African Journal of Biotechnology Vol. 8 (9), pp. 1943-1949, 4 May, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Principal components analysis and age at harvest effect on quality of gari from four elite cassava varieties in Ghana

Franklin Brian Apea-Bah[1]*, Ibok Oduro[2], William Otto Ellis[2] and Osei Safo-Kantanka[3]

[1]Biotechnology and Nuclear Agriculture Research Institute (BNARI), Ghana Atomic Energy Commission (GAEC), P. O. Box LG 80, Legon, Ghana.
[2]Biochemistry and Biotechnology Department, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.
[3]Crop Science Department, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.

Accepted 23 February, 2009

Four elite cassava varieties in Ghana released under the local names *Afisiafi, Tekbankye, Abasafitaa* and *Gblemoduade* were planted in June and harvested the following year at 9, 10, 11, 12, 13, 14 and 15 months after planting, and processed into gari. The effect that age at harvest had on selected physicochemical properties indicative of gari quality was studied in the four varieties. The parameters studied include moisture content, ash, pH, titratable acidity (% lactic acid), crude fibre, swelling capacity and yield. Moisture was between 9.54 - 11.57% while ash was between 0.88 - 1.39%. Titratable acidity was between 0.85 - 1.62% while pH ranged between 3.58 and 4.21. Swelling capacity was slightly below 3 while yield ranged between 12 and 26%. The four principal components identified were dry matter, extent of fermentation, starch content and elemental composition of the gari. Age at harvest significantly affected ($p < 0.05$) moisture, pH and bulk density of the gari samples. Varietal effect was not significant.

Key words: Cassava, gari, age at harvest, variety, physicochemical property, principal components analysis.

INTRODUCTION

Cassava is one of the most important root crops in the world and provides a lot of energy to consumers due to the large amount of carbohydrates accumulated in its roots. It contributes significantly to the economy of most tropical countries through its processing into various products. Cassava is highly perishable and undergoes post-harvest physiological deterioration within three days of harvesting, partly due to the high water content as well as its rich store of carbohydrates. It is therefore important to process it into dry forms that can store for longer periods. One such form is gari, which is prepared by grating and pressing peeled cassava roots, allowing the mash to ferment and roasting in an open steel pan.

Four improved cassava varieties were released in Ghana by the Crops Research Institute of the Council for Scientific and Industrial Research under the local names *Afisiafi, Tekbankye, Abasafitaa* and *Gblemoduade*. These varieties gave higher root yields and were reportedly more disease and pest resistant than existing local varieties (RTIP Factsheet, 2002). They are also suitable for processing into various products such as gari and starch. However, little was known about the effect of age on the physicochemical properties of products prepared from them. The objective of this study therefore, was to determine whether age at harvest and varietal difference had any effect on the physicochemical properties of gari prepared from these four varieties.

MATERIALS AND METHODS

Source of raw materials

Cassava varieties were obtained from experimental plots at the Wenchi Agricultural Research Station in Ghana. The four varieties

*Corresponding author. E-mail: franklinapeabah@yahoo.com. Tel:+233-242048033.

Table 1. Moisture content of Gari from four cassava varieties at different ages at harvest.

Months after planting	*Afisiafi*	*Tekbankye*	*Abasafitaa*	*Gblemoduade*	Mean[1]
9	10.60	9.57	10.11	10.04	10.08[ab]
10	10.57	10.49	10.03	10.35	10.36[abc]
11	10.24	10.03	10.11	9.54	9.98[a]
12	10.62	10.22	10.22	11.33	10.60[bc]
13	10.65	11.15	10.08	10.83	10.68[c]
14	11.57	10.97	10.46	10.64	10.91[c]
15	10.35	10.08	10.25	9.62	10.08[a]

[1]Means with different lowercase letters as superscripts were significantly different ($p < 0.05$) from each other.

studied were *Afisiafi* (AFS), *Tekbankye* (TEK), *Abasafitaa* (ABS) and *Gblemoduade* (GBM). The varieties, planted in June, were harvested the following year at 9, 10, 11, 12, 13, 14 and 15 months after planting and processed into gari.

Processing of cassava roots into gari

Preparation of the gari was done as described by Vasconcelos et al. (1990). Fresh roots harvested from the farm were peeled, washed with water and grated with commercial mechanical graters. The mash obtained from grating the roots was loaded into woven polypropylene sacks and pressed using manual screw-press to dehydrate it. It was then allowed to ferment for about 48 h after which it was sifted to remove larger chunks. The fermented mash was roasted in an open pan greased with palm kernel oil, while stirring continuously with a broken piece of calabash. The roasted granules (gari) was then sieved through a cane mesh and packed into woven polypropylene sacks for storage and analysis.

