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Food Chemistry 99 (2006) 663–669

Food Chemistry

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Pasting characteristics of fresh yams (*Dioscorea* spp.) as indicators of textural quality in a major food product – 'pounded yam'

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Received 10 January 2005; received in revised form 22 August 2005; accepted 22 August 2005

Abstract

Low efficiency of available screening procedures constrains breeding and selection of yams (*Dioscorea* spp.) towards high textural quality of food products made from their tubers. This study was undertaken to determine the potential usefulness of pasting characteristics of fresh yams as rapid indicators of food textural quality in 'pounded yam', a staple food for millions of yam consumers, especially in West and Central Africa. Significant associations ($P < 0.05$) were found, through canonical correlation analysis, between pasting characteristics of fresh yams from six varieties, each, of *Dioscorea rotundata* and *Dioscorea alata* and the textural quality of pounded yam samples prepared from them. Good textural quality of pounded yam was associated with high peak viscosity, breakdown, final viscosity, holding strength and setback viscosity but with low pasting temperature in the fresh yam.

Keywords: *Dioscorea*; Pasting properties; Textural quality; Pounded yam

1. Introduction

Yams (*Dioscorea* spp.) are important in household food security and income generation, especially in West and Central Africa where most of the world's production occurs. The dominant species cultivated in this sub-region are the indigenous *Dioscorea rotundata* Poir., and *Dioscorea alata* L. introduced from Asia (Orkwor, 1998). Pounded yam is a very popular food product from the crop in West and Central Africa. It is a glutinous dough made by peeling the yam, cutting to pieces, boiling, pounding and kneading. For consumption, the dough is usually cut with the fingers, moulded in the palm, dipped into stew and swallowed without mastication.

Quality of the tuber for the production of yam-based dishes is a major criterion for acceptance of new yam varieties by farmers, processors and consumers. Yams show variation in suitability to the making of specific food products across species and varieties and yam breeders rely on sensory evaluation for screening of new breeding lines for this attribute. Such assessment is necessary to ensure high acceptability of new varieties. However, carrying out such assessment is very cumbersome and extremely time-consuming. Only a few lines can be objectively evaluated within a day and the screening can only be done close to the end of the selection cycle when the numbers of genotypes have been reduced on the basis of other selection criteria. There is therefore a need to identify physicochemical factors in fresh yams that control the textural quality of yam foods. Such factors could then form the basis for development of screening tools that will enable plant breeders to select yam varieties, with good food quality attributes, more efficiently.

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doi:10.1016/j.foodchem.2005.08.041

Texture is one of the three main acceptability factors used by consumers to evaluate food, the other two being appearance and flavour (Bourne, 1990). Food processors therefore place a lot of weight on development of products that have the textural attributes desired by consumers since foods can be rejected or accepted on the basis of their textural quality. Ayernor (1976) confirmed that a defect in perceived texture leads to negative impact on consumers' hedonic responses to the product. According to Bourne (1982) textural quality is a group of physical characteristics that arise from the structural elements of the food, sensed by the feelings of touch, related to deformation, disintegration and flow under a force, and measured objectively by force, distance and time. Texture is an important index of quality of pounded yam and the textural qualities relevant to the product are springiness, cohesiveness (mouldability), hardness, smoothness and adhesiveness (stickiness).

Pasting characteristics of starches have been associated with cooking quality and texture of various food products (Kim, Wiesenborn, Orr, & Grant, 1995; Moorthy, 1994, 2002; Wiesenborn, Orr, Casper, & Tacke, 1994). Pasting is the result of a combination of processes that follows gelatinisation from granule rupture to subsequent polymer alignment, due to mechanical shear during the heating and cooling of starches. This study was undertaken to determine the potential usefulness of pasting characteristics of yams as indicators of food textural quality in pounded yam. This would be useful in the breeding and selection of yams for this attribute as well as in commercial processing.

2. Materials and methods

2.1. Sample selection and handling

Fresh yams from six varieties of each of *D. rotundata* and *D. alata*, the two most widely cultivated and consumed yam species, were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan. The yams were harvested from field plots set up in randomised complete block design with three replications. The varieties were selected to represent variation in cooking and eating characteristics, from very good to very poor. Four healthy-looking yams of each variety, from each of the three replications, were cleaned and peeled. Each yam was then split into four longitudinal sections. Four sub-samples, containing a quarter from each of the four yams, were assembled for each variety, from each replication. One from each of these four sub-samples was used for determination of dry matter, a second for pasting properties and a third for preparation and sensory evaluation of pounded yam. The use of portions from the same tuber was to ensure a valid assessment of association between the pasting characteristics of the fresh yams and textural quality of the product made from them. The determinations of dry matter and pasting properties were carried out in duplicate, giving six values per variety for each attribute (considering the three replications in the field).

