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THE RELEVANCE OF SOME ENGINEERING PROPERTIES OF COCOYAM (COLOCASIA ESCULENTA) IN THE DESIGN OF POSTHARVEST PROCESSING MACHINERY

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ABSTRACT

In this study the determination of some engineering properties of cocoyam, (shape, size, colour, volume, particle density, Sphericity, weight, surface area and compressive strength) was determined at moisture contents of 71.8 %. Under approved standard laboratory conditions and using standard methods and instruments, experiments were conducted and results were obtained. The highest value of compressive strength for cocoyam when placed horizontally and vertically is 1.84 KN and 1.40 KN respectively. The maximum values of the Major, Intermediate and Minor Diameter are 112.3mm, 48.2mm and 46.0mm respectively. The minimum values were calculated to be 56.0mm, 29.0mm and 38.77mm respectively, and mean to be 74.33mm, 41.04mm and 38.77mm respectively. These values were used for sorting, grading and construction of sieve to separate the values below the mean obtained. The coefficient of variation of the major, minor and intermediate was gotten to be 19.0%, 14.8% and 15.5% respectively. These results are important for maximum efficiency in designing equipment required for further processing of Cocoyam and the reduction of mechanical damage to agricultural produce during postharvest handling and processing.

Keywords: Engineering properties of Cocoyam, Postharvest Handling and Processing

INTRODUCTION

The ever increasing importance of agricultural products together with the complexity of modern technology for their production, processing and storage need a better knowledge of the engineering properties of these products. It is however necessary to understand the physical laws guiding the response of these agricultural products so that machines, processes and handling operations can be designed for maximum efficiency and the highest quality of the final end products (Mohsenin, 1970).

CONTEXT AND LITERATURE REVIEW

Agricultural products especially those of the plant origin (for example cocoyam) are now frequently used for a wide range of activities with importance of other increasingly emerging products. These agricultural products have over the years been underexploited in the regions of which they are produced especially in the developing countries. It is therefore necessary to determine their engineering properties which are important in the design of agricultural machinery, equipment and facilities for proper design of equipment for handling, conveying, separation, drying etc.

Cocoyam can be used as food for man and feed for animals, and mucilage which can be utilized in the paper industry or possibly in medicinal tablet manufacture. Cocoyam can be used as a source of power (Alemede, 1994; Montaldo, 1991; Wilson, 1984; Tambong et al., 1997; Lebot&Aradhya, 1991; Onokpise, 1999; Kolawole, 2005; Montaldo, 1999; Douglas, 1994)

The major cocoyam producing areas are located in the humid zones and the production relies on small farmers having 0.5 – 2.0 ha in production. The production area has decreased drastically during the last few years, from 30,000 ha in year 2001 to 13,000 ha in year 2002, a decrease that is mainly due to diseases, and unstable prices. The demand for fresh cocoyam has, however, gradually been increasing in Europe and in the United States, and recently, farmers in non-traditional cocoyam-producing areas (north western dry zones) have started to establish small commercial areas to expand the production for export (Esther and Aaron, 2001).

The top 5 producers of cocoyam in West Africa are Nigeria – 25, 000 tonnes, Cameroon – 21, 450 tonnes, Ghana – 17,800 tonnes, Cote d' Ivore – 16,000 tonnes and Liberia – 14, 600 tonnes.

The shortage of processing and preservative machines and equipment for cocoyam, which may be due to the fact that data on the engineering properties of cocoyam required for the design of these machines are insufficient and not available in some cases, necessitated this research work.

Statement of the Problem

The shortage of processing and preservative machines and equipment for cocoyam, which may be due to the fact that data on the engineering properties of cocoyam required for the design of these machines are insufficient and not available in some cases.

Objectives of the Study

The objective of this study is to determine the relevant engineering properties of cocoyam; (shape, size, colour, seed weight, volume, particle density, bulk density, porosity, surface area, angle of repose and compressive strength) which are considered important in the design of agricultural machinery, equipment and facilities for proper handling, conveying, separation, drying etc.

METHODS

Materials Selection

The agricultural crop used in determining these engineering properties is Cocoyam *Colocasiaesculenta* and 50 pieces of the specimen was used during the experiment. The Cocoyam was obtained from Kure Market, Minna, Niger state, within the month of October, 2010. The 50 samples were cleaned to remove foreign matter, dust and dirt. For the experiment the samples were randomly selected and extra care was ensured to select good cocoyam without any sign of blemish, so as to eliminate getting incorrect results (Narsi, 2006).

Determination of the Engineering Properties

The engineering properties of cocoyam (30 pieces) at an average moisture contents of 71.8 % (shape, size, geometric mean diameter, sphericity, colour, seed mass, volume, particle density, bulk density, porosity, surface area, angle of repose, and compressive strength) were determined according to established standards and procedure (Agbetoyey*et al*, 2009; ASAE, 2003; Handerson et al., 1997; Mohsenin, et al., 1980; Schott, 2003; Altuntas*et al.,* 2005; Mohsenin, 1970).

