heating elements, thus preventing excessive heat loss to the environment. To produce hygiene-sensitive foods, the dryer also has an additional air filter to clean the incoming air, in order to prevent food contamination.

2.2 Sample preparation

Cassava tubers used for the studies were collected from Teaching and Research Farm, Obafemi Awolowo University, Ile Ife. Care was taken to harvest tubers from cassava stands that were of the same variety (TMS 30572) and age (11 months). The harvested cassava tubers were washed, peeled and washed again to remove any form of dirt or impurity. The peeled roots were grated using a cassava grater and the grated mash was collected in perforated propylene bags and allowed to ferment for two days. The bags were tied and placed under the press for dewatering the pulp into a cake devoid of free liquid. The pressed cassava cake was then pulverized and sifted using a raffia sieve of 2.5 mm aperture to produce wet cassava mash from which samples were taken for the various experiments. Fermented cassava mash was also roasted using traditional fryer to produce *garri* which was used as control i.e. for comparison with the *garri* produced using the CRD.

2.3 Drying/roasting of cassava mash using the CRD

Preliminary testing of the CDR showed that parameters such drying temperature, air vapor extraction rate, number of flights and breakers, drum speed and batch quality affected the quality of dried *garri* produced from the CDR. To further investigate the effect of these parameters, the Taguchi method of experimental design (Table 1) was used to determine the optimal combination of the parameters that gave the best quality characteristics for the production of *garri*.

Table. 1 Orthogonal array design for studying the effect of parameters on drying of *garri* using the conductive rotary drier

Sample	Drum speed (rpm)	Air-vapor extraction rate (m^3/s)	Number Of Flights	Batch quantity (kg)	Number of breakers	Drum temperature ^oC
1	10	0.0075	2	5	1	140
2	15	0.0075	3	5	2	190
3	15	0.03	3	8	2	190
4	10	0.03	2	5	3	140
5	15	0.03	3	5	1	190
6	10	0.0075	2	8	3	140
7	15	0.0075	3	8	1	190

2.4 Determination of quality of *gari* produced from CDR

Some physiochemical properties were determined to assess the quality of *garri* produced from the CDR. These properties included the particle size distribution, bulk density, colour, swelling capacity, pH, angle of repose, coefficient of friction of the samples.

Particle size of *garri* samples were determined according to the methods used by Serpil and Servet (2006) and Sanni *et al.,* (2008). Two hundred gram (200g) of each sample was weighed put in a mechanical sieve shaker (endecotts test sieve shaker) with standard test sieves (mesh sizes 2.36 mm, 1.70 mm, 1.00 mm, 0.50 mm, 0.25 mm, 0.15 mm, 0.075 mm, 0.053 mm and pan) and agitated for 15 minutes. The material retained on each sieve was collected and weighed using an electronic balance (readability ±0.001) and the particle size analyses was recorded as percentage of sample retained on each sieve. Other parameters such as Fineness modulus (FM), average particle size and uniformity index were determined from the data obtained from the sieve analysis.

Fineness modulus (FM) and average particle size was determined by using the method described by Sahay and Singh, 2001 while the uniformity index was determined using the method described by Igbeka, 2013.The average particle size (D) of each sample was calculated using the following equation

$$D = 0.135\,(1.366)^{FM} \qquad (1)$$

The method given by Owuamanam *et al.* (2010) was used to determine the bulk density of the samples.Swelling capacity for the samples was determined according to the method used by Udofia *et al*. (2011).

The angle of repose was determined using a method similar to the method used by Ogunjimi *et al*., 2002. An open-ended cylinder of diameter 15cm and height 30cm was placed at the center of a circular plate filled with the samples. The cylinder was raised slowly until the samples formed a cone on the circular plate. The height (h) and diameter (d) of the cone was measured the angle of repose (θ) was calculated using the expression

$$\theta = \tan^{-1}\left(\frac{2h}{d}\right) \quad (2)$$

The static coefficient of friction (μ) of the samples was determined on four surfaces mild steel, galvanized steel, glass and plywood by using an inclined plane apparatus (Owolarafe *et al.,* 2007). Samples were analyzed for color using the Munsell Color chart(Munsell, 1976) while pH was determined using a pH meter (Hanna Instrument, accuracy ±0.1). For proximate analysis, the samples were evaluated for moisture, carbohydrate, crude fiber, crude protein and ash contents using the AOAC (2001) Standards.

