Textural Characteristics Of Seven Different Yams (*Dioscorea Species*) Grown And Consumed In Ghana

Delali Polycarp

Abstract: Texture is one of the most important indexes of quality in food products. It encompasses the structural and mechanical properties of a food and its sensory perception in the hand and in the mouth. This study was designed to evaluate the textural properties of the most cultivated and consumed yam (*Dioscorea*) varieties in Ghana in order to assess their potential alternative food and industrial processing applications. Matured yam varieties were obtained from the Roots and Tuber Conservatory Division of the Council for Scientific and Industrial Research-Plant Genetic Resources Research Institute, Bunso Ghana. Textural profile of the cooked yam cultivars was established using texture analyser (TA-XT2i Stable Microsystem Godalming, England) with built-in Texture Expert Exceed software. Cluster observation and principal component analyses were used to characterize the varieties based on similarities and differences in properties. The study showed that significant variations existed ($p<0.05$) in the textural properties of different yam varieties. Cooked samples of *D. esculenta* had the least hardness and chewiness (5.05 N and 0.22 respectively) and will be suitable for food applications that require mashing while *D. praehensalis* had highest values for hardness and chewiness (49.9 N and 4.36). There were no significant differences ($p<0.05$) in adhesiveness of the yam varieties examined. *D. rotundata, D. alata* and *D. bulbifera* varieties had tolerable textural properties appropriate for efficient industrial and food process applications. This information may be helpful in breeding and varietal improvement programmes for selecting varieties with similar textural properties for further study.

Key Words: Yam, *Dioscorea*, Texture, Hardness, Gumminess, Chewiness, Fracturability.

1 Introduction

YAMS (*Dioscorea*) are crops produced on over 5 million hectares in about several countries in tropical and subtropical regions of the world [1]. The tubers have been reported to be highly nutritious, containing good amounts of proteins, lipids, crude fibre, starch and minerals {[2],[3],[4] & [5]}. Ghana is the second leading producer of yams with over 6.6 million tonnes below Nigeria with 38 million tonnes [6]. Yam production in Côte d'Ivoire has reduced to about 5.7 million tonnes from 6.9 million in 2005, while production in Bénin has doubled from 1.8 million tonnes in 2005 to 2.7 million tonnes in 2012 [6]. The most important varieties grown and consumed as food in Ghana and most West African countries are white yam (Dioscorea rotundata), yellow yam (D. cayenensis), trifoliate or bitter yam (D. dumetorum), water yam (D. alata), potato yam (D. esculenta), aerial yam (D. bulbifera) and bush yam (D. praehensalis) [5]. Texture is an important index of quality in many food products. Food texture is a multidimensional attribute that encompasses the structural and mechanical properties of the food and its sensory perception in the hand and in the mouth. The textural qualities of yams that can be of great value in the development of new products include hardness, springiness, cohesiveness (mouldability) and adhesiveness (stickiness). Previous studies on yams in Ghana were centred on characterizing them based on their chemical composition and anti-nutritional factors [5], biochemical composition and cell wall constituents of the major yam varieties [7], and rheological properties of Ghanaian yams [8]. This study investigated the textural properties of yam varieties in the Ghanaian yam germplasm.

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2 MATERIALS AND METHOD

2.1 Yam Samples

Seven matured yam varieties grown and harvested under the same climatic and edaphic factors were obtained from the Roots and Tuber Conservatory Division of the Council for Scientific and Industrial Research-Plant Genetic Resources Research Institute, Bunso Ghana. The samples were *D. rotundata* (Pona), *D. alata* (Matches), *D. dumetorum* (Yellow flesh), *D. esculenta* (Large tuber), *D. cayenensis* (Pure yellow flesh), *D. bulbifera* (Deep brown skin) and *D. praehensalis* (Bush yam). Each sample was cleaned by brushing off soil particles and transported at tropical ambient temperature (28-31°C) to the laboratory for analysis.

