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Multivariate Analysis and Age at Harvest Effect on Sensory Preference of Gari from Four Cassava Varieties

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Abstract: In sub-Saharan African and other tropical countries where cassava is cultivated, breeding programs aim at obtaining varieties that are disease and pest resistant, high yielding, early bulking or have high starch content. Varieties grown for food are tested for suitability in preparing specific dishes. However, the effect that age at harvest or climatic factors such as rainfall pattern have on sensory quality of foods prepared from the cassava varieties is not widely studied. Time of harvesting cassava roots is usually based on maturity characteristics such as bulkiness, mealiness or cooking quality of roots. This study underscores the importance of age at harvest of cassava roots to consumer preference and acceptability of gari prepared from them. Four cassava varieties *Afisiafi, Tekbankye, Abasafitaa* and *Gblemoduade* planted in June, were harvested each month from 10 months until 15 months after planting and processed into gari. Samples were subjected to affective sensory evaluation by 24 assessors who evaluated consumer preference in relation to age at harvest using a nine-point hedonic scale, where 1 represented dislike extremely, 5 represented neither like not dislike and 9 represented like extremely. The sensory attributes evaluated were taste, colour, crispiness, aroma, appearance and overall acceptability. Taste was significantly affected ($p<0.01$) by age at harvest and panelists. All the other sensory attributes were significantly affected ($p<0.01$) by age at harvest, variety and panelists. Gari prepared from older harvests of 14 months and 15 months after planting were more preferred by panelists to gari from younger harvests. One principal component was extracted that contributed 90% of the variability in the response variables. It was observed from cluster analysis that aroma was the sensory attribute that contributed most to the overall acceptability of gari. This study has the potential to guide in decision making on the optimum harvesting time required for cassava varieties if their roots are to be processed into gari.

Key words: Gari · Age at harvest · Sensory evaluation · Principal component analysis · cluster analysis

INTRODUCTION

Cassava is one of the most important root crops in Africa [1] and provides a lot of energy to consumers due to the large amount of carbohydrates accumulated in its roots [1-3]. 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, due to the high water content, rich store of carbohydrates and presence of endogenous degradative enzymes in the tissues [2]. It is therefore important to process it into dry forms that can store for longer periods. One such form is gari which is the most commercialized cassava product in Ghana and continues to increase in production due to the increasing urban demand and export market potential [4]. In 1997, 4197.54MT of gari was exported from Ghana, yielding revenue of US$418,169.43 and by 2003, even though exports fell to 3067.68MT, the resulting revenue more than tripled recording US$1,502,993.52 [5]. Gari is prepared by grating and pressing peeled cassava roots, allowing the mash to ferment and roasting in an open steel pan [6].

In the 1990s, four cassava accessions introduced into Ghana from the International Institute for Tropical Agriculture (IITA), Nigeria, were improved and released as varieties by the Crops Research Institute of the Council for Scientific and Industrial Research and the Crop

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Science Department of the Kwame Nkrumah University of Science and Technology, under the local names *Afisiafi, Tekbankye, Abasafitaa* and *Gblemoduade*. Improvement of *Tekbankye* was achieved through mutation breeding using gamma radiation from a Cobalt-60 (^{60}Co) irradiator at the Ghana Atomic Energy Commission. These varieties reportedly gave higher root yields and were more disease and pest resistant than existing local varieties [7]. They were also suitable for processing into various products such as high quality flour, starch and gari. The effect of age at harvest on the physicochemical and functional quality of flour and gari from these varieties has been studied [8,9]. The knowledge gap which was the focus of this current study was to determine whether age at harvest had any effect on the sensory quality, in terms of consumer preference, of gari prepared from these four cassava varieties. Knowledge obtained from this study will guide in decision making on the optimum harvesting time for the cassava varieties if their roots are to be processed into gari.

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 studied were *Afisiafi*, *Tekbankye*, *Abasafitaa* and *Gblemoduade*. The varieties, planted in June, were harvested from 10 months after planting through 15 months after planting and processed into gari.

