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Effect of mash quantity and roasting duration on some physical and pasting properties of *gari*

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Abstract

Central composite rotatable of response surface methodology experimental design was used to determine effect of mash quantity and roasting duration on physical, pasting and sensory properties of *gari.* Five levels of quantity (317, 400, 600, 800 and 882.2 g) and roasting time (37.1, 35, 40, 45 and 47.1 min) were used at a fixed roasting temperature (95^{o}C). The responses were moisture, pH, bulk density, water absorption capacity, swelling index, and peak, trough, breakdown, final and setback viscosities, peak time, pasting temperature and acceptability of the products. Moisture content, pH, bulk density, water absorption capacity and swelling index of the samples were (11.1 – 18.8 %), (2.4 -3.4), (1.02 – 1.11 g/cm^3), (2.0 – 5.4 ml/g) and (2.4 – 3.4 ml/ml) respectively. Among the physical properties determined, only bulk density was not significantly ($p > 0.05$) affected. Peak and break down viscosities were not significantly ($p > 0.05$) affected, while other pasting properties studied (trough, final viscosity, set back viscosity, peak time and pasting temperature) were significantly ($p < 0 .05$) affected by mash quantity and roasting duration. Recorded mean were peak 1907.58 ± 983.3 RVU, trough 1987.42 ± 501.89 RVU, break 228.15 ± 280.43 RVU, final 3827.46 ± 735.51 RVU, set back 1840.04 ± 419.75 RVU, peak time 6.38 ± 0.66 min and pasting temperature 54.02 ± 3.82^{o}C. All samples roasted for more than 35 min were poorly rated.

Introduction

Cassava (*Manihot escutenta* Crantz) is a major food crop in Nigeria, supplying about 70% of the daily calorie for over 50 million people in Nigeria (Oluwole *et al.*, 2004) and provides food for over 500 million people in the world (Abu *et al*., 2006). Edible part of fresh cassava root contains 32 – 35% carbohydrate, 2 – 3% protein, 75 – 80% moisture, 0.1% fat, fibre and 0.70 – 2.50% ash (Oluwole *et al.*, 2004). It is cultivated for its roots, which provide a cheap source of energy and raw materials for industries. Wide varieties of products are obtained from the processing of cassava. These include fermented cassava flour (*lafun*, *kanyang*, *makessa*, *luku*), roasted fermented cassava grits (*gari*, *kapok*, *agbelima*, *pogari*), fermented cassava mash (*fufu*, *foofoo*, *akpu*, *foufou*), steamed and fermented cassava chips (*chikwangue*, *mangbele*, *ntuka*), fermented steamed cassava grits (*atieke*, *attieke*, *atcheke*) and smoked fermented cassava balls (*pupuru*, *pukuru*). In addition, cassava leaves is rich in protein, vitamins and essential minerals that makes it suitable as vegetable (FIIRO, 2003).

One of the major problems associated with cassava is the rapid post-harvest deterioration, which renders it unpalatable as food (Akinoso and Kasali, 2012). Initially, deterioration is due to physiological processes, which occur within 2 – 3 days of harvest, and subsequently followed by microbial deterioration within 5 – 7 days (FIIRO, 2003). Deterioration necessitates the prompt consumption or processing of cassava soon after harvest. Different methods are used for processing cassava in several parts of the world and these methods have resulted in the production of a wide variety of food products (Akinoso and Kasali, 2012) including *gari. Gari* (cassava mash) is a staple food widely consumed in Nigeria and other West African countries. It is the most popular cassava product and a food of choice even in the face of alternative food options in urban area (Maziya-Dixon *et al*., 2004). The processing operations involve peeling, washing, grating, bagging, fermentation, dewatering, pulverising, sifting and garification (simultaneous cooking and dehydrating operation).

Gari processing is fast becoming a large enterprise providing an employment and income generation opportunity for many farmers and commercially oriented people in the rural economy. Traditional *gari* processing is labour intensive and productivity is often too low to justify the investment of labour, time and money. In addition, the yields from many

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indigenous processes are often of poor quality further reducing their market value and the profitability of the industry. The improvement of cassava processing techniques would therefore greatly increase labour efficiency, income and living standard of cassava farmers and urban poor as well as enhance shelf life of the product (Hahn, 2007). According to Akinoso and Kasali (2012), garification (simultaneous cooking and dehydrating operation) is major difference between medium and high levels of *gari* factory mechanization, and is an important factor in performance efficiency and energy demand. Development of garification machine requires scientific data on quantity of mash and garification duration. Both parameters are essential in the design of capacity and heat transfer systems. Therefore, effect of cassava mash quantity and garification duration on some physical, pasting and sensory properties of *gari* were determined using response surface methodology.