2.2 Textural Profile Analysis

Peeled and washed mid section of yam tubers were cut into slices of 1 cm thick and 5 cm diameter using a hand slicer. The sliced samples were immersed in sufficient boiling water contained in aluminium sauce pan on the smallest heating coil of an electric stove (General Electric Stove, UK). Samples were removed from the water bath at an average time of 25 minutes and pressed between the fingers to estimate cooked slices. Cooked samples were allowed to cool at room temperature (27°C) before being analysed with the texture analyser (TA-XT2i Stable Microsystem Godalming, England) with built-in Texture Expert Exceed software. Cooked tubers were cut into uniform shapes and heights using a 20 mm diameter cork-borer with a height of 20 mm, along their major axis. Each piece was placed perpendicular to the knife edge in its natural resting position to get a uniform contact area between the platform and the cutting or compression device.

2.2.1 Compression Test

Compression studies were carried out using a 5 mm stainless steel cylindrical probe at a test speed of 2 mm s^{-1} for a distance of 5 mm. The following parameters were calculated from the force–deformation curve obtained in the compression experiments: hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness and modulus of deformation.

2.2.2 Cut Test

A stainless steel knife with an HDP/BSK for cutting/shearing was used at a test speed of 2 mm s^{-1} for a distance of 5 mm. In the cutting experiment, the peak force obtained from the graph was taken to be shearing force (N) and the area under the curve as shear energy (N m). Measurements were made ten (10) times for each tuber.

3.0 RESULTS AND DISCUSSION

3.1 Textural Profile Analysis (Compression-Test) for Yam Varieties

Typical force-time texture profile analysis curves for compression and cut tests on cooked yam varieties obtained from the TA-XT2 Texture Analyzer with built-in Texture Expert Exceed software are shown in Figures 1 and 2 respectively. Significant differences (p<0.05) existed between the textural profile of the cooked yam varieties. Multipliers can be especially confusing. Write “Magnetization (kA/m)” or “Magnetization (103 A/m).” Do not write “Magnetization (A/m) × 1,000” because the reader would not know whether the top axis label in Fig. 1 meant 16,000 A/m or 0.016 A/m. Figure labels should be legible, approximately 8 to 12 point type. When creating your graphics, especially in complex graphs and charts, please ensure that line weights are thick enough that when reproduced at print size, they will still be legible. We suggest at least 1 point.

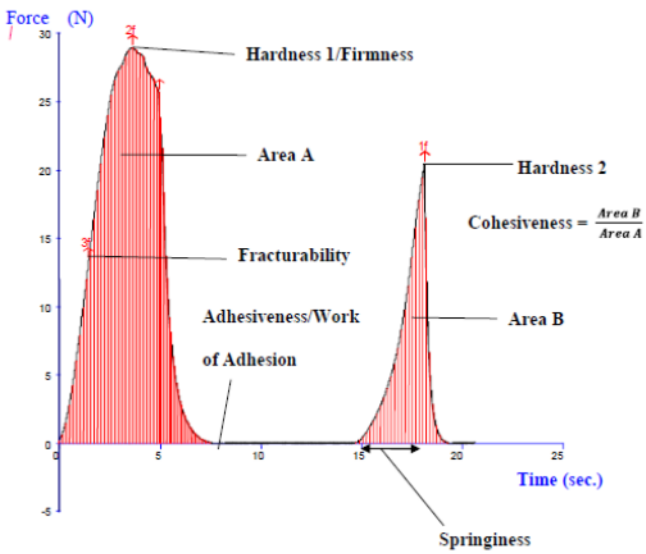

Figure 1: *A typical force-time Texture Profile Analysis (compression-test) on cooked yam varieties.*