Processing of Gari and Sensory Evaluation: Preparation of the gari was done as described by Vasconcelos *et al.* [6]. All the gari samples were prepared by only one experienced commercial gari processor in order to eliminate or reduce variability due to different processing methods [4]. Samples for sensory evaluation were packaged in high density polyethylene bags and stored at r oom temperature (29 ± 1°C) until used. Gari samples from the four varieties were poured into four identical dishes that were labeled with three digit codes and presented in the dry granule form [10] to a panel of 24 assessors to conduct preference tests [11-13] over the period of harvest, using a nine-point hedonic scale (9=like extremely and 1=dislike extremely). The assessors comprised equal number of undergraduate male and female students at the Biochemistry Department of the Kwame Nkrumah University of Science and Technology in Kumasi, Ghana, who are very familiar with gari. The sensory attributes evaluated were taste, colour, crispiness, aroma, appearance and overall acceptability.

Data Analysis: A completely randomized design in factorial experiment was set up where age at harvest and variety were factors [14]. A multifactor analysis of variance [13-15] was used to determine the age, varietal and panelists effects on the sensory attributes. Where significant difference ($p<0.05$) existed, least significant difference was used for mean separation. Principal components analysis was conducted to study which few factors contributed most of the variability in the response variables [12]. Cluster analysis was then used to identify the attributes that contributed most to the overall acceptability of the gari samples [16, 17]. Statgraphics Centurion XV statistical software was used for all statistical analyses.

RESULTS

Taste of Gari: Mean preference scores for taste of the gari from varieties *Afisiafi* and *Tekbankye* samples ranged between 5.17 and 7.67 indicating a range between neither like nor dislike to like moderately, while that of *Abasafitaa* and *Gblemoduade* were between 4.67 and 7.50 indicating dislike slightly to like moderately (Table 1). *Tekbankye* and *Abasafitaa* had preference scores increasing from 13 months after planting until 15 months after planting while for *Afisiafi* and *Gblemoduade*, the increase was from 14

Table 1: Mean preference scores for taste of gari at different ages at harvest for four elite Ghanaian cassava varieties

	Age (months after planting)						
Variety	10	11	12	13	14	15	Mean
Afisiafi	5.96	5.42	6.21	6.67	6.67	7.50	6.40
Tekbankye	5.17	6.75	5.63	5.42	6.75	7.67	6.23
Abasafitaa	7.29	5.92	4.96	5.88	6.46	7.46	6.33
Gblemoduade	4.67	5.50	6.79	6.46	6.38	7.50	6.22
Mean†	5.77^{a}	5.90^{ab}	5.90^{ab}	6.10^{b}	6.56^{c}	7.53^{d}	

†Rows with different superscripts are significantly different from each other ($p<0.0001$). Standard error (S.E.) = 0.094

months after planting to 15 months after planting. Age significantly affected ($p<0.0001$) mean preference scores of the panelists for taste but varietal effect was not significant ($p>0.05$). Panelists' effect was also significant ($p<0.0001$) indicating that the test assessors varied in their perception and assessment of the taste of the samples. The effect of interaction between age and variety as well as age and panelist on taste was also significant ($p<0.001$).

Colour of Gari: Overall mean acceptance for colour ranged between 5 and 7 indicating a range between neither like nor dislike and like moderately (Table 2). Age, varietal and panelist effects on colour were all significant ($p<0.0001$). The effect of interaction between age and variety as well as age and panelist on colour was also Afisiafi and *Gblemoduade*. With regards to age at harvest, however, overall means indicated a drop in panelists' likeness for colour from 10 months after planting to 11 months after planting, after which mean preference scores increased uniformly and sequentially until 15 months after planting. Mean separation using least significant difference (LSD) showed overall mean preference scores for older harvests of 13 months after planting, 14 months after planting and 15 months after planting to be significantly different from each other. Similarly, mean preference scores for colour of gari from 10 months and 11 month harvests were significantly different from each other (Table 2). The overall mean scores for colour started from 5 (neither like nor dislike) at 10 months and 11 months after planting and increased to 6 (like slightly) from 12 months after planting until 14 months after planting, reaching an overall mean score of 7 (like moderately) at 15 months after planting (Table 2).

Crispiness of Gari: Effects of age, variety and panelists on crispiness was significant ($p<0.0001$). The effect of interaction between age and variety as well as age and panelist on crispiness was also significant ($p<0.0001$). Gari prepared from variety *Afisiafi* was most preferred for crispiness, followed by *Abasafitaa* while *Tekbankye* and *Gblemoduade* were the least preferred. However, overall mean scores for the four varieties indicated that they were all liked slightly (Table 3). With regards to age at harvest, mean preference scores of gari was 5 for 10, 11 and 13 months harvested roots indicating that they were neither liked not disliked while preference increased to 6 indicating like slightly for 12 months and 14 months harvests and finally reaching a peak of 7 (like moderately) for the 15 months harvest (Table 3). Mean acceptance score for crispness of *Tekbankye* increased uniformly from 11 months after planting until 15 months after planting while that of all the other varieties increased uniformly from 13 months after planting until 15 months after planting.