Experimental design and statistical analysis

A randomized complete block design was used in designing the study. Age at harvest and varieties were considered as factors while experimental plots were blocked. Two way analysis of variance (Montgomery, 1999) was used to determine significant effects of age and variety on the response variables at 5% level ($p < 0.05$) while least significant difference (LSD) was used for mean comparison. Principal components analysis was conducted to obtain a small number of factors that account for most of the variability in the response variables. Statgraphics centurion XV (2006) software (www.statgraphics.com) was used for the data analysis.

Physicochemical properties determination

Moisture, ash pH and total titratable acidity were determined using the AOAC (2000) methods. Swelling capacity was determined by the method of Bainbridge et al. (1996). A 50 ml glass measuring cylinder was filled with gari to the 10 ml mark and distilled water at room temperature (27 - 29°C) added to give a total volume of 50 ml. The top of the cylinder was tightly covered and the contents mixed by inverting the cylinder. After 2 min, the cylinder was inverted again for the contents to mix. The cylinder was left to stand for 3 min, giving a total of 5 min. The final volume occupied by the swollen gari after 5 min was recorded and the swelling capacity determined by dividing the swollen gari volume by the initial gari volume. Bulk density was obtained by dividing the mass of gari by its volume in the measuring cylinder. Gari yield was determined as a percentage of the mass of gari obtained from 100 kg of fresh cassava roots.

RESULTS AND DISCUSSION

Moisture content of gari

Moisture content of gari ranged between 9.54 - 11.57% (Table 1). Statistical analysis showed significant difference ($p < 0.05$) existing between months after planting but not among varieties. Other factors such as processing method or the extent of roasting affect the moisture content of gari. Moisture content of 8.5 – 10.6% was reported by Ikujenlola and Opawale (2007) from studies on gari, 'pupuru', lafun, chips and starch. Mean values obtained in the current study compare well with the reported values. Codex standards for gari (Codex Alimentarius Commission, 1989) gave a maximum value of 12.0% for moisture. Moisture content of the gari samples was therefore within specification.

Ash content of gari

Ash content was not significantly affected by age at harvest and variety ($p > 0.05$). Values ranged between 0.88 and 1.39% (Table 2). Ash content, which is a measure of the mineral element content in the plant, depends on the mineral content of the soil. During processing, the grated cassava mash is dewatered (Ikujenlola and Opawale, 2007; Graham et al., 1988) by pressing with a screw press. This may result in loss of some minerals in the expressed water thereby reducing ash content. All gari samples had ash lower than the

Table 2. Ash content of Gari from four cassava varieties at different ages at harvest.

Months after planting	*Afisiafi*	*Tekbankye*	*Abasafitaa*	*Gblemoduade*
9	1.15	1.03	1.16	1.03
10	1.15	0.97	1.03	1.28
11	1.05	0.88	1.36	1.07
12	1.03	0.90	1.30	1.24
13	1.39	1.05	1.16	1.17
14	1.34	0.98	0.90	1.10
15	1.31	1.29	1.25	1.11

Table 3. pH of Gari from four cassava varieties at different ages at harvest

Months after planting	*Afisiafi*	*Tekbankye*	*Abasafitaa*	*Gblemoduade*	Mean[1]
9	3.91	4.00	3.69	3.76	3.84[a]
10	3.58	3.68	4.05	3.89	3.80[a]
11	3.60	3.92	3.85	4.08	3.86[a]
12	3.79	3.99	3.96	4.05	3.95[a]
13	3.75	4.02	4.03	3.76	3.89[a]
14	3.75	4.21	3.72	3.95	3.91[a]
15	4.12	4.10	4.59	4.24	4.26[b]

[1]Means with different lowercase letters as superscripts were significantly different ($p < 0.05$) from each other.

maximum of 2.75% specified by Codex Alimentarius (1989). This indicates less likelihood of heavy metal and dust contamination during processing.

