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Original Research Article

Determination of Effects of Location of Loading on Mechanical Properties of Different Cultivars of Yam (*Dioscorea Spp*) Tubers

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Abstract

In this work, the effects of storage period on nine mechanical properties and moisture content of stored yam (Dioscorea spp) tubers were investigated. The mechanical properties of whole intact yam tubers of three yam (Dioscorea spp) cultivars in various treatments including: four levels of storage time at 75 days interval spanning 225 days, and four levels of loading positions namely at the head, middle, tail and vertical, were presented in this study. Mechanical compression tests were performed on three different cultivars namely: Ogoja, Gbangu and Agbo-yian. The results of the study showed that the force at bio-yield point, force at peak point, force at breaking point, and energy at bio-yield point during compression test in general is significantly higher in the middle of the tuber than other locations. The value for bio-yield force range from 1059 N for Agbo-yian to 4,500 N for Gbangu. So for safe stacking of Dioscorea alata in containers and stacks 1059 N is safe while for Dioscorea rotundata 4,500 N would be adequate. Energy follows the same pattern as forces. Results obtained from this study will be helpful in the design and fabrication of yam tubers harvesting and handling machines.

Keywords: Mechanical properties, yam tubers, location of loading, bio-yield point.

INTRODUCTION

Yam, *Dioscorea spp*, is a semi-perishable class of food due to its relatively high moisture [1] and carbohydrate contents. Yam provides around 110 calories per 100 grams of produce. It contains mainly carbohydrates with little amounts of proteins, lipids and vitamins [2]. An understanding of the map of mechanical characteristics of yam tubers over its body may improve planting, harvesting, handling and processing equipment design and manufacturing. The edible yam (*Dioscorea* spp.) tubers are important staple food for millions of people in tropical countries especially in West Africa [3]. The tubers of various species of *Dioscorea spp* constitute one of the stable carbohydrate foods for the people in many tropical countries [4]. Many different forms and cultivars of the edible yam species are available in different areas and it is likely that they differ not only in composition and nutritional values [5] but also in mechanical properties.

Armando *et al.*, [6] after studying two varieties of yam (*Dioscorea alata*): *Diamante* 22 and *Picode Botella* concluded that mechanical damage to yam tubers is the major limiting factor of the automation of its production and increased productivity. The cell wall matrix of yam plays an important role in controlling the mechanical behaviour of cell walls. Plant tissue can be viewed in engineering theory as composite material, which contains a solid phase, i.e. cell walls that variously partitions a fluid phase, i.e. living protoplasm in parenchyma [7].

The ever increasing importance of agricultural produce such as yam (*Dioscorea spp)* together with the complexity of modern technology for their production, processing and storage need a definite knowledge of mechanical properties at bio-yield point, peak and rupture point of these crops, It therefore becomes very necessary to understand the distribution of these properties over the body of tubers to maximize efficiency and the quality of the final products. With this increasing application, little information is available on the basic engineering properties of these materials, particularly in developing country like Nigeria. For example little is known of the mechanical properties of *Ogoja*, *Gbangu* and *Agbo-yian* yam cultivars grown in the Benue River Basin of Nigeria. Besides most of the previous studies were conducted using cut out sections of other yam cultivars for their studies, which may not be obtainable under real handling and storage conditions. Therefore, the objective of this study is to determine the mechanical properties of yam tubers at different locations of loading, namely head, middle, and tail and along the vertical axis using quasi-static loading.

MATERRIALS AND METHOFDS

Yams

Freshly harvested yam tubers (*Ogoja, Gbangu and Agbo-yain*) used for the research were obtained from Gboko area of Benue state, Nigeria. The yams were planted in heaps and about 700 heaps in one hectare of land. Fertilizer (NPK 15-15-15) application was manually done, at the rate of 50kg/ha in the third month after planting. Prior to experiment, the yam tubers were cleaned by soft brush to remove the adhering soil and other foreign materials.

Experimental Design

The experimental design for the statistical analyses followed two-treatment effects which are, loading position and cultivar in a Completely Randomized Design involving three observations per experimental unit. The indices would comprise of four mechanical properties at each of bio-yield point, peak or ultimate point and c) rupture or breaking point. The mechanical properties are force, deformation, strain and energy giving a total of 12 indices however, since strain is a normalized deformation given as percentage with respect to diameter of the tuber, it will be omitted and only nine properties would be used making 81 (9 indices x 3 yam cultivars x 3 replications = 81) observations.

Determination of the Mechanical Properties (Compression Test)

The compression test was performed on the whole intact yam tubers to determine the force and deformation at bio-yield point, force at peak point and at rupture for the three different yam cultivars. The test was conducted in the materials testing laboratory of the National Centre for Agricultural Mechanization (NCAM) Ilorin, Kwara State, using the 50kN capacity universal testing machine (Testometric, series 500-532) in February 2016.