Aroma of Gari: Age, varietal and panelist effects on aroma were significant ($p<0.0001$). There were also significant interactive effects between age and variety as well as age and panelists on the aroma of gari ($p<0.0001$). Mean preference scores for aroma indicated that gari from all the four varieties were liked slightly although *Afisiafi* and *Tekbankye* were preferred to *Abasafitaa* and *Gblemoduade* as shown by mean separation using least significant difference (Table 4). In terms of age at harvest, mean preference score for the gari aroma increased uniformly from the 10 months harvest until 15 months harvest, with the exception of the 11 months harvest at which aroma preference fell to 5.45 indicating neither like nor dislike (Table 4). Mean separation by least significant difference (LSD) revealed that gari from 10, 12 and 13 months harvests were liked slightly and they were not significantly different from each other. Gari from the 14 and 15 months harvests were liked moderately and they were also not significantly different from each other but were significantly more preferred to gari from the earlier harvests.

Table 2: Mean preference scores for colour of gari at different ages at harvest for four elite Ghanaian cassava varieties

	Age (months after planting)						
Variety	10	11	12	13	14	15	Mean*
Afisiafi	5.08	5.88	5.54	5.96	7.13	7.04	6.10^{e}
Tekbankye	6.08	5.83	7.04	5.71	7.13	7.71	6.58^{f}
Abasafitaa	6.75	6.42	5.58	5.96	6.96	7.13	6.47^{f}
Gblemoduade	5.71	4.46	6.38	7.25	6.17	7.63	6.26^{e}
Mean†	5.91^{g}	5.65^{i}	6.14^{gh}	6.22^{h}	6.84^{j}	7.38^{k}	

*Columns with different superscripts are significantly different from each other ($p<0.0001$). S.E. = 0.070

†Rows with different superscripts are significantly different from each other ($p<0.0001$). S.E. = 0.086

Table 3: Mean preference scores for crispiness of gari at different ages at harvest for four elite Ghanaian cassava varieties

	Age (months after planting)						
Variety	10	11	12	13	14	15	Mean*
Afisiafi	6.08	5.96	7.63	6.00	6.79	7.25	6.62[t]
Tekbankye	4.92	4.75	5.58	6.17	7.25	7.29	5.99[m]
Abasafitaa	6.67	5.92	6.63	5.08	6.83	7.46	6.43[n]
Gblemoduade	4.58	5.29	6.71	5.75	6.75	7.33	6.07[m]
Mean†	5.56[oq]	5.48°	6.64[p]	5.75[q]	6.91[r]	7.33[s]	

*Columns with different superscripts are significantly different from each other (p<0.0001). S.E. = 0.065

†Rows with different superscripts are significantly different from each other (p<0.0001). S.E. = 0.080

Table 4: Mean preference scores for aroma of gari at different ages at harvest for four elite Ghanaian cassava varieties

	Age (months after planting)						
Variety	10	11	12	13	14	15	Mean*
Afisiafi	5.63	5.54	6.83	6.13	7.29	7.29	6.45[t]
Tekbankye	6.17	6.00	6.50	5.71	7.46	7.38	6.53[t]
Abasafitaa	6.58	4.96	5.21	6.13	7.25	7.25	6.23[u]
Gblemoduade	5.63	5.29	5.63	6.42	7.29	7.42	6.28[u]
Mean†	6.00[v]	5.45[w]	6.04[v]	6.09[v]	7.32[x]	7.33[x]	

*Means in column with different superscripts are significantly different from each other (p<0.001). S.E. = 0.058

†Mean in row with different superscripts are significantly different from each other (p<0.0001). S.E. = 0.071

Appearance of Gari: Age at harvest, variety and panelists significantly affected (p<0.0001) appearance. The effect of interaction between age and variety as well as age and panelist on appearance was also significant (p<0.0001). Gari from variety *Afisiafi* had an overall mean preference score of 6.03 indicating like slightly, while the other varieties had overall mean scores between 5.64 and 5.75 indicating neither like nor dislike. Gari from *Afisiafi* was the most preferred variety while the other varieties did not differ significantly from each other (Table 5). With regards to age, however, panelists' preference was for gari from the older harvests of 14 months after planting and 15 months after planting both of which were significantly higher than the younger harvests (Table 5).