pH of gari

pH of the gari samples ranged between 3.58 and 4.21 as shown in Table 3 below. Even though pH depends on the extent of fermentation (Ikujenlola and Opawale, 2007) analysis of variance showed it to be significantly affected ($p < 0.05$) by age at harvest but not variety. This is due to the different carbohydrate contents present in cassava roots at different maturity stages. Mean comparison using least significant difference (LSD) showed that pH at 15 months after planting was significantly higher than pH at all other ages at harvest. This may be attributed to most of the carbohydrates in the roots present as starch at 15 months after planting in comparison to lower ages at harvest where some may have existed as fermentable sugars and hence easily fermented, leading to lower pH. Wholey and Booth (2006) suggested that variations in root starch content could be influenced by climatic factors, particularly rainfall and soil moisture. It is worth noting that the crops were 9 months old in the month of March when there was the onset of rains. With the onset of rains, there is starch mobilization for new shoot formation hence most carbohydrates present in the roots will be in the form of fermentable sugars. By September when the roots were 15 months old, more starch would have been formed from photosynthesis and starch biosynthetic pathways hence less fermentable sugars may have been available for fermentation.

Total titratable acidity of gari

Total titratable acidity, expressed as percent lactic acid of the samples ranged between 0.77 and 1.62% (Table 4). Neither age at harvest nor varietal difference significantly affected ($p > 0.05$) total titratable acidity. This is probably due to the fact that titratable acidity depends more on the extent or duration of fermentation of the mash than on age or variety. Also the roasting process during preparation may have caused most of the lactic acid and other organic acids contributing to the total acidity to evaporate hence the effect of age at harvest on total acidity was not observed. The codex standard of total acidity for gari is

Table 4. Total titratable acidity of Gari from four cassava varieties at different ages at harvest.

Months after planting	*Afisiafi*	*Tekbankye*	*Abasafitaa*	*Gblemoduade*
9	1.61	1.61	1.61	1.24
10	1.50	1.56	0.87	1.24
11	1.62	0.85	1.14	1.07
12	1.18	1.17	1.30	1.08
13	1.54	1.03	1.37	1.46
14	1.52	1.01	1.51	1.08
15	1.30	1.27	0.77	1.13

Table 5. Crude fibre content of gari from four cassava varieties at different ages at harvest.

Months after planting	*Afisiafi*	*Tekbankye*	*Abasafitaa*	*Gblemoduade*	Mean[a]
9	2.03	1.81	2.56	2.72	2.28
10	2.49	2.25	2.14	2.32	2.30
11	3.33	2.07	2.18	2.08	2.42
12	2.77	1.61	3.63	1.91	2.48
13	2.00	1.61	1.87	1.87	1.84
14	2.19	1.62	2.02	1.90	1.93
15	2.15	1.89	2.33	1.80	2.04
Mean[b]	2.39	2.42	2.09	1.84	

Standard errors for means: 0.21[a] and 0.16[b].

between 0.6 and 1.0%, expressed as percent lactic acid (Codex Alimentarius Commission, 1989). Although samples of varieties *Afisiafi* and *Gblemoduade* for all the ages at harvest, had values slightly above 1.0%, they were quite close to the codex standard.

Crude fibre of gari

Crude fibre content of the gari samples was in the range of 1.61 and 3.63%. Codex standards for gari (Codex Alimentarius Commission, 1989) give a maximum of 2.0% for crude fibre. Even though some of the samples had values above the codex standard, overall means for the ages at harvest and varieties did not show much deviation from the codex standard (Table 5). Studies conducted by Oduro et al. (2000) on quality of gari from some selected gari processing centres in Ghana showed crude fibre values to range between 1.47 and 2.50%. These values compare well with the mean values reported in the current study. Neither age nor variety significantly affected ($p > 0.05$) crude fibre content of gari. *Tekbankye* had its values falling from 10 months after planting until 12 months after planting while that of *Gblemoduade* dropped sequentially from 9 months after planting until 13 months after planting. This may be due to starch build up with increasing age after the rains, with subsequent decrease in fibre content.

Swelling capacity of gari

Swelling capacity is important in determining gari quality. The higher the swelling capacity, the greater is its suitability for use in most West African dishes such as 'eba' or 'gari foto', which are typical delicacies of Nigerians and Ghanaians. Swelling capacity of gari also indicates its starch content and the extent of gelatinization of starch, since it is the starch component of gari that enable it to swell. Good quality gari is expected to swell to three times its volume when placed in water (Balagopalan et al., 1988; Oduro et al., 2000). Values obtained in the current study ranged between 2.53 - 2.93 (Table 6). Even though these values were lower than 3, they compare well with values reported by other workers (Blanshard et al., 1994; Ajibola et al., 1987; Chuzel et al.,

Table 6. Swelling capacity of gari from four cassava varieties at different ages at harvest.