3.0 RESULTS AND DISCUSSION

3.1 Particle Size Analysis

Table 2 shows results for particle size analysis (in terms of fineness modulus, average particle size and uniformity index) of *garri* samples roasted using the CDR and traditional fryer. The Fineness Modulus values were highest for *garri* produced using the traditional fryer while values for *garri* produced from the CDR ranged from 4.37 to 4.94. These values were within the range of values (3.8 - 4.9) obtained by Burubai and Etekpe (2014).

In terms of the average particle size, the particle size of *garri* samples from the CDR ranged between 0.53 and 0.63 mm while the overall average particle size was 0.59 mm. The average particle size (0.7 mm) of *garri* produced using the traditional fryer was slightly higher than the samples from the CDR. This implies that the *garri* produced from the machine were smaller in size than the *garri* produced by traditional fryer. However, the particle size of *garri* samples produced from CRD were similar to those obtained by Agbetoye and Oyeleke (2013) who reported that the particle size of *garri* samples from South West, Nigeria was 553.31μm and Oduro *et al*. (2000) who recommended that the standard average size of *garri* should be between 0.25 and 1.00 mm. Thus, the particle sizes of *garri* produced from CRD were within the acceptable range reported in literature.

Table 2 Particle size analysis of *garri* samples

Gari Samples	Fineness Modulus	Average particle Size (mm)	Uniformity Index (Coarse, Medium, Fine)
Traditional	5.25	0.70	4, 6, 0
1	4.48	0.56	2, 8, 0
2	4.94	0.63	3, 7, 0
3	4.37	0.53	1, 8, 1
4	4.64	0.57	2, 8, 0
5	4.64	0.57	2, 8, 0
6	4.58	0.56	2, 8, 0
7	4.63	0.57	2, 7, 1
Average	4.69	0.59	-

Uniformity index of *garri* produced from the traditional fryer was 40:60:0 for coarse, medium and fine, respectively. The ratio for coarse, medium and fine texture of *garri* produced from the CDR varied. It was however, observed that 50 % of the *garri* samples from the CDR had uniformity grouping as 20:80:0 for coarse, medium and fine, respectively. Thus, the *garri* obtained from the CDR could be said to have particles that are mostly of medium grains and this conforms to the standard suggested by Burubai and Etekpe (2014) that the acceptable uniformity index for premium quality *garri* should be 20 -30 % coarse, 50 - 80 % medium and 0 – 20 % fine.

3.2 Physiochemical properties

Table 3 gives results of physiochemical properties obtained for *garri* samples. The bulk density obtained for *garri* samples from the CRD ranged from 381.78 to 487. 24 kg/ m^3. Only one sample had a density value (487. 24 kg/m^3) higher than that of the *garri* produced by traditional fryer (472.74 kg/m^3). Bulk densities obtained in this study were general low in comparison to those given in literature.

Table 3 Some physiochemical properties of *garri* samples

Garri Samples	Angle of repose (°)	Coefficient of static friction			
		Mild steel	Plywood	Glass	Galvanized Sheet
Traditional	41.32	0.51	0.79	0.79	0.73
1	36.76	0.67	0.81	0.69	0.76
2	40.56	0.49	0.70	0.72	0.69
3	36.20	0.48	0.82	0.66	0.68
4	39.40	0.65	0.72	0.81	0.65
5	36.89	0.55	0.99	0.72	0.74
6	36.86	0.66	0.90	0.72	0.73
7	39.65	0.59	1.12	0.98	0.71
Mean	38.05	0.58	0.87	0.76	0.71

Only one sample had a density value (487. 24 kg/m^3) higher than that of the *garri* produced by traditional fryer (472.74 kg/m^3). Bulk densities obtained in this study were general low in comparison to those given in literature. For example, values from 490 to 580 kg/m^3 (Apea-Bah *et al*., 2009) and 550 to 820 kg/m^3(Komolafe and Arawande, 2010) were given in literature for various *garri* samples. These lower values may be due to the method of filling used for the determination of bulk density of the samples.