Fig-1: Yam tuber under test

Each yam tuber was placed in the machine under the flat compression tool (Figure-1), ensuring that the centre of the tool was in alignment with the peak of the curvature of the yam tuber. The test speed was set at 50 mm per minute [8] and the yam tuber is loaded to the point of rupture. Force-deformation curve was produced automatically by the universal testing machine. Each test was carried out using three (3) yam tubers. As quasi compression of the yam tuber progressed, a force-deflection curve was plotted automatically by the Universal Testing Machine (Figure-2), in relation of the sample to the compression, up to the rupture point.

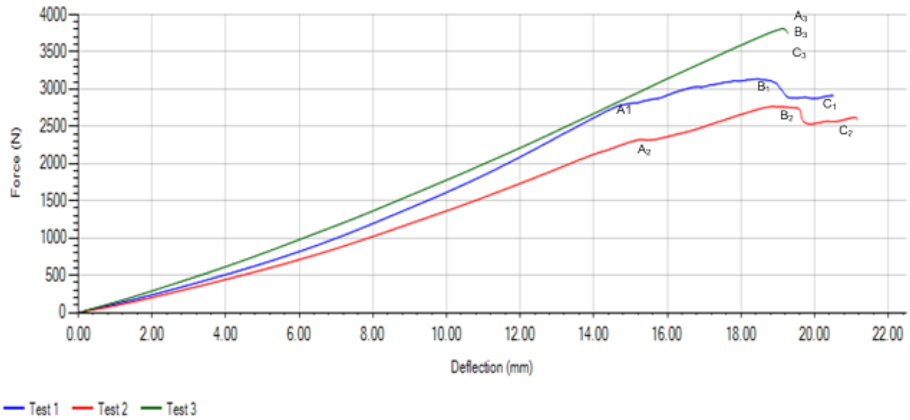

Fig-2: A typical Force - deformation curve of *Agboyian* yam tuber under compression loading

A = Elastic limit, which is equivalent to the force at bio-yield point
B= Ultimate compressive strength, which is equivalent to the force at peak
C= Breaking point strength, which is equivalent to force at rupture
Subscripts 1, 2, and 3, = the replications

RESULTS AND DISCUSSIONS

Figure-2 shows a typical compression load-deformation curve generated for a tuber sample under compression test. The three points of interest on the curve are labeled A, B and C which is bio-yield point, peak and rupture (breaking) point respectively. For each point the machine generates force, deformation, energy and strain making 12 mechanical properties per a sample under test. Consequently, the machine tabulates the mechanical properties which are 1) Bio-yield force, N, 2) Force at peak point, N, 3) Force at breaking (or rupture) point, N, 4) Deformation at bio-yield point, mm, 5) Deformation at peak point, mm, 6) Deformation at rupture point, mm, 7) Strain at bio-yield point, %, 8) Strain at peak point, %, 9) Strain at rupture, %, 10) Energy at bio-yield point, Nm, 11) Energy at peak Nm, and 12) Energy at rupture, Nm. Data collected from compression tests were subjected to ANOVA using the SPSS 110 software package and shown in Table-1. Treatment means were compared using Duncan's New Multiple Range Test ($P< 0.05$) and the results displayed in Table-2.

Table-1: Analysis of variance of nine mechanical properties in three yam cultivars

Yam cultivar	**source**	**Df**	**Force at Bio-yield pt.**	**Force at peak pt.**	**Force at breakpt**	**Energy at Bio-yield Pt.**	**Strain at peak point**
Gbangu	(S)	3	6.63E-10*	1.20E-10*	3.16E-08*	0.0049883*	5.18E-08*
Ogoja	(S)	3	3.15E-07*	2.48E-11*	4.73E-10*	0.028755092*	1.48E-13*
Agboyian	(S)	3	9.1359E-05*	9.16E-06*	8.28762E-05*	0.003964944*	0.02288718*

Yam cultivar	Yam section	Df	Energy at braking pt	Strain at bio-yield pt	Strain at break pt	Energy at peak pt
Gbangu	(S)	3	0.0092019*	1.81E-08*	2.15E-07*	0.00457462*
Ogoja	(S)	3	0.003725968*	7.46E-10*	3.7E-11*	0.007926079*
Agboyian	(S)	3	5.85E-10*	0.001155212*	0.038780631*	1.89E-06*

* =Significant on the level of 5%, ns= non significant; S = Yam Section

Force and Energy Studies

Figures 3, 4, 5 and 6 show the influence of yam loading section on the forces of intact *Agbo-yian*, *Gbangu* and *Ogoia* yam tubers. In the figures the force at bio-yield point, force at peak point and the force at breaking point, are invariably highest at the middle part of the yam tuber during compression, contrary to the cut out yam section results of Judith [9] which identified the head as being capable of withstanding the highest force. This is analogous to a pipe on the ground being stronger than when it stands alone. The ground provides some buffering effects as do the head and tail sections. So this difference may be due to error in using cut out parts on the part of Judith [9] or instrumentation of either of the investigators and needs further enquiry. For the purpose of piling yams in transportation and storage, the bio-yield force of tubers should be the guiding criterion in design or containers.