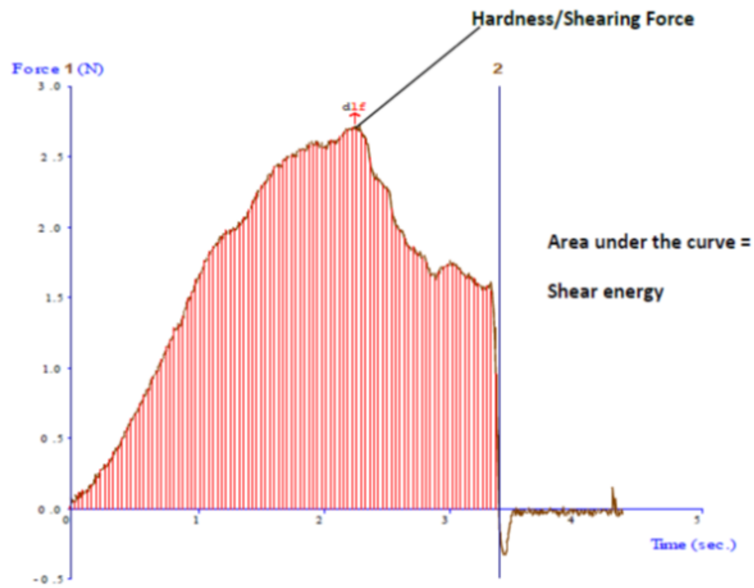

Figure 2*: A typical force-time Texture Profile Analysis for cut test on cooked yam varieties.*

The textural attributes of cooked yam tubers presented in Tables 1 and 2 confirmed that wide genotypic variabilities existed between the Ghanaian yam varieties. Hardness values varied from 5.05 N for *D. esculenta* to 49.91 N for *D. praehensalis* (Table 1). Similar values (8.36–53.88 N) were obtained for cooked cassava root tubers [9]. Fracturability occurred by a minimum force of 3.68 N for *D. esculenta* and a maximum of 23.72 for *D. praehensalis*. Adhesiveness was very low, ranging from -0.42 for *D. dumetorum* to -0.14 for *D. alata*.

Table 1: *Texture Profile (Compression-test) Analysis of cooked yam varieties*

Yam variety	Hardness (N)	Fraturability (N)	Adhesiveness (N)	Springiness (mm)	Cohesiveness	Gumminess (N)	Chewiness
D. rotundata	21.47 ± 1.04^{b}	$12.84\pm4.39^{c,d}$	-0.16 ± 0.06^{a}	$0.51\pm0.04^{b,c}$	$0.17\pm0.02^{a,b}$	$4.37\pm0.28^{b,c}$	$0.98\pm0.27^{a,b}$
D. alata	$22.60\pm1.93^{b,c}$	9.79 ± 1.72^{b}	-0.14 ± 0.16^{a}	$0.39\pm0.02^{a,b}$	$0.18\pm0.02^{a,b}$	4.04 ± 0.09^{b}	$1.57\pm0.09^{a,b}$
D. dumetorum	25.79 ± 1.39^{c}	14.47 ± 1.15^{d}	-0.42 ± 0.18^{a}	$0.43\pm0.08^{a,b}$	0.11 ± 0.02^{a}	$2.27\pm0.42^{a,b}$	$2.25\pm0.27^{b,c}$
D. esculenta	5.05 ± 2.03^{a}	3.68 ± 0.39^{a}	-0.18 ± 0.11^{a}	0.32 ± 0.12^{a}	$0.13\pm0.02^{a,b}$	0.65 ± 0.17^{a}	0.22 ± 0.15^{a}
D. cayenensis	35.89 ± 2.75^{d}	$6.65\pm1.40^{a,b}$	-0.24 ± 0.19^{a}	$0.52\pm0.09^{b,c}$	0.21 ± 0.06^{b}	$7.28\pm1.70^{c,d}$	$3.82\pm1.15^{c,d}$
D. bulbifera	21.30 ± 1.23^{b}	8.80 ± 2.12^{b}	-0.27 ± 0.23^{a}	$0.47\pm0.01^{b,c}$	$0.16\pm0.04^{a,b}$	$3.48\pm1.04^{a,b}$	$1.64\pm0.47^{a,b}$
D. praehensalis	49.91 ± 1.58^{e}	23.72 ± 6.84^{e}	-0.23 ± 0.04^{a}	0.55 ± 0.04^{c}	$0.16\pm0.05^{a,b}$	7.89 ± 2.72^{d}	4.36 ± 1.58^{d}