The swelling index values obtained for *garri* samples produced using the CDR ranged between 1.61 and 2.89. A relative higher swelling index of 3.69 was obtained for *garri* samples produced using the traditional fryer. For most of the CDR *garri* samples, the swelling index was less than the acceptable standards that say that *garri* should swell between 2.0 and 4.0 times its original volume. Hence, values obtained for these samples were lower than values reported for *garri* in literature (Irtwange and Achimba, 2009; Apea-Bah *et al*., 2009; Owuamanam *et al*., 2010; Sanni *et al*., 2008). According to Sanni *et al.,* (2008), a low swelling index may be due to samples being affected by drying temperature, degree of gelatinization and moisture content; therefore a slight increase in drum temperature or slight increase in roasting time could help to increase the swelling index of the *garri* produced. It is however, good to note that two of the samples (Samples 2 and 5) dried using the CDR had a swelling index greater than 2.0.

pH values for CDR roasted *garri* samples ranged between 5.6 to 6.1 while a lower pH was obtained for the traditionally fried sample (6.5). The pH of *garri* from the CRD were close to values of 6.4 – 6.6 given by Okolie *et al*., 2012 for *garri* samples from Lagos metropolis but higher than values of 3.58 to 4.47 reported by Oduro *et al*. (2000), 3.58 to 4.21 by Apea-Bah *et al*. (2009), 3.60 to 4.0 by Komolafe and Arawande, (2010) and 4.3 to 4.5 given by Makanjuola *et al*., 2012 in literature. This implies that the pH of CRD and traditional fried samples less acidic than for samples reported in literature. This probably is due to the fermentation period (two days) used for the samples.

For color of the *garri* samples, six samples (out of seven *garri* samples) had hue ranging from 50 to 85 % green-yellow colour , the Munsell value ranged from 8.15 to 9.18 (very light) and a low Munsell chroma for *garri* produced from CRD. However, one sample and the traditional sample fall under the same hue (50% yellow) slight difference were observed in their value (9.18 and 8.55 respectively). Generally, colour of *garri* samples produced from the CRD is the almost same with the traditionally produced *garri*.

3.3.1 Angle of repose and coefficient of sliding friction of *garri* samples

Angle of repose values obtained for *garri* samples (Table 4) from the CRD ranged from 36.20 – 40.56^o while a slightly higher value (41.32^o) was obtained for the traditionally fried *garri*.

Table 4 Angle of repose and coefficient of static friction of *garri* samples

Garri Samples	Moisture Content (%)	Bulk Density (kg/m^3)	Swelling Index	pH	Colour Specification
Traditional	11.74	472.74	3.69	6.5	(2.82Y8.55/2.43)
1	16.12	447.50	1.72	5.6	7.5GY 9.10/0.25
2	6.77	443.32	2.89	6.1	5Y 9.18/0.25
3	9.43	455.72	1.94	5.8	8.5GY 9.14/0.30
4	16.07	487.24	1.67	5.7	5GY 8.99/10.5
5	7.24	451.10	2.06	5.9	7.5GY 9.14/0.35
6	14.98	381.78	1.61	5.6	6.25GY 8.15/2.5
7	8.53	434.26	1.72	5.7	5GY 8.99/10.5
Average	11.31	442.99	1.94	5.8	-

This shows that, according to Lumay *et al*., 2012, *garri* samples from the CDR fell within the range of angle of repose of 36- 40 degrees used to classify fair flowing powders and grains. The average value of angle of repose (38.05^o) for the CRD samples was close to the value of 39.42 degrees reported by Agbetoye and Oyedele (2013) for *garri* samples in literature.

The mean of static coefficient of friction on plywood, mild steel, glass and galvanise sheet were 0.58, 0.87, 0.76, 0.71, for *garri* samples. The *Garri* samples from the CDR could be classified as abrasive agricultural products using Mohsenin (1986) that gave coefficient of friction of values 0.4–0.5 for non–abrasive and 0.6–0.7 for abrasive agricultural materials.