Materials and Methods

Materials

The raw material used in the experiments was sweet variety of cassava of cultivar TMS3575. It was obtained from the research farm of Ladoke Akintola University of Technology, Ogbomoso Oyo state Nigeria.

Experimental design

Central composite rotatable design of response surface methodology as reported by Montgomery (2005) was employed to investigate the effect of roasting duration and mash quantity on quality parameters. Five levels of each variable were used (Table 1). The responses were physical properties (bulk density, water absorption capacity, swelling Index, pH and moisture content) and pasting characteristics (peak, trough, breakdown, final and setback viscosity, peak time and pasting temperature). Preliminary data from trial experiment and literature (Akinoso and Kasali, 2012) served as guide for the design.

Gari processing

The experiment was conducted at the *gari* processing division of Agricultural Extension Department, LAUTECH, Ogbomoso. Freshly harvested cassava roots were peeled manually, washed and milled using cassava grating machine (NOVA Technologies, Nigeria). Obtained pulp was packed in sack, pressed using hydraulic press (NOVA Technologies, Nigeria) and allowed to ferment for three days. Each sample of measured quantity was roasted using cast-iron pot for desired duration (Table 1) at fixed sample temperature of 95^{o}C. The mash was stirred manually for uniform temperature distribution.

Table 1. Experimental design for the garification process

Variables	Levels				
Code	-1.414	-1	0	+1	+1.414
Mash Quantity (g)	317	400	600	800	882.8
Garification Duration (min)	32.1	35	40	45	47.1

Determination of bulk density

In determining the bulk density, a dish of known volume was washed, dried and weighed. Each *gari* sample was filled into the dish, tapped 10 times and then re-weighed. Bulk density was calculated as ratio of weight to volume of the sample. Six determinations were carried out for each sample and mean value was recorded as obtained data (Badmus *et al*., 2012).

Determination of water absorption capacity

One gram of the sample was put in clean dry centrifuge tube of known weight after which 20 ml of distilled water was added. The mixture was centrifuge at 3500 rpm for 45 min. Gain in weight of tube and sample after discarding supernatant was recorded as water absorbed (Badmus *et al*., 2012).

Determination of swelling capacity

Swelling capacity of the *gari* was determined using the method reported by Ikpeme-Emmanuel *et al*. (2010). One gram of the sample was weighed and transferred into a clean dry test tube and then weighed (M1). The sample was then dispersed in 50 ml distilled water using a magnetic stirrer (Magnestir Labcraft, London). The resulting slurry was heated at 70°C for 30 min in a thermostat water bath (Techmel and Tecmel, Texas, USA). The mixture was cooled to the room temperature (29°C) and then centrifuged at 2,200 rpm for 15 min. The residue obtained after centrifugation and the water it retained was re-weighed (M2). Swelling index calculated as the difference between M2 – M1.

Determination of pH

The pH of the samples was determined using the method of AOAC (2005). Ten grams of the sample was mixed with 100 ml distilled water. pH of the mixture was measured using pH meter (Prazisions PH meter ES10 model).

Determination of moisture content

Moisture content of the granules was determined using ASABE (2008) method. About 2 g of the granules was placed in Petri dish and heated in an oven at 105^{o}C for 2 hr after which it was removed, cooled in glass jar containing silica gel desiccant for about 15 min. Weight of the Petri dish containing the cooled sample was measured using digital weight balance (ED2201-CW, Sartorious, Berlin, Germany). The sample was further dried for 30 min, cooled and reweighed. This procedure was repeated until a constant weight was observed. The experiment was duplicated for accuracy. Moisture content was calculated using equation 1.