Values are Means ± standard deviation from ten (10) analyses. Those with the same superscripts in the same column are not significantly different (P < 0.05).

Table 2: *Texture Profile (Cut-test) Analysis of cooked yam varieties*

Yam variety	Maximum Shearing Force (N)	Surface Elasticity (mm)	Shear Energy (N.s)
D. rotundata	$1.48 \pm 0.10^{a,b}$	3.96 ± 1.19^{b}	3.43 ± 0.22^{a}
D. alata (Matches)	$2.54 \pm 0.10^{b,c}$	3.47 ± 0.58^{b}	4.58 ± 0.31^{a}
D. dumetorum	2.95 ± 0.10^{c}	4.13 ± 1.31^{b}	7.12 ± 0.38^{b}
D. esculenta	1.16 ± 0.10^{a}	1.18 ± 0.21^{a}	2.83 ± 0.14^{a}
D. cayenensis	5.51 ± 0.29^{d}	4.17 ± 0.54^{b}	13.37 ± 1.21^{c}
D. bulbifera	5.24 ± 0.32^{d}	$3.01 \pm 1.20^{a,b}$	12.17 ± 1.06^{c}
D. praehensalis	7.08 ± 1.20^{e}	3.67 ± 1.94^{b}	13.42 ± 1.55^{c}

Values are Means ± standard deviation from ten (10) analyses. Those with the same superscripts in the same column are not significantly different (P < 0.05).

There were no significant differences (p<0.05) in adhesiveness of the yam varieties examined; indicating that little force is required to remove a sample adhering to the teeth during chewing of yam. Springiness varied from 0.32 to 0.55 mm, indicating that the range of variation in recoverable deformity was narrow among varieties. Gumminess was high in *D. praehensalis* (7.89 N) and *D. cayenensis* (7.28 N) but significantly lower in the other varieties. The textural variation of plant tissues can be attributed to the presence of biopolymers (such as starch, cellulose and pectin) and the cellular and molecular organisation of the plant materials (i. e. composition of the cell wall, cell size and intercellular spacing, turgor pressure, overall structure and shape of the cell). The wide variability in texture of the tubers in the present study may be due to the variation in the physicochemical and biochemical properties of tubers of different varieties {[5]&[7]}.

Cluster and principal component analysis for textural characteristics of yam varieties

Cluster analysis was carried out to group the yam varieties based on their various textural parameters. The results are displayed in the form of a dendogram (Figure 3). Five clusters were obtained based on the similarities of the varieties to textural characteristics. *D. rotundata, D. alata* and *D. bulbifera* (first cluster) are dissimilar from the other varieties; each of which also has noticeable textural characteristics that permit it to stand alone. This information may be helpful in breeding and varietal improvement programmes for selecting varieties with similar textural properties for further study. Dry yam flour is generally prepared by powdering dry chips in a hammer mill. The energy required for crushing the chips depends on their hardness and toughness. Principal component (PC) analysis applied to the textural characteristics point out that, two components described a total of 80.7% of the dissimilarity; PC1 accounted for 62.2% of the variation while PC2 explained 18.5% (Figure 4). The loadings of the samples on the score plot (Figure 4) supports the clusters observed in the dendogram. While varieties in the first cluster (*D. rotundata, D. alata* and *D. bulbifera*) were located proximal to the reference line (0, 0), the others were found scattered distal to the reference point in each quadrant. PC1 is influenced by hardness, springiness, gumminess, chewiness, shearing force and shear energy while adhesiveness and cohesiveness were the major determinants of PC2. Loading of the texture variables (Figure 5) showed that most of the variables were closer to each other on the negative side of PC1, which is related to the loadings of *D. praehensalis* (Figure 4). Gumminess, springiness and cohesiveness were prominent in *D. cayenensis. D. esculenta* had the least of all the textural variables studied in this work.