Months after planting	*Afisiafi*	*Tekbankye*	*Abasafitaa*	*Gblemoduade*
9	2.80	2.67	2.80	2.93
10	2.80	2.73	2.63	2.73
11	2.80	2.87	2.80	2.73
12	2.87	2.77	2.57	2.73
13	2.93	2.60	2.53	2.63
14	2.77	2.80	2.87	2.80
15	2.90	2.70	2.90	2.83

Table 7. Bulk density of gari from four cassava varieties at different ages at harvest.

Months after planting	*Afisiafi*	*Tekbankye*	*Abasafitaa*	*Gblemoduade*	Mean[1]
9	0.55	0.52	0.50	0.49	0.52[a]
10	0.51	0.53	0.52	0.50	0.52[a]
11	0.51	0.56	0.53	0.53	0.53[ab]
12	0.54	0.57	0.53	0.54	0.55[b]
13	0.58	0.56	0.51	0.54	0.55[b]
14	0.53	0.57	0.56	0.52	0.55[b]
15	0.56	0.55	0.56	0.57	0.56[b]

[1]Means with different lowercase letters as superscripts were significantly different ($p<0.05$) from each other.

1988). Age at harvest and varietal difference had no significant effect ($p > 0.05$) on the swelling capacity of the gari samples.

Bulk density of gari

Bulk density of the gari samples ranged between 0.49 and 0.58 g/ml (Table 7). These values were higher than those reported by Achinewhu et al. (1998) for six different cassava cultivars whose relative bulk densities ranged between 0.15 and 0.30 g/cm^3. Bulk density was significantly affected ($p < 0.05$) by age at harvest. Generally, bulk density of the samples with age above 11 months after planting were significantly higher than those with ages below 11 months after planting. This may be attributed to possibly higher starch content in the older samples that contributed more to the mass and hence relative bulk density than the younger samples that might have had most of their starch mobilized for shoot development with the onset of rains during which period they were harvested. It is note worthy that variations in root starch content could be influenced by climatic factors such as rainfall (Wholey and Booth, 2006).

Yield of gari (kg gari/100 kg whole roots)

Yield of gari from whole roots is important in revealing the age at harvest that gives optimum gari yield for each cassava variety. Young cassava plants may have most of their carbohydrates in the form of sugars and these may be lost through leaching and fermentation (Achinewhu et al., 1998; Ikujenlola and Opawale, 2007) during gari preparation. Over-aged cassava roots, on the other hand, may be fibrous hence yielding gari of low quality and reduced net amount. Gari yield ranged between 12.2 and 26.2% (w/w) as shown in Table 8. Six cassava cultivars studied in the Rivers State in Nigeria, gave gari yields in the range 21 to 34% (Achinewhu et al., 1998), and these were slightly higher than yields obtained in the current study. Factors that affect gari yield include variety, soil composition and dry matter of the roots among others. Age at harvest and varietal difference did not significantly affect ($p > 0.05$) yield of gari from the four varieties studied. Since variations in root starch content and hence root yield and possibly gari yield could be influenced by climatic factors such as rainfall as well as soil moisture (Wholey and Booth, 2006), such factors could be considered in subsequent similar studies.

Table 8. Yield (kg gari/100 kg whole roots) of gari from four cassava varieties at different ages at harvest.

Months after planting	*Afisiafi*	*Tekbankye*	*Abasafitaa*	*Gblemoduade*
9	20.2	19.0	12.6	12.8
10	16.2	17.4	13.2	13.4
11	12.8	18.8	20.2	18.6
12	12.2	19.2	18.4	18.8
13	19.4	17.2	20.6	18.2
14	26.2	22.6	15.6	17.8
15	19.1	19.0	19.6	17.6

Table 9. Principal components analysis of gari.

Component number	Eigen value	Percent of variance	Cumulative percentage
1	2.561	32.015	32.015
2	1.611	20.140	52.155
3	1.184	14.797	66.952
4	1.039	12.986	79.938
5	0.722	9.020	88.958
6	0.404	5.047	94.005
7	0.319	3.991	97.996
8	0.160	2.004	100.000

Table 10. Factor loading matrix after varimax rotation.