Force at peak is higher than that of rupture for *Agbo-yian* while it tallies with peak force for both *Gbangu* and *Ogoja*, which both belong to *Dioscorea rotundata*. In all peak force has a wide range from 1059 N for *Agboyian* to 4,500 N for *Gbangu* and for practical purposes it would be preferred to view them in terms of *D. alata* and *D. rotundata*. Therefore, for processing a force of 1059 N should be used for *D. alata* and 4,500 N for *D. rotundata*. Vertical force is lowest for *D. rotundata* cultivars and intermediate for *Agbo-yian* which again is *D. alata* cultivar. Vertical force is in many instances lower than other values. Since most stacking of yams as at present is done horizontally, this would be noted for future use.

Table-2: The mean effect of sections on selected mechanical properties of tubers of three yam cultivars

Yam Cultivar	Section	Bio-yield point		Force at peak point		Force at breaking Pt		Bio-yield energy		Strain at peak Pt.		Energy at breaking pt.		Strain at Bio-yield pt.	
		$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Agbo-yian	Head	985	348.716	1190.33	239.233	1152	217.414	4.975	2.188	12.335	3.283	8.379	1.868	10.515	2.152
	Middle	2028	459.157	2380	329.847	2224	133.72	8.714	1.830	14.840	1.817	23.710	10.357	9.273	1.876
	Tail	1046	84.871	1059	68.608	1059	68.608	6.102	0.695	13.895	0.771	6.332	0.356	13.643	0.780
	Vertical	1776.667	288.791	1897.667	459.671	1852.33	409.343	19.435	4.694	10.013	2.000	23.588	11.385	9.247	0.737
Gbangu	Head	1967.667	815.728	4268.667	676.831	4261.33	664.548	10.695	6.731	27.704	1.962	35.944	9.276	23.257	9.19
	Middle	2479.	1449.687	4492.667	993.3	4448.00	1020.93	15.627	15.6	22.817	0.59	37.828	6.879	14.784	7.446
	Tail	2103.667	1700.663	2342.00	1303.061	2266.667	1301.271	16.972	14.63	19.357	4.80	18.777	11.830	15.912	10.72
	Vertical	1028.00	334.471	1117.33	183.438	998.33	184.082	21.361	15.02	11.396	3.156	29.434	8.048	10.001	4.3793
Ogoja	Head	2569.667	972.208	2688.00	874.664	2562.000	1018.985	18.745	11.131	31.39	3.251	20.773	9.337	29.964	4.622
	Middle	2831.000	912.796	4094.667	599.367	4094.667	599.367	16.994	8.469	23.148	1.703	33.007	7.421	17.18	3.674
	Tail	2619.333	522.050	2624.333	530.68	2611.000	540.933	15.406	6.511	16.507	3.834	15.674	6.924	16.411	3.674
	Vertical	1505.333	1505.333	1451	512.811	1451.000	512.811	30.645	11.484	14.08	2.827	33.307	9.922	13.346	2.728