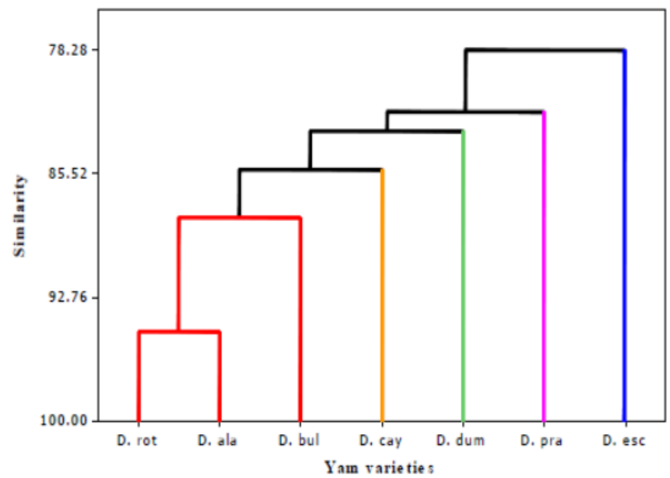

Figure 3: *Cluster observation dendogram for textural characteristics of yam varieties*
***KEY*: D. rot** = *D. rotundata*, **D. ala** = *D. alata*, **D. cay** = *D. cayenensis*, **D. bul** = *D. bulbifera*, **D. pra** = *D. praehensalis*, **D. esc** = *D. esculenta*, **D. dum** = *D. dumetorum*

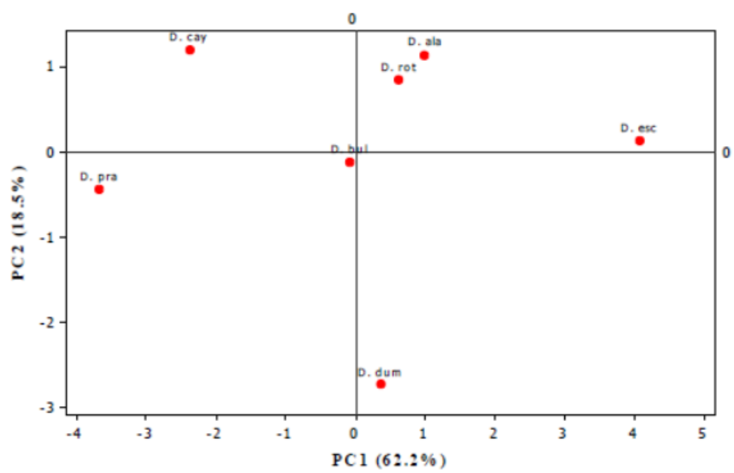

Figure 4: *Sample score plot for the Principal Component Analysis of textural characteristics of the yam varieties*
***KEY*: D. rot** = *D. rotundata*, **D. ala** = *D. alata*, **D. cay** = *D. cayenensis*, **D. bul** = *D. bulbifera*, **D. pra** = *D. praehensalis*, **D. esc** = *D. esculenta*, **D. dum** = *D. dumetorum*

D. alata, D. rotundata, D. bulbifera and *D. dumetorum* scored average values in the textural variables; *D. bulbifera* scored values that come very close to the mean with *D. dumetorum* scoring above the mean while *D. rotundata* and *D. alata* are very much related in scoring values slightly below the mean.