Statistical Analysis

The tool used for computation and comparison are mean, standard deviation and coefficient of variation using Microsoft Excel 2007 at 95% confidence level.

FINDINGS AND DISCUSSION

Discussion of Result on Physical Properties

It was observed from Appendixes 1 to 5 that the length (D_1), width (D_2) and thickness (D_3) for the cocoyam have mean values of 74.33, 41.04, and 38.77 respectively. With known axial dimensions, the product can be effectively graded. In the design of machine for processing, the knowledge of different dimensions is important so as to minimize wastage or breakage while grading, peeling and cleaning.

The mean values of the weight and the volume are 70.44 and 52 respectively. The weights of agricultural products are exploited in the design of cleaning equipment using aerodynamic forces, also practical application of mass is in the design of cleaning equipment for separation, conveying and elevating unit operations. The weight and mass of the cocoyam is a useful index in measuring the relative amount of dockage or foreign material in a given lot of material.

The data in Appendix 5 gives the means, standard deviation and coefficient of variation of calculated values of calculated parameters of the cocoyam. Arithmetic mean diameter (AMD) has a mean of 51.38 mm, geometric mean diameter (GMD) has a mean of 49.09 mm, square mean diameter (SMD) has a mean 50.07 mm and equivalent diameter (ED) has a mean of 50.18 mm. The arithmetic mean and geometric mean can therefore be used to determine the average diameter of cocoyam. This is useful in determining the diameter of sieve hole.

Sphericity (Sc) and aspect ratio ranged from 0.56 to 0.62 and 0.41 to 0.46 and mean values of 0.66 and 0.55 respectively. Sphericity values of most agricultural produce have been reported to range between 0.32 and 1.00 and the more regular an object is, the lower the sphericity (Mohsenin, 1970). This is important information for hopper, separation and conveying equipment design.

The particle density ranged from 1.05 g/cm^3 to 1.08 g/cm^3 with a mean value of 1.35 g/cm^3. The particle density of agricultural products have been reported to play significant importance in the design of silos and storage bins, maturity and quality evaluation of products which are essential to cocoyam and tubers marketing.

The values obtain when compared to the standard charted values on other tubers (Mohsenin, 1986) shows that cocoyam are relatively smaller in size compared to the rest, and also weigh lesser and less denser to other tubers. It also spoils easily when exposed to sunlight, humidity and other climatic condition, and breaks easily when exposed to much cold. Since it is not completely spherical like other tubers more consideration is put in designing its hopper and conveying equipment. From the surface area obtain from the experiment and compared to the standard charted of tubers, it shows that the surface area of cocoyam is smaller which makes it easier to peel, which should be taken into consideration when designing the peelers for cocoyam and any other processing equipment.

Discussion of Result on Mechanical Properties

With the anvil height set on the Universal Material Testing Machine. For the 5 cocoyam samples, the compressive load at break is 1.84KN, 1.37 KN, 1.03 KN, 0.84 KN, and 0.71 KN when the cocoyam was placed in horizontal position and for another 5 cocoyam sample the compressive load at break is 1.40 KN, 1.05 KN, 0.88 KN, 0.63 KN and 0.56 KN when the cocoyam was placed in vertical position. From the graph in Fig 4.1 and Fig 4.2, it shows that as more pressure is placed on the cocoyam samples it begins to extend towards its axis thereby causing a break or crack, which increase as more load is placed on it, thereby giving the upward slope in the graph which shows that increase in load result to the increase in extension of the cocoyam. From the values obtained above it shows that the pressure in cracking the cocoyam in the horizontal position is greater than when placed in the vertical position, this can be concluded that in case of storage and bagging the cocoyam should be placed at the horizontal position because it takes more force to break or crack the cocoyam in that position compared to the vertical position. This knowledge could be applied in the design of harvesting equipment and storage devices for cocoyam.

CONCLUSIONS

The physical and mechanical properties of cocoyam including shape, size, geometric mean diameter, sphericity, colour, mass, volume, particle density, surface area and compressive strength were determined at 71.7% moisture content. The relationships derived between the size, surface area, weight, and sphericity all follow a particular pattern which would be useful in the design of machine for processing, cocoyam having a moisture content of 71.7% shows that cocoyam is mainly composed of water, and there will spoil easily if not preserved properly, so it is necessary to gather relevant data on the engineering properties of cocoyam so as an accurate measurement in the design and fabrication of equipment for handling and processing of the cocoyam and storage devices. Mass and volume of food materials and agricultural products play an important role in the design or cellars, barns or storage bins; mechanical compressing of ensilages and maturity evaluation. Result showed that cocoyam had an oblong, ovate and elliptical shape and the particle densities of cocoyam had greater values than their aspect ratio. Densities have been of interest in breakage susceptibility and hardness studies. Also the knowledge of compressive strength is of great importance to engineers handling agricultural products.

These parameters obtained are of importance in designing equipment for handling and processing operations of the product. From the data obtained for the selected physical and mechanical properties of cocoyam, it was established that, they are useful in design of post harvest handling and processing operations.