2.2. Determination of pasting characteristics

The pasting profiles of the fresh yams were studied using a Rapid Visco Analyser (RVA) (Series 4, Newport Scientific PTY LTD. NSW, Australia) (Anonymous, 2003). Many authors (Blakeney, Welsh, & Martin, 1992; Deffenbaugh & Walker, 1989, 1996; Farhat, Oguntona, & Neale, 1999; Perez, Breene, & Bahnassey, 1998) have compared the pasting curves of various starches and flours using the RVA, a rapid method (12–20 min) requiring small amounts of sample, to the conventional Brabender Viscoamylograph, which uses about 10–100 g sample for analysis and is typically carried out over a 45–120 min period. It has been widely reported that the pasting curves obtained with the two types of instruments are very similar and viscosity results are reproducible.

One sub-sample of fresh yam sections (as described in Section 2.1) for each variety was washed and diced into small cubes. This analysis was conducted on fresh yams and not on yam flour (pounded yam is usually locally processed from boiled fresh yams) and, since RVA is normally used on dry weight basis, the weight of fresh yam used for RVA analysis was calculated by correcting it to dry weight basis. The weight of material taken per sample was calculated using this formula:

$$\text{Corrected sample weight for RVA}(S) = \frac{A \times 100}{100 - M},$$

where A is the sample weight (depending on the type of sample, this is taken from the general guide on weight of sample from RVA manual), and M the actual moisture content of the sample. Distilled water was added to the weighed yam sample in a blender (Waring blender 21/8110ES, Model 38BL40, Christison Particle Technologies, Gateshead, UK). The volume (W) of distilled water was determined as

$$W = 25(S - A),$$

where S is the corrected sample weight for RVA and A the sample weight (as in previous formula).

The material was blended for 5 min to get a fine slurry; 25 ml of this slurry were dispensed into a canister, and three drops of antifoam A were added to it, to prevent foaming. The canister was inserted into the RVA machine. The 12-min profile was used, with the following time-temperature regime: idle temperature 50 °C for 1 min, heated from 50 to 95 °C in 3 min 45 s, then held at 95 °C for 2 min 30 s. The sample was subsequently cooled to 50 °C over a 3 min 45 s period, followed by a period of 2 min where the temperature was controlled at 50 °C.

2.3. Preparation of pounded yam

A sub-sample of yam sections (as explained in Section 2.1) was washed and sliced to about 5 mm thickness. From this, 900 g of sliced yam were cooked with 500 ml of water for 20 min in the cooking regime of the National yam pounder (Model sd-900Y, National Electronic Co. Ltd., Tokyo, Japan). Pounding was done with the yam pounder for 10 min after boiling. The same weight of yams and volume of water were used throughout for preparing pounded yam for all samples. The weight and amount of water used were enough to give pounded yam with the same consistency as that of the traditionally prepared pounded yam. The mechanical yam pounder was used in order to ensure uniformity in the conditions of sample preparation that could not be guaranteed with the traditional practice of manual kneading in a mortar with a pestle. It was assumed that the shear degradation from the mechanical action within the RVA mimics the impact of the traditional kneading practice. Pounded yam samples were prepared from six of the yam varieties (three from *D. alata* and three from *D. rotundata*) selected at random within each species for each sensory evaluation session. The remaining six varieties were assessed the following day. Each pounded yam sample was wrapped in aluminium foil immediately after preparation, to prevent drying of the surface, and kept warm in a Styrofoam box prior to evaluation.

2.4. Textural quality evaluation

Textural qualities of the pounded yam samples were evaluated objectively by the Texture Profile Analysis (TPA) method, as described by Brandt, Skinner, and Coleman (1963), as well as Szczesniak, Brandt, and Friedman (1963) and modified by Otegbayo (2004). This is a descriptive sensory evaluation method that involves the use of highly trained panellists to evaluate the textural parameters. Twelve panellists, comprising staff and graduate students at IITA headquarters, Ibadan, were selected and trained in a quiet, conducive, comfortable and well-lit spacious room. The panellists were selected on the basis of their being conversant with eating of pounded yam, interest, availability and ability to articulate their findings. They were trained to enhance their sensitivity, discriminating and descriptive ability. There were six one-hour training sessions over two weeks, using locally available and commonly-used food items, described by Otegbayo (2004), before the actual sample evaluation started. Textural quality parameters evaluated were cohesiveness, smoothness, springiness, adhesiveness, and fibrousness. Panellists were presented with randomised, replicated and coded samples of pounded yam.