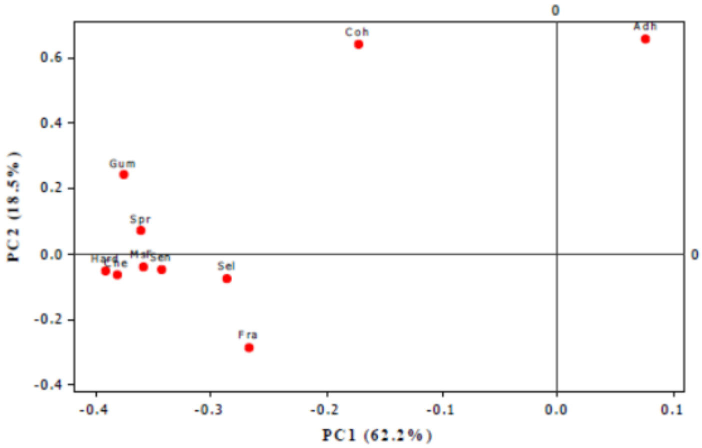

Figure 5: *Variable weights plot for the Principal Component Analysis of textural characteristics of the yam varieties*
***KEY: Hard** = Hardness, **Fra** = Fracturability, **Adh** = Adhesiveness, **Spr** = Springiness, **Coh** = Cohesiveness, **Gum** = Gumminess, **Che** = Chewiness, **MsF** = Maximum shearing force, **Sel** = Surface elasticity, **Sen** = Shear energy*

4 CONCLUSION

The present study showed that significant variations existed ($p<0.05$) in the textural properties of different yam varieties. Cooked samples of *D. esculenta* had the least hardness and will be suitable for food applications that require mashing. *D. rotundata, D. alata* and *D. bulbifera* varieties had tolerable textural properties appropriate for efficient industrial and food process applications.

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REFERENCES

[1] FAO. (2008). Food and Agricultural Organisation of the United Nations. FAO Statistics 2008. FAO, Rome. http://faostat.fao.org/ Date retrieved: October 15, 2010.

[2] Afoakwa, E. O. and Sefa-Dedeh, S. (2001).Chemical composition and quality changes occurring in Dioscorea dumetorum pax tubers after harvest. Food Chemistry 75: 85–91.

[3] Bhandari, M. R., Kasai, T., and Kawabata, J. (2003). Nutritional evaluation of wild edible yam (Dioscorea sp.) tubers of Nepal. Food Chemistry, 82 (4): 619–623.

[4] Shanthakumari, S., Mohan, V. R. and John de Britto. (2008). Nutritional Evaluation and Elimination of Toxic Principles in Wild Yam (Dioscorea spp.), Tropical and Subtropical Agrosystems, 8: 319-325.

[5] Polycarp, D., Afoakwa, E. O., Budu, A. S. and Otoo, E. (2012). Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam (Dioscorea) germplasm. International Food Research Journal 19 (3): 985-992.

[6] FAOSTAT. (2012). Food and Agricultural Organisation of the United Nations. FAO Statistics 2012. FAO, Rome. http://faostat.fao.org/ Date retrieved: July 4, 2016.

[7] Afoakwa E. O., Polycarp D., Budu A. S., Mensah-Brown H. and E. Otoo (2013). Variability in biochemical composition and cell wall constituents among seven varieties in ghanaian yam (Dioscorea sp.) germplasm. African Journal of Food, Agriculture, Nutrition and Development Vol 13 (4): 8106-8127.

[8] Polycarp, D., Afoakwa, E.O. and Anane-Asamoah, A.K. (2016). Rheological properties of seven different yams (Dioscorea species) within the yam germplasm. International Journal of Innovation and Scientific Research. 26 (2): 445-452.

[9] Sajeev, M. S., Sreekumar, J., Moorthy, S. N., Suja, G. and Shanavas, S. (2008). Texture analysis of raw and cooked tubers of short-duration lines of cassava by multivariate and fractional conversion techniques. Journal of the Science of Food and Agriculture 88:569–580.