% moisture content = (weight of water)/(weight of dry product) x 100 (1)

Determination of pasting properties

A rapid viscosity analyzer (model 3D New Port Scientific PTY. Ltd, Australia) was used to determine the pasting properties of the samples. Three gram of *gari* of 14% moisture ontent was mixed with 25 ml distilled water. The slurry heated from 50 to 95°C at a rate of 1.5°C/min, held for 15 min, cooled to 50°C at 1.5°C/min and finally held at 50°C for 15 min. The process was a programmed heating and cooling cycle under constant shear. Pasting parameters determined were pasting temperature, peak viscosity, holding strength, breakdown viscosity, set back from holding strength and peak time.

Sensory evaluation

The method of Larmond (1977) was used for sensory evaluation, which was performed by 25 panellists, who consume *gari* on daily basis. Each panellist was served a 50 g sample in clear plastic plates. The serving was at room temperature and the room had both fluorescent illumination and natural light. Panellists were asked to rank the products on a hedonic scale of 1 to 9, with 9 being excellent, and 1 being very poor for each of the following characteristics: colour, mouth feel, taste, consistency, aroma and overall acceptability. The panellists assessed the samples based on the aforementioned parameters. Taste, aroma, testure and overall acceptability of the *gari* were evaluated under amber light while appearance was under bright illumination.

Statistical analysis

The procedures were repeated in replicates and mean values recorded as data obtained (Cochran and Cox 1992). Design expert version 8.0.1.0 (Stat ease Inc; Minneapolis USA, Version) was used for regression analysis while SPSS was used for ANOVA at $p < 0.05$.

Table 2. Effect of treatment on physical properties of *gari*

Quantity (g)	Time (min)	Moisture content (%)	pH	Bulk density (g/cm^3)	WAC (ml/g)	Swelling Index (ml/ml)
600	35	11.1	2.87	1.06	3.6	2.87
400	30	14.6	2.97	1.05	3.6	2.97
400	40	18.8	2.75	1.02	4.2	2.75
600	32.1	14.0	3.39	1.05	5.4	3.39
600	35	11.1	2.39	1.11	3.8	2.39
800	40	11.9	2.71	1.08	4.2	2.71
600	42	12.8	2.63	1.05	2	2.63
600	35	13.3	3.44	1.06	4.3	3.44
317	32	15.3	3.39	1.11	4.2	3.39
600	35	13.3	2.76	1.09	4.5	2.87
600	35	14.6	2.97	1.05	3.6	2.97
882.8	35	14.6	2.97	1.05	3.6	2.97
800	30	18.8	2.75	1.02	3.6	2.75

Table 3. Effect of treatment on pasting properties of *gari*

Quantity (g)	Time (min)	Peak visc (RVU)	Trough (RVU)	Break (RVU)	Final Visc (RVU)	Setback value (RVU)	Peak Time (min)	Pasting Temp (°C)
600	35	1471	1323.5	151.5	3229.5	1906	7	50.8
400	30	2224.5	2136.5	88	4263	2126.5	6.5	51.73
400	40	2467	2363.5	103.5	3706.5	1343	6.5	51
600	32.1	3216.5	2445	771.5	4079.5	1634.5	5.2	54.6
600	35	1767.5	1668.5	99	3670	2001.5	5.6	62.8
800	40	862	775	87	1690.5	915.5	7	62.7
600	42	1810.5	1592	218.5	3924	2332	7	52.5
600	35	2499.5	2333.5	166	4353	2019.5	7	56.2
317	32	3172.5	2245.5	927	4039	1793.5	5.1	51.7
600	35	2391.5	2317	74.5	4569.5	2252.5	6.6	53.8
600	35	224.5	2136.5	88	4263	2126.5	6.5	51.73
882.8	35	224.5	2136.5	88	4263	2126.5	6.5	51.73
800	30	2467	2363.5	103.5	3706.5	1343	6.5	51