2.5. Statistical analyses

Analysis of variance and mean separations were conducted by the general linear models procedure (GLM), using the SAS package (Statistical Analysis Systems, version 8 of SAS Institute, Inc). Differences ($P \leqslant 0.05$) between variables were evaluated by least square means procedures. Canonical correlation analysis was also done by the CANCORR procedure of SAS to determine association and interrelationships between pasting characteristics of the fresh yams and textural quality of pounded yam made from them.

3. Results and discussion

Pastes from *D. rotundata* generally had higher values for peak viscosity, breakdown, holding strength, final viscosity, and setback viscosity but lower values for pasting temperature than those from *D. alata* (Table 1). Peak time values were about equal for varieties of the two species.

Table 1
Mean[a] pasting characteristics of fresh yams from *Dioscorea rotundata* and *D. alata* varieties

Variety	Peak visc[b] (RVU)	H strength (RVU)	B down (RVU)	Final visc (RVU)	Setback (RVU)	Peak time (Min)	Pasting temp (°C)
D rotundata							
TDr 93-79	369.13	226.71	142.42	326.43	99.73	4.63	80.19
TDr 99-12	388.85	203.62	184.93	448.99	245.07	4.71	78.40
TDr 99-9	393.20	156.21	237.99	504.39	348.18	4.60	78.58
TDr 96/02229	325.06	169.60	154.96	276.78	106.98	4.52	78.50
TDr 131	414.14	257.50	156.64	335.84	78.33	4.75	82.06
TDr 93-31	359.56	200.98	158.59	493.61	292.64	4.52	79.24
Mean	374.99	202.48	172.59	397.67	195.10	4.62	79.49
SEM	181.55	84.32	142.74	124.89	103.26	0.39	2.14
D. alata							
TDa 291	238.22	161.45	76.78	213.43	51.99	4.53	80.72
TDa 297	262.21	128.30	133.92	179.29	51.00	4.43	80.27
TDa 85/00250	206.88	157.28	49.60	199.47	42.20	4.55	83.64
TDa 95/00328	205.81	181.77	24.04	222.34	40.57	4.83	82.85
TDa 93-36	285.22	221.98	63.25	269.80	47.82	4.9	83.87
TDa 92-2	189.82	107.34	82.49	129.27	21.93	4.48	84.07
Mean	231.36	159.68	71.68	202.26	42.58	4.62	82.57
SEM	115.13	91.17	46.61	114.44	35.14	0.27	2.66

[a] Each mean is based on six values.

[b] Peak visc, peak viscosity; H strength, holding strength; B down, breakdown; Final visc, final viscosity.

The pasting curves (Fig. 1(a)–(c)) of the yams from both species had characteristic profiles, similar to those reported for *Dioscorea* starches by various authors (Alves et al., 2002; Amani, Buleon, Kamenan, & Colonna, 2004; Brunschweiler et al., 2005; Faboya & Asagbara, 1990; Farhat et al., 1999; Moorthy & Nair, 1989; Moorthy, 2002). From Table 1, the pasting temperatures of the fresh pastes from the two yam species were between 78 and 84 °C. Above the pasting temperature, the curves rose sharply but without the peaks typical of potato and cassava starch because of a high resistance to swelling (Farhat et al., 1999; Rasper, 1969). The generally lower pasting temperature of the *D. rotundata* pastes (78.50–82.06 °C) than the *D. alata* ones (80.27–84.07 °C) implies that, generally, the *D. rotundata* varieties had a lower gelatinisation temperature and hence, a shorter cooking time. Table 2 shows the mean scores for sensory textural qualities of pounded yam samples made from the different varieties, including TDr 99-9, TDr 99-12, and TDr 93-31 of *D. rotundata*, that are good for making pounded yam with consumer-preferred textural qualities. Pastes from these three varieties all had relatively low pasting temperatures (Table 1) compared to TDr 93-79 and TDr 131 from the same species that are less preferred for pounded yam.