Overall Acceptability of Gari: Although varietal effect on overall acceptability was significant (p<0.01), the difference among varieties was slight. *Abasafitaa* was preferred to *Tekbankye* and *Gblemoduade* both of which were comparable. *Afisiafi* was comparable to all the other three varieties in terms of overall acceptability of the gari (Table 6). Overall means for the varieties ranged between 5.94 (neither like nor dislike) and 6.19 (like slightly). Age at harvest and panelists significantly affected (p<0.0001) overall acceptability. The effect of interaction between age and variety as well as age and panelist on overall acceptability of gari was also significant (p<0.001). Gari from the younger harvests of 10 months until 13 months after planting had overall mean preference score within the range of 5.30 to 5.73 indicating neither like nor dislike. Preference increased to 6.93 (like slightly) at 14 months after planting, reaching 7.01 (like moderately) at 15 months after planting. Gari prepared from older harvest of 15 months after planting had the highest overall acceptability preference score while the least was at 11 months after planting as seen in the other sensory attributes above (Table 6).

Principal Components and Cluster Analyses: Principal components analysis resulted in the extraction of six principal components out of which only one had eigen value greater than 1.0 and contributed 90% of the variability in the response variables. None of the other five principal components individually, contributed up to 5% of the variability in the response variables (Fig. 1). Since only one significant principal component was extracted, varimax rotation had no effect on the factor loading matrix and estimated communality in this case (Table 7).

From cluster analysis, the agglomeration schedule obtained shows which variables were combined at each stage of the clustering process (Table 8). In the first stage, aroma which is shown as the fourth variable, combined with the sixth variable, overall acceptability at a squared euclidean distance of 90.95. Colour then combined with this first cluster followed by appearance, taste and finally crispness as shown in the dendrogram (Figure 2).

Table 5: Mean preference scores for appearance of gari at different ages at harvest for four elite Ghanaian cassava varieties

	Age (months after planting)						
Variety	10	11	12	13	14	15	Mean*
Afisiafi	4.83	4.25	7.50	5.50	7.33	6.79	6.03^{y}
Tekbankye	5.21	4.71	6.54	4.25	6.75	7.04	5.75^{z}
Abasafitaa	5.63	5.08	4.58	4.67	7.38	6.50	5.64^{z}
Gblemoduade	4.13	6.08	4.13	5.83	6.83	7.13	5.69^{z}
Mean†	4.95^{á}	5.03^{á}	5.69^{å}	5.06^{á}	7.07^{ã}	6.86^{ã}	

*Columns with different superscripts are significantly different from each other ($p<0.01$). S.E. = 0.080

†Rows with different superscripts are significantly different from each other ($p<0.0001$). S.E. = 0.098

Table 6: Mean preference scores for overall acceptability of gari at different ages at harvest for four elite Ghanaian cassava varieties

	Age (months after planting)						
Variety	10	11	12	13	14	15	Mean*
Afisiafi	4.75	5.04	6.92	5.71	7.04	7.04	6.08^{ae}
Tekbankye	5.92	5.21	5.46	4.92	7.13	7.04	5.94^{a}
Abasafitaa	6.71	6.13	4.75	5.71	7.04	6.83	6.19^{e}
Gblemoduade	5.08	4.83	5.79	6.33	6.50	7.13	5.94^{a}
Mean†	5.61^{i}	5.30^{á}	5.73^{i}	5.67^{i}	6.93^{è}	7.01^{è}	

*Columns with different superscripts are significantly different from each other ($p<0.05$). S.E. = 0.073

†Rows with different superscripts are significantly different from each other ($p<0.0001$). S.E. = 0.089

Table 7: Factor loading matrix showing estimated communality and specific variance

No.	Sensory Attribute	Factor loading matrix	Estimated Communality	Specific Variance	Factor Score Coefficients
1	Taste	0.94654	0.895938	0.104062	0.175213
2	Colour	0.943788	0.890735	0.109265	-28.4946
3	Crispness	0.937806	0.87948	0.12052	-26.7253
4	Aroma	0.962118	0.925671	0.0743291	-15.2303
5	Appearance	0.934873	0.873987	0.126013	15.3731
6	Overall Acceptability	0.967692	0.936428	0.0635716	-14.7101

Table 8: Cluster analysis of sensory attributes of gari from preference test by nearest neighbor method showing agglomeration schedule and squared euclidean distance metric