Results and Discussion

Physical properties

Results of effect of quantity of *gari* mash and roasting time on some physical properties of *gari* are presented in Table 2. Moisture content, pH, bulk density water absorption capacity and swelling index of the samples were 11.1 – 18.8 %, 2.4 -3.4, 1.02 – 1.11 g/cm^3, 2.0 – 5.4 ml/g and 2.4 – 3.4 ml/ml respectively. Of all the determined physical properties, only bulk density was not significantly ($p > 0.05$) affected (Table 3). Conversely, only moisture content model was significant, an indication of fitness of the model in predicting the effects of quantity (Equation 2). Where X_1 and X_2 were mash quantity and roasting time respectively. Coefficient of determination R^2 of the model is 0.8357. Models generated for pH, bulk density, water absorption capacity and swelling index gave p-values greater than 0.05 and negative predicted R-squared. This implies that the overall mean is a better predictor than the models. Mean values of moisture content, pH, bulk density water absorption capacity and swelling index of the samples were 14.17 ± 1.3%, 2.92 ± 0.32, 1.06 ± 0.03 g/cm^3, 0.27 ± 0.7 ml/g and 2.93 ± 0.34 ml/ml, respectively.

$$\text{Moisture} = +34.31 + 0.05X_1 - 1.76X^2 + 4.19E{-}005X_1^2 + 0.05X_2^2 - 2.85E - 003X_1 X_2 \quad (2)$$

Table 4. Summary of ANOVA of the properties

Properties	Sum of Squares	df	Mean Square	F	Sig.
Moisture content	100.781	8	12.598	8.692	0.001
pH	1.879	8	0.235	10.48	0.000
Density	0.010	8	.001	2.830	0.051
Water Absorption Capacity	12.778	8	1.597	26.621	0.000
Swelling Capacity	1.893	8	.237	12.196	0.000
Peak Viscosity	7750378.452	8	968797.307	1.532	0.244
Trough Viscosity	5565921.367	8	695740.171	195.819	0.000
Break Viscosity	756684.438	8	94585.555	2.016	0.132
Final Viscosity	1.145E7	8	1430865.983	41.994	0.000
Set Back Viscosity	3091300.300	8	386412.538	8.517	0.001
Peak time Viscosity	7.200	8	.900	6.618	0.002
Pasting Temperature	384.735	8	48.092	128.948	0.000
Acceptability	11.851	8	1.481	2.564	0.069

Dehydration during roasting accounts for significant moisture loss. Dehydration is a function of temperature, humidity and air movement (Raji and Ojediran, 2011). Moisture content is major quality determinate in most crops and foods including *gari* (Akinoso and Kasali, 2012). Food is preserved at safe moisture content in which deteriorative microorganism activities is discouraged. *Gari* of water activity 0.52 to 0.85 corresponding to moisture of 7 to 17% is recommended for storage (FIIRO, 2003). Excessive mash quantity may retard moisture removal while very long roasting time might influence other quality parameters such as colour, taste and aroma. Ray and Sivakumar (2009) reported lactic fermentation in cassava. During the fermentation process; lactic acid bacteria hydrolyse carbohydrates (notably, starch) in the cassava into sugar, alcohols and organic acids. The production of organic acids which increases with fermentation time, leads to an increase in acidity of the sample and the resultant decrease in pH. Ray and Sivakumar (2009) further reported that pH of *gari* depends on the extent of fermentation. Thus, significant influence of roasting duration on *gari* pH cannot be easily explained.

As porosity can cause an increase in water retention capacity of starchy fibre (Abu *et al*., 2006), it could be deduced that increase in time of garification can confer some degree of textured porosity to the *gari* sample and it could be hypothesized that different garifying period exert different porosity of *gari* and damaged starchy granules. Water absorption capacity is important for certain product characteristics such as moistness of the product, starchy retro gradation and subsequent product staling (Siddiq *et al*., 2010). Range of swelling capacity of *gari* recorded fall within reported values by Oduro *et al.* (2000). It indicates the starch content and the extent of gelatinization, since it is the starch component of *gari* that enables it to swell. Good quality *gari* is expected to swell to three times its volume when placed in water (Oduro *et al.*, 2000).

Pasting properties

Peak and break down viscosities of the samples varied respectively between 224.5 and 3216.5 RVU and 74 to 927.5 RVU (Table 4). However, treatments did not have significant ($p > 0.05$) effects on the two properties (Table 4). Peak viscosity determines cooking characteristics of starch materials. It was reported to be closely associated with the degree of starch damage, and high starch damage results in high peak viscosity (Sanni *et al*., 2004). The rate of starch breakdown depends on the nature of the material, the temperature and the degree of mixing and shear applied to the mixture (Olorunda *et al.*, 1981). Adebowale *et al.* (2005) reported that the higher the breakdown in viscosity, the lower the ability of the sample to with stand heating and stress during cooking.