The higher peak viscosities of pastes from the *D. rotundata* varieties compared to those from *D. alata* implies that the *D. rotundata* varieties were able to form thicker pastes on cooking. This may be attributed to higher swelling power of starches in the *D. rotundata* varieties since peak viscosity occurs at the equilibrium between granule swelling, which increases viscosity and granule rupture, and alignment due to mechanical shear, which causes its decrease. Ayernor (1985) explained that the high swelling capacity of *D. rotundata* starch might be as a result of weak internal bonding between the starch granules. The *D. rotundata* varieties that gave high peak viscosities were the ones that produced pounded yam with good textural quality, whereas the *D. alata* varieties, with lower peak viscosities, did not give pounded yam of acceptable textural quality. This suggests that high peak viscosity might have contributed to the good textural quality of the pounded yam samples. This finding is also in agreement with the report of Rasper and Coursey (1967), that the high viscosity attained by *D. rotundata* starches is very significant in the

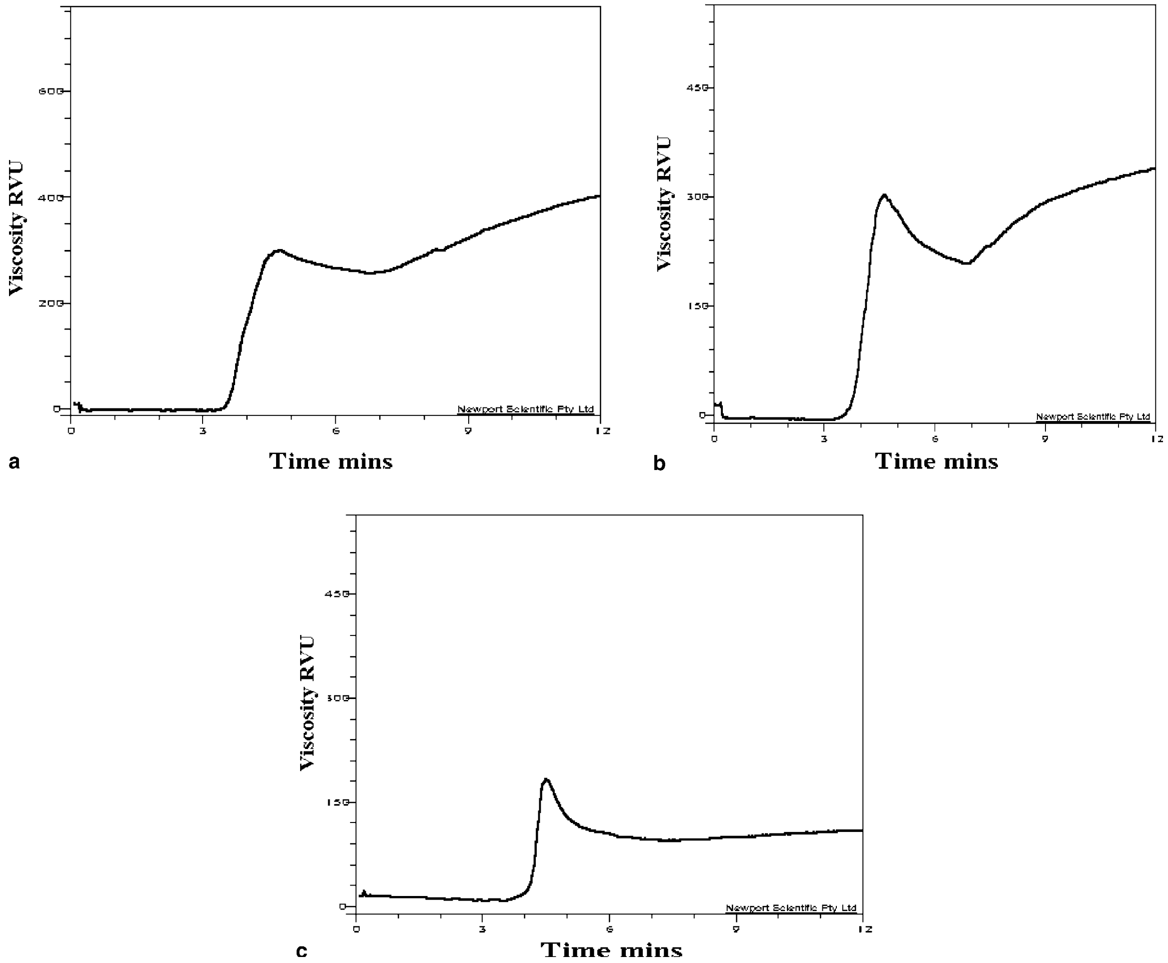

Fig. 1. Representative pasting curves of yams with different textural qualities: (a) *Dioscorea rotundata* with acceptable textural quality; (b) *Dioscorea rotundata* with unacceptable textural quality; (c) *Dioscorea alata* with unacceptable textural quality.