Stage	Combined Cluster 1	Combined Cluster 2	Distance	Previous Stage Cluster 1	Previous Stage Cluster 2	Next Stage
1	4	6	90.9521	0	0	2
2	2	4	109.016	0	1	3
3	2	5	109.398	2	0	4
4	1	2	119.657	0	3	5
5	1	3	129.005	4	0	0

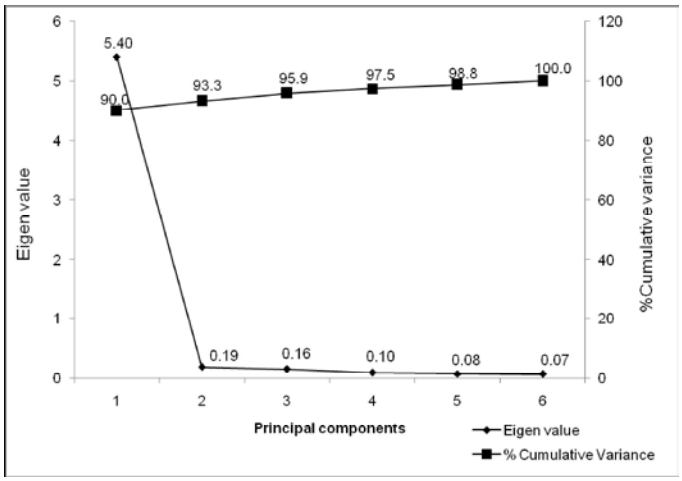

Fig. 1: Scree plot of the six extracted principal components showing their eigen values and cumulative percent variance

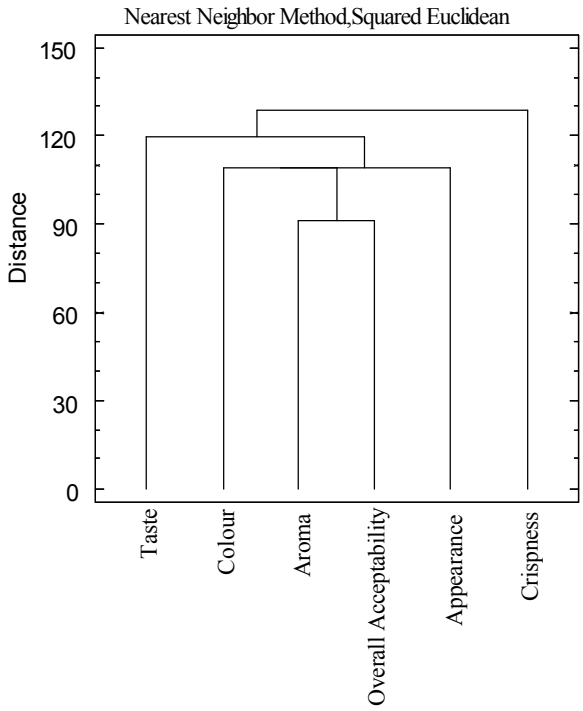

Fig. 2: Dendrogram of sensory attributes of gari from preference test showing nearest neighbours with Squared Euclidean Method

DISCUSSION

Taste: For all four varieties, preference for taste of gari was highest when prepared from cassava roots harvested at 15 months after planting (Table 1). This may be due to optimum starch build up at 15 months after planting resulting in availability of abundant substrate for fermentation and residual sugars after fermentation imparting positively on the taste. Below 12 months after planting, there were no consistent trends observed in preference for taste probably due to the rains which started in the latter part of March and continued through to June, resulting in starch mobilization for shoot formation. After 12 months after planting, however, there was a uniform increase in panelists preference for taste in all the cassava varieties studied due to starch build up. It is worth noting that preference for taste was assessed based on both sweetness from residual sugars after fermentation and sourness resulting from lactic acid fermentation of the grated cassava mash.

Colour: Colour of gari is considered an important attribute in assessing quality and affects price [18]. Even though some consumers prefer gari with a white colour, most consumers in Ghana and Nigeria readily identify with gari having a creamy to slightly yellow colour [4,18]. With regards to the cassava varieties, panelists preferred the colour of gari from *Tekbanye* and *Abasafitaa* to that of *Afisiafi* and *Gblemoduade* while with regards to age, panelists' preference for colour increased with increasing age up to the 15 months harvest. It can be deduced from this study therefore that cassava roots from the varieties studied when harvested at 15 months after planting will yield gari with the most acceptable colour.