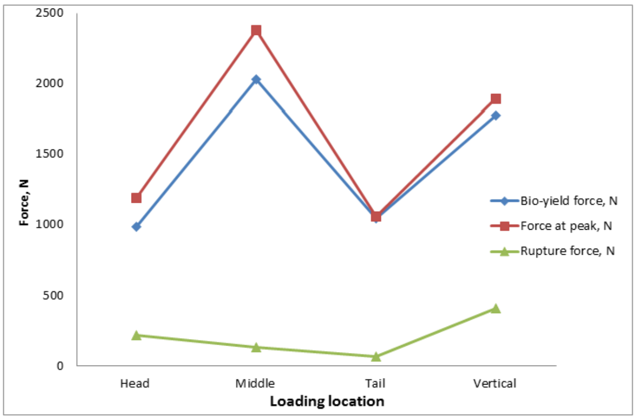

Fig-3: Effect of loading location on forces in *Agbo-yian* yam tuber

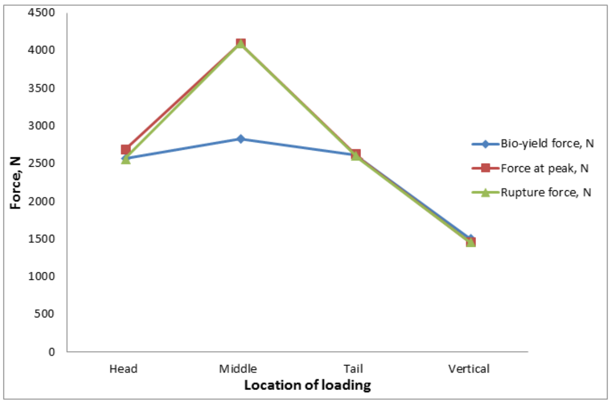

Fig-5: Effect of loading location on forces in *Ogoja* yam tuber

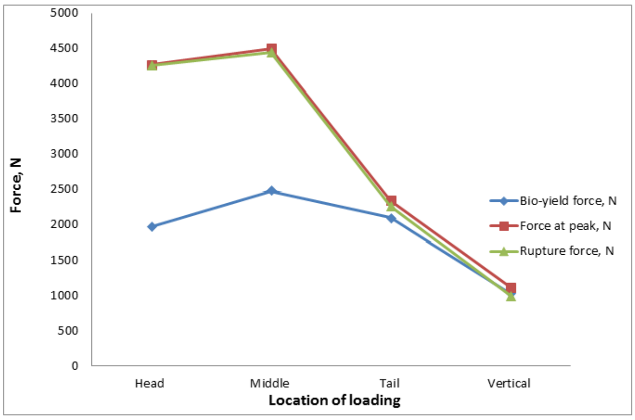

Fig-4: Effect of loading location on forces in *Gbangu* yam tuber

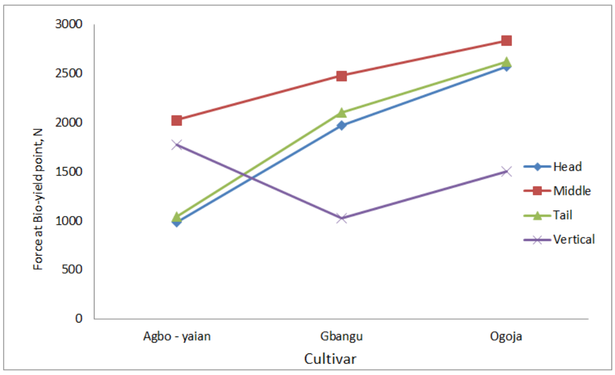

Fig-6: Effect of loading location on forces in three yam cultivars

CONCLUSIONS

This study focused on the mechanical properties of three different economically promising cultivars of intact yam tubers as affected by location of loading. The results of the study showed that the force at bio-yield point, force at peak point, force at breaking point, and energy at bio-yield point during compression test in general is significantly higher in the middle of the tuber than other locations. The value for bio-yield force range from 1059 N for *Agbo-yian* to 4,500 N for *Gbangu*. So for safe stacking *of Dioscoreaalata* in containers and stacks 1059 N is safe while for *Dioscorearotundata* 4,500 N would be adequate. Energy follow the same pattern as forces.

REFERENCES

1. Jimoh, K. O., & Olatidoye, O. P. (2009). Evaluation of physicochemical and rheological characteristics of soybean fortified yam flour. *Journal of Applied Biosciences*, *13*, 703-706.
2. Babalola, M., & Oyenuga, V. A (2001). Value of Yam (*Dioscoreaspp*.) in Nigeria Food and Feeding Stuff, Ibadan.University Press, Ibadan, Nigeria. 110-114.
3. Roudaut, G., Maglione, M., van Dusschoten, D., & Le Meste, M. (1999). Molecular mobility in glassy bread: a multispectroscopy approach. *Cereal chemistry*, *76*(1), 70-77.
4. Akissoe N, Hounhoui J, Mestres C, Nago M. (2003). How blanching and drying affect the colour and functional characteristics of yam (*Dioscoreacayenensis-rotundata*) flour. Food Chem. 82: 257-264.
5. Bhandari, M. R., Kawabata, J., & Kasai, T. (2003). Nutritional evaluation of wild yam (*Dioscoreaspp*.) tubers of Nepal. *Food Chem*. 80: 619-623.
6. Armando A., Mar V., & Maite R. M. (2010). Mechanical and viscoelastic properties of yam. *Journal of Texture Studies*.
7. Niklas, K. J. (1992). Plant biomechanics: An engineering approach to plant form and function. The University of Chicago Press, Chicago, US. 263-270.
8. Taylor, S. E., Buffington, D. E., Collier, R. J., & DeLorenzo, M. A. (1986). Evaporative Cooling For Dairy Cows In Florida. In *Paper-American Society of Agricultural Engineers*. ASAE.
9. Judith, B. (2004). Structure and texture of yam (*Dioscorea spp*.) and processed yam products, A PhD dissertation submitted to the Swiss Federal Institute of Technology Zurich. 100-152.