Table 2
Mean scores[a] for sensory texture qualities[b] of pounded yam samples made from varieties of *Dioscorea rotundata* and *D. alata*

Variety	Smoothness	Fibrousness	Adhesiveness	Cohesiveness	Springiness	Hardness
D. rotundata						
TDr 93-79	1.01	1.3	1.09	1.0	1.69	2.00
TDr 99-12[c]	*1.00*	*1.42*	*1.29*	*1.04*	*1.29*	*1.62*
TDr 99-9[c]	*1.03*	*1.59*	*1.24*	*1.0*	*1.29*	*1.52*
TDr 96/02229	1.04	1.54	1.76	1.05	1.48	1.67
TDr 131	1.07	1.43	1.76	1.0	1.86	2.09
TDr 93-31[c]	*1.1*	*1.38*	*1.95*	*1.10*	*1.00*	*1.71*
Mean	1.04	1.44	1.51	1.03	1.43	1.77
SEM	0.048	0.112	0.156	0.046	0.172	0.175
D. alata						
TDa 291	2.11	1.89	2.10	1.71	2.76	2.10
TDa 297	1.96	1.78	2.15	1.95	2.33	2.33
TDa 85/00250	2.48	1.75	2.62	2.86	3.00	2.95
TDa 95/00328	2.31	1.69	2.62	2.71	3.00	2.95
TDa 93-36	1.47	1.81	2.52	1.95	2.48	2.43
TDa 92-2	2.22	1.60	2.48	2.52	3.00	3.00
Mean	2.09	1.76	2.40	2.29	2.79	2.63
SEM	0.196	0.066	0.192	0.186	0.130	0.190

[a] Based on scores from 12 panellists.

[b] Scale of 1–3, where 1, most intense; 2, moderate; 3, least intense.

[c] Variety suited to preparation of pounded yam with good textural quality.

making of pounded yam. Essential textural attributes, such as springiness and ability to form dough, as in pounded yam, depend on both high viscosity and moderately high gel strength.

The higher breakdown values of *D. rotundata* pastes compared to *D. alata* ones (Table 1) imply that there was less granule rupture for starches from the former. They were also more resistant to breakdown in viscosity and hence their cooked pastes were more stable than those of *D. alata* starches (Farhat et al., 1999; Rasper, 1969). Oduro, Ellis, Aryeetey, Ahenkora, and Otoo (2000) reported that starches with low paste stability or breakdown show very weak cross-linking among the granules. This may explain some of the differences in pasting characteristics observed in this study, suggesting that the *D. alata* starches had weaker cross-linking between their granules.

Higher setback values were observed for *D. rotundata* than for *D. alata* (Table 1) and *D. rotundata* varieties TDr 99-9, TDr 99-12, and TDr 93-31, from which pounded yam samples with good textural quality were produced; all had higher setback values than the others (TDr 93-79, TDr 96/02229, TDr 131). The association of setback values with cohesiveness of pastes in potato by Kim et al. (1995) was also observed in this study. Pounded yam samples from *D. alata* varieties with very low setback values of their pastes were poor in cohesiveness. TDa 92-2 had a particularly low setback and the pounded yam from it was very difficult to mould. Oduro et al. (2000) also reported that domestic products, such as pounded yam, require high setback, high viscosity and high paste stability.

The final viscosity of the *D. rotundata* starches increased on cooling, indicating that they formed a firm gel after cooking and cooling, rather than a viscous paste, as was the case for *D. alata* starch wherein the final viscosity decreased. This result is in agreement with the findings of Rasper (1969) and Rasper and Coursey (1967) in their studies on pasting properties of West African yams. The final viscosities of the *D. rotundata* starch were generally higher than their peak viscosities but this was the reverse of *D. alata*. The final viscosities of starches from *D. rotundata* varieties TDr 99-9, TDr 99-12 and TDr 93-31, that produced firm and springy pounded yam were higher than their peak viscosities, as compared to TDr 93-79 and TDr 131 (Table 1), that produced less springy but firm pounded yam samples (Table 2). The viscosities rose only slowly in *D. alata* varieties, remained comparatively low upon cooling and they were lower than their corresponding peak viscosities, except for TDa 95/00328. Final viscosity can therefore be an important parameter in predicting and defining the final textural quality of pounded yam in terms of its springiness.