Crispiness: Crispiness of gari is indicative of the freshness and dryness of the gari and is vital when assessing gari quality. It is also a measure of the extent of gelatinization of starch during the roasting process in gari preparation. Improperly packaged gari absorbs moisture from the atmosphere and may get flat or lose their crispiness. Such gari easily grows moldy and has low consumer acceptability. It is worth noting that the variety *Afisiafi* was most preferred for crispiness, followed by *Abasafitaa* while *Tekbankye* and *Gblemoduade* were the least preferred. Crispiness increased with age, especially for the harvests after 13 months to 15 months after planting as seen earlier for taste and colour. The highest starch content of older harvests resulted in better gelatinization during roasting and hence they were crispier to taste than younger harvests.

Aroma: Aroma of gari is contributed by the natural aroma of the root, which may vary from one variety to another [10]. The aroma of gari also depends on the aroma developed by the activities of *Corynebacterium manihot*, *Geotrichum candida*, *Lactobacillus and Streptococcus spp*. *Aspergillus flavus*, *Fusarium*, *Oligosporium*, *Saccharomyces cerevisiae* and *Rhodotorula minuta* during fermentation of the cassava mash [19-21]. The lactic acid and other organic acids produced by the fermentative action of these microorganisms will also affect taste of the gari. Since the microflora involved in spontaneous fermentation may depend on the type of substrate, which also varies with the age at harvest, aroma of the gari was significantly affected ($p<0.001$) by age. It was observed from the results that, just like with the other attributes mentioned earlier, panelists' preference for gari aroma was higher for older harvests than for younger ones. This may be due to the younger roots having most of their carbohydrates in the form of sugars which on exposure to roasting, result in burnt sugar aroma and this may be undesirable to the panel.

Appearance: Appearance of the samples was a measure of their particle size and amount of fibre present. Particle size is one of the major attributes that determine the quality and use of gari and in West Africa, the preference is generally for fine particles [10]. Also, the higher the amount of fibre in gari, the lower is its consumer appeal. Panelists' preference for gari was higher for the older harvests of 14 months and 15 months than the lower harvests. Starch production in the roots increase with age hence there will be more starch dextrinization in older harvests during roasting than in the younger harvests resulting in gari with attractive granules [22]. Also, when starch content is high, fibre content in the roots are usually low and therefore this improves the appearance of its gari products.

Overall Acceptability: Considering the results obtained, it is clear from this study that although gari can be prepared from all the four cassava varieties studied when harvested anytime between 10 months and 15 months after planting, consumer acceptance of the product in terms of sensory quality will be highest if prepared from roots harvested at 14 months or 15 months after planting.
Principal components and cluster analyses

The principal component that was extracted relates to age at harvest since all the measurable sensory attributes studied depend on it and a uniform trend was observed that was common to all the measurable attributes. Panelists' preference for the gari increased for harvests done above 13 months and was highest for the 15 months harvests. Therefore sensory quality of gari, in terms of acceptance and preference, depends on age at which the cassava roots were harvested.

With regards to the cluster analysis, it is worth noting that the distances of colour and appearance at the second and third stages are very close (Table 8). This indicates how close the perceptions of colour and appearance were to the panelists who assessed both attributes by visual observation. From the resulting dendrogram (Fig. 2), it was observed that the sensory attribute that most closely related to overall acceptability of gari was aroma. It suggests therefore that in this study, aroma was the sensory attribute that contributed most to overall acceptability of the gari. This is supported by the observation that aroma is a more sensitive index of gari quality when compared to other attributes such as particle size, crunchiness and taste [10]. It is when the aroma of a gari sample is satisfactory to a consumer that the person goes ahead to assess the colour and appearance. After being satisfied with the colour and appearance, the consumer or customer may want to evaluate the taste and in the process, may also evaluate the crispiness of the gari sample. From the foregoing, it is suggested from the study that in the evaluation of the sensory quality of gari, the olfactory senses play a leading role, followed by the visual senses and finally the senses of taste including texture in the mouth. This phenomenon is observed in nature especially among insects visiting an odoriferous flower to feed [23].

CONCLUSION

The study has shown that from the four cassava varieties, roots harvested at 14 months and 15 months after planting can be used to produce gari having high consumer acceptance and appeal. Among the sensory attributes indicative of gari quality, aroma contributes most to overall acceptability of the product. About 90% of the variability in sensory quality of gari is attributable to age at harvest of cassava roots used in its preparation.

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