REFERENCES

Agbetoyey, A. S., Oladele, P., Kolawole, L. and Ogunlowo (2007): International Journal of Food Engineering; Strength and Elastic Properties of Cassava Tuber, 17(3): 13 – 18.

Aguegia, A. And Onokpise, O.U. (2004): Evaluation of Cocoyam (*ColocasiaEsculenta*) plantation in Cameroon. Agricultural Engineering international: the CIGR Journal of Food Science. Vol. I. March 2004.

Alemede, S.U. (1994): Physical Properties of Fruits and Vegetables Journal of Agricultural Engineering Research 32: 39 – 52.

Altuntas E, Ozgoz, H. And Taser, O.F. (2005): Some Physical Properties of Tubers. Journal of food engineering, 58, 42 - 47.

Anazodo, U.G.N. (1983): Force-Deformation Analysis for Biomaterials in Radial Compression: Maximum Contact Stress. Nigerian Journal of Technology. 5 (2): 1 – 10.

Awe, O.O., Odeku O.A., Popoola, A., M.A.Odeniyi and O.A. Itiola (2005): Compression and Mechanical Properties of Sweet Potato and Cocoyam.

ASAE Standards. (1996): compression test of food materials of convex shape ASAE S368.1.

ASAE Standards. (2003): Moisture Measurement – Root and Stem Tubers. S352.2. ASAE. St Joseph, Mich, USA.

Babayemi, O.J and Bamikole, M.A. (2009): Nutrient Value and in Vitro Gas Production Of African Wild Cocoyam (ColocasiaEsculentum). African Journal of Food Agriculture Nutrition and Development. 9(11): 11 – 16.

Baryeh E.A. (1997): Mechanical Properties of Yam and Cassava. International Journal Of Applied Science And Technology, 2(4): 63 - 70.

Choudhury, C. (1998): Physical Properties of Stem Tubers. Journal of Food Engineering, 23:167– 171.

Chukwu, M. and Asoegwu, S.U. (2001): determination of the physical properties of cassava, cocoyam, yam, potatoes. 33-39.

Douglas, H. (1994): Underground Crops Long-Term Trends in Production of Roots and Tubers.

Esther, K. And Aaron, B. (2001): Variation in the growth of cocoyam in West-Africa and Southern Africa. African Journal of Food Science.Vol 1. 3(4): 45 – 51.

FAO (Food and Agricultural Organization of the United Nations) Food Outlook (1990), Rome, Italy.

Food and Agricultural Organization (FAO) (1999): Food and Agricultural Organization of the United States. Yearbook, 1999 (http:/apps.fao.org.

Goenage, G. and Hepperly, K. (1990): Nutritional Analysis on Root Tubers, Stem Tuber and Corm. Agricultural Engineering journal. 12: 10 – 12.

Goenaga, G. and Chardon, K. (1995): Diseases and Pest That Affect Tubers and Corms. Agricultural Engineering journal. 18: 14 - 15

Henderson, S.M., Perry, R.L. and Young, J.H. (1997): Principles of Process Engineering. Fourth Edition ASAE Michigan USA. 280 – 283.

Innvista, (2007): http:/en.innivista.org/ *ColocasiaEsculenta*, (html document).

James, E.A. (2001): Effect of Wild Cocoyam on the performance of Ruminent diet. Agricultural Engineering journal: the CIGR EJournal, 10, 11 – 14.

John D., Davies, E. and Ibrahim R.M. (2008): Some Properties of Cocoyam (*ColocasiaEsculenta*) and Cassava (*ManihotEsculenta*) Grown in Africa. African Journal of Food Science. Vol 2.2(12):102- 111.

Kachru, R.P., Gupta, and Alan,A. (1994): Physico-Chemical Constituents and Engineering properties of Food Crops, Scientific Publishers, Jodhpur, India, 56 – 67.

Kolawole, L. (2005): Growing Cocoyams in Nigeria. Commercial Crop Production Guide Series, Nigerian Journal of Technology.

Krishiworld, (2008): http://en. Krishiworld.org/*Discoreaalata*,

Lebot, L. And Aradhya, B.A. (1991).Physical Variation of Cocoyam, Potatoes and Yam in the Tropics and Sub-tropical Areas.Journal of Agricultural Engineering Research. 12: 15 – 16.

Matthew, K.W.S. (1996): The Effect of the Moisture Content on the Physical Properties of Yam. 43, 114 – 156.

Mohsenin, N.N. (1970): Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York.

Mohsenin, N.N. (1980): Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York.

Mohsenin, N.N. (1986): Physical Properties of Plant and Animal Materials, 2^{nd} Ed. Gordon and Breach Science Publishers, New York.

Montaldo, M.O. (1999): Effect of Climate on Cocoyam and Potatoes Grown in Tropics. Journal of Agricultural Engineering Research 22: 19 – 21.

Munsell, O. (1990): Factors affecting The Grading and Sorting of Agricultural Produce, Journal of Agricultural Engineering Research 25: 16 – 18.

Narsi, R.G. (2006): A Study of Crop Yield Distributions and Crop Insurance. 4: 30 - 31.

Nyman, M. and Reyes C.G. (2005): Agronomic performance