Other pasting properties studied (trough, final viscosity, set back viscosity, peak time and pasting temperature) were significantly ($p < 0.05$) influenced by mash quantity and roasting time (Table 3). Generated regression models with exception of trough viscosity lacks of fit were significant and their predicted R-squared were negative. This suggested use of recorded mean values for behaviour prediction. Recorded mean were peak viscosity 1907.58 ± 983.3 RVU, trough 1987.42 ± 501.89 RVU, break down 228.15 ± 280.43 RVU, final viscosity 3827.46 ± 735.51 RVU, set back value 1840.04 ± 419.75 RVU, peak time 6.38 ± 0.66 min and pasting temperature 54.02 ± 3.82°C. Coefficient of determination R^2 of model for trough viscosity is 0.62 (Equation 3) and predicted R-squared is positive. This model can be used to navigate the design space. Where X_1 and X_2 were mash quantity and roasting time respectively.

$$\text{Trough viscousity} = -4025.97 + 14.25X_1 + 191.42X_2 - 0.44X_1X_2 \quad (3)$$

The ability of starch to swell and give a viscous paste when an aqueous suspension of the starch granules are heated above the gelatinization temperature is one of the most important functional properties of starch (Afoakwa and Sefa-Dedeh, 2002). Prolonged heating of the starch granules leads to disintegration of the granules, which brings about significant change in the viscosity and other rheological properties of the paste. Trough viscosity is the minimum viscosity value in the constant temperature phase of the RVA profile and is an index of starch granule stability to heating (Sanni *et al*., 2008). Shimelis *et al*. (2006) reported that final viscosity is used to indicate the ability of starch to form various paste or gel after cooling and that less stability of starch paste is commonly accompanied with high value of breakdown. This implies that *gari* produced at the level of 600 g with garifying time 32.1 min will be less stable after cooling compared to other levels of garification. The variation in the final viscosity might be due to the simple effect of cooling on viscosity and re-association of starch molecules in the samples (Ikegwu *et al*., 2009). The setback viscosity is an index of the retro gradation of linear starch molecules during cooling. Sanni *et al.* (2004) reported that lower setback during the cooling of paste from starch or a starch based food indicates greater resistance to retro gradation.

The peak time is a measure of the cooking time (Adebowale *et al*., 2005). The value obtained is in this study is slightly higher that values reported by Shittu *et al.* (2007) for cassava flour. The pasting temperature is the temperature at which the first detectable viscosity is measured. It characterized by an initial change in the viscosity due to the swelling properties of the starch granules. Starch concentration influences pasting temperature. It is a reflection of the swelling of the starch granules (Oluwamukomi and Jolayemi, 2012). In this experiment, the pasting temperature that ranged between 0.8^{o}C to 62.8^{o}C agreed with previous work reported by Ikegwu *et al.* (2009). The pasting temperature is one of the pasting properties, which provide an indication of the minimum temperature required for sample cooking, energy cost involved and other component stability. It is clear from the results that *gari* produced from 600 g with 35 min garifying time will cook faster and less energy consumed, thereby saving cost and time compared to the other *gari* samples because of its lower pasting temperature. Prolong exposure of sample to heat gelatinize the mash, and thus reduce the pasting temperature. Several researchers have reported partial gelatinization during heat treatment of cassava mash (Ademiluyi *et al*., 2008).

Sensory evaluation

Overall acceptability of the product ranged between 3.1 (600 g garified for 42 min) and 5.6 (600 g garified for 32.1 min). The treatments did not have significant ($p > 0.05$) influence on sensory attributes (Table 4). It was observed that all samples roasted for more than 35 min were poorly rated. This may be associated with noticeable change in taste, odour and colour, a deviation from familiar *gari.* Maillard reaction and caramelization are non-enzymatic browning promoted by heating (McGee, 2004).

Conclusions

Moisture content, pH, water absorption capacity, swelling index, trough, final viscosity, set back viscosity, peak time and pasting temperature of *gari* depend on mash quantity and garification duration. Regression models were not appropriate in expressing relationship between the treatments and properties studied except for moisture content and trough viscosity. Use of mean values is recommended for data projection. All samples roasted for more than 35 min were poorly rated.

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