3.4 Proximate Composition

The moisture content for *garri* samples produced using the CDR ranged from 6.77 to 16.12 %, wet basis (Table *3*). The proximate composition of four CDR processed *garri* samples (with moisture contents less than 12 %, wet basis) and the control sample is shown in Table 5.

Table 5 Proximate composition of some of the *garri* samples

Samples	Proximate composition (%)					
	Moisture Content	Ash	Ether Extract	Crude Fibre	Carbohydrate	Crude Protein
2	6.82	1.57	0.44	1.97	85.40	1.97
5	7.31	1.96	0.63	1.71	86.01	1.77
8	8.56	1.72	0.54	1.55	85.07	1.94
3	9.01	1.62	0.65	1.61	85.11	1.94
6	9.33	1.73	0.61	1.62	85.07	1.53
Mean	8.21	1.72	0.57	1.69	85.33	1.83
Traditional	8.01	1.16	0.39	1.50	87.21	1.53

These four samples had moisture content below that of the *garri* produced using the traditional fryer (11.74 %, wet basis). For these samples, the moisture content fell between the ranges of moisture content reported in the literature such as 9.54 – 11.57 % (Apea-Bah *et al.,* 2009) and 8 – 10 % (Okolie *et al*., 2012). They were also within the values of 12 % given as maximum allowable moisture content for *garri* by Codex (1989) Standards. It is pertinent to note that two of the samples (samples 2 and 5) from the CRD had very low moisture contents of 6.77 and 7.24% (wet basis), such very low moisture values, has not been reported for *garri* using traditional methods (fryers) in literature. Hence, the CRD can be said to have the possibility of producing *garri* that has good storage potential.

Protein content of *garri* samples produced from the CRD ranged from 1.53 to 1.97 %. The crude protein value of the samples from the dryer were higher than the *garri* sample from traditional fryer (1.53 %) and values of 1.04 to 1.40 % reported by Komolafe and Arawande (2010) but fell within the range of 1.2 to 2.0 % reported by Obatolu and Osho (1992) and 1 – 3 % reported by Okolie *et al*. (2012). The carbohydrate content (85.07 – 86.01 %) obtained for *garri* produced from the CRD was close to carbohydrate values for the fried *garri* (87.21%) and the values of 85 – 87 % (Okolie *et al*., 2012), 84.55 % (Ojo and Akande, 2013) and 82.92 – 83.31 % (Komolafe and Arawande, 2010) reported for carbohydrate content of *garri* in literature.

Standards given for ash values for *garri* in literature state that its ash content should not be more than 3 % (Codex, 1989; Okolie *et al*., 2012). Ash contents obtained for *garri* samples used for this study fell within this range; although the ash value (1.16 %) for *garri* product from the traditional fryer was lower than values for samples obtained from the CDR. Crude fibre obtained for the *garri* samples used for this study ranged from 1.50 to 1.97 % which is within the nutritional allowable maximum level of 3.0 % reported by Ibe, (1999) and 2.0 % recommended by the Codex standard of *garri* (Codex, 1989) and the Nigerian Industrial Standard, NIS (1988).

5. Conclusion

The quality (*viz-a viz* its particle size, physiochemical properties and proximate composition) of *garri* produced from a conductive rotary dryer was determined. The data generated would be useful in varying parameters in the CRD which will in turn enhance the optimisation of the use of the dryer for roasting cassava mash into high quality *garri*.

Specifically, the following conclusions can be drawn from the results obtained from the study:

1. *Garri* produced using the CDR were medium grained with average particle size of 0.59mm. Generally, the color of *garri* produced by the CRD was yellowish in colour, with very light value and low chroma.
2. The angle of repose and coefficient of sliding fracture values, respectively, showed that *garri* processed using the CDR could be described as fairly free flowing and abrasive agricultural material.
3. Proximate composition of *garri* samples produced using the CDR is within values reported in literature for *garri* sold in different markets in Nigeria.

4. High quality premium *garri* can be produced by using and further investigating parameters of the machine used to produce the CDR samples 2 and 5 from the Tanguchi experimental layout.

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