The canonical correlation analysis of the interrelationships among the pasting characteristics and the textural quality of the pounded yam supported the foregoing discussion. The estimated canonical correlation coefficients for *D. rotundata* (δ_{tdr}) and for *D. alata* (δ_{tda}), standard errors of estimate S and the percentage contribution of the canonical correlation ($P\%$) to the relationship are as follows:

$$\delta_{\mathrm{tdr=}}(0.96, 0.93, 0.84, 0.47, 0.26, 0.09)$$

$$S = (0.02, 0.03, 0.07, 0.17, 0.21, 0.22)$$

$$P\% = (53.78, 32.76, 11.70, 1.37, 0.35, 0.05)$$

$$\delta_{\mathrm{tda=}}(1.00, 0.93, 0.77, 0.72, 0.62, 0.38)$$

$$S = (0.00, 0.03, 0.09, 0.10, 0.14, 0.19)$$

$$P\% = (94.17, 3.89, 0.85, 0.63, 0.37, 0.1).$$

Table 3
Correlations between individual variables and the first two pairs of the canonical variates

Parameters (pasting characteristics)	1st canonical variable	2nd canonical variable	Parameters (textural quality)	1st canonical variable	2nd canonical variable
D. rotundata					
Peak viscosity	−0.07	0.40	Adhesiveness	0.31	−0.04
Holding strength	−0.04	0.45	Cohesiveness	−0.01	0.01
Breakdown	−0.06	0.13	Springiness	*−0.52*	0.17
Final viscosity	*0.67*[a]	−0.11	Hardness	0.01	0.43
Setback	*0.61*	−0.31	Smoothness	0.36	−0.37
Peak time	0.19	*0.58*	Fibrousness	0.36	*0.66*
Pasting temperature	−0.46	0.36			
D. alata					
Peak viscosity	0.27	*0.71*	Adhesiveness	*0.98*	0.16
Holding strength	−0.03	0.49	Cohesiveness	0.13	*−0.87*
Breakdown	−0.07	0.48	Springiness	*0.98*	0.15
Final viscosity	−0.05	*0.58*	Hardness	0.14	*−0.52*
Setback	−0.08	*0.60*	Smoothness	−0.03	−0.27
Peak time	0.06	0.01	Fibrousness	−0.07	*0.81*
Pasting temperature	*0.94*	0.16			

[a] Effects in italics show most important contributory variable(s) in the canonical variate.

In both yam species, the correlations between the 1st and 2nd canonical variates ($r = 0.96$ and 0.93 for *D. rotundata*, $r = 0.99$ and 0.99 for *D. alata*) were statistically significant and these coefficients contributed approximately 87% for *D. rotundata* and 98% for *D. alata* to the correlation. Table 3 shows the canonical correlation coefficients between the pasting characteristics of the yams and textural quality of the pounded yam samples made from them. The final viscosity, setback and peak time contributed significantly to the canonical correlation, while springiness and fibrousness contributed significantly to the textural qualities in *D. rotundata*. In *D. alata*, pasting temperature, peak viscosity, final viscosity, setback and holding strength, among the pasting characteristics, as well as stickiness, springiness, fibrousness, and hardness amongst the textural qualities, contributed significantly to the canonical correlation.

Among the *D. rotundata* varieties, there was strong association or interrelationships between the final viscosity, setback, and peak time of the yam starch and springiness and fibrousness of the pounded yam. Similarly, among the *D. alata* varieties, there was a significant association between peak viscosity, final viscosity, and setback of the starch and stickiness, springiness, cohesiveness and hardness of the pounded yam samples made from them.

4. Conclusion

D. rotundata varieties that produced pounded yam with good textural qualities, of moderate softness, springiness, cohesiveness and smoothness, had significantly high peak viscosities, holding strength, breakdown, final viscosities, setback and low pasting temperature. *D. alata* varieties, that gave pounded yam of unacceptable textural quality, had low peak viscosity, breakdown, final viscosity and setback, coupled with low holding strength and pasting temperature. These suggest that the high peak viscosity, final viscosity, breakdown and setback of the fresh paste of *D. rotundata* are related to the doughy, firm, springy and cohesive nature of the pounded yam produced from them. The canonical correlation analysis showed a strong interrelationship between final viscosity, setback and peak viscosity of paste from the yams and the springiness, stickiness, cohesiveness and hardness of the pounded yam samples in both yam species. Based on this strong association, the pasting characteristics of fresh yams of the two most important food yam species (*D. rotundata* and *D. alata*) can be used as indicators of textural quality in pounded yam made from them.

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