Response variables	Factor 1	Factor 2	Factor 3	Factor 4
Yield	0.781	-0.132	0.355	-0.142
Swelling capacity	-0.034	0.008	-0.017	0.964
Bulk density	0.699	-0.341	-0.090	0.404
pH	0.246	-0.914	0.123	-0.056
TTA	-0.060	0.837	0.105	-0.074
Crude fibre	-0.747	0.256	0.349	0.140
Moisture	0.587	0.434	0.252	0.071
Ash	0.051	0.013	0.953	-0.030

Principal components analysis

Factor analysis using principal components resulted in the extraction of four (4) factors that had eigen values ≥ 1 and together accounted for 79.9% of the variability in the eight response variables studied (Table 9). After varimax rotation (Table 10), the first factor (factor 1) contributed to most of the variability in gari yield and bulk density while it showed a negative relationship with crude fibre. Since cassava with high dry matter yield more gari and higher bulk density, it is likely that factor 1 represents dry matter or extent of solids in the cassava. Factor 2 showed strong positive indication for titratable acidity and a strong negative indication for pH, both of which depend on extent of fermentation. Hence the extent of fermentation represents factor 2. The third factor gave a strong indication for ash content implying that in the absence of dust particles, the third important factor is the mineral composition of the samples. The fourth factor related well to swelling capacity which depends on the starch content

of the gari. Hence the four factors that contributed 79.9% of the variability in the response variables are dry matter, extent of fermentation, starch content and elemental composition of the gari.

Conclusion

The study has shown that the age at which some cassava roots are harvested can affect some physicochemical properties such as moisture, pH and bulk density of gari prepared from them. Varietal effect on the physicochemical properties of the gari studied was not observed. It is concluded from the study that such factors as dry matter, extent of fermentation, starch content and elemental composition of gari are important in contributing to their overall quality.

ACKNOWLEDGEMENTS

The authors are grateful to the Root and Tuber Improvement and Marketing Programme (RTIMP) of the Ministry of Food and Agriculture, Ghana, for funding the study and the Wenchi Agricultural Research Station for providing cassava varieties for the work.

REFERENCES

Achinewhu SC, Barber LI, Ijeoma IO (1998). Physicochemical properties and garification (gari yield) of selected cassava cultivars in Rivers State, Nigeria. Plant Foods for Human Nutrition (Formerly Qualitas Plantarum). Springer Netherlands Publishers. 52(2): 133-140.

Ajibola OO, Makanjuola GA, Almazan AM (1987). Effects of processing factors on the quality of gari produced by a steam gelatinization technique. J. Agric. Eng. Res. 38: 313-320.

AOAC (2000). Official Methods of Analysis 18th Ed. Association of Official Analytical Chemists Arlington, Virginia.

Bainbridge Z, Tomlins K, Wellings K, Westby A (1996). Methods for Assessing Quality Institute, Ghatham, UK, pp. 22-23.

Balagopalan C, Padmaja G, Nanda SK, Moorthy SN (1988). Cassava in Food, Feed and Industry. CRC Press. Boca Raton, Florida.

Blanshard AFJ, Dahniya NT, Poulter NH, Taylor AJ (1994). Quality of cassava foods in Sierra Leone. J. Sci. Food Agric. 64: 425-432.

Chuzel G, Gevaudan A, Griffon D (1988). Cassava processing for gari production. Abstract, Cemagref publications, March 3-5, Paris p. 169.

Codex Alimentarius Commission (1989). Codex Standard for Gari. Codex Stan 151-1989 (Rev, 1-1995). 7: 1-6

Graham GG, Lembcke J. Morales E (1988). Effects of Cassava Variety and Processing on Energy and Protein Digestibility and Utilization by Young Children. J. Nutr. 118: 877-882

Ikujenlola AV, Opawale BO (2007). Effects of processing on the yield and physico-chemical properties of cassava products. Adv. Mater. Res. 18-19: 165-170. www.scientific.net

Montgomery DC (1999). Design and Analysis of Experiments, 3rd Edition. John Wiley and Sons, NY. pp. 134-140.

Oduro I, Ellis WO, Dziedzoave NT, Nimako-Yeboah K (2000). Quality of gari from selected processing zones in Ghana. Food Control. Vol. 11. Issue 4. p. 297-303. Elsevier Sci. Ltd.

RTIP Fact sheet No. 1, Rev. June 2002.

Statgraphics Centurion XV (2006). Version 15.1.02. StatPoint Inc. www.statgraphics.com

Vasconcelos AT, Twiddy DR, Westby A, Reilly PJA (1990). Detoxification of cassava during gari preparation. Int. J. Food Sci. Technol. 25: 198-203.

Wholey DW, Booth RH (2006). Influence of variety and planting density on starch accumulation in cassava roots. J. Sci. Food Agric. 30(2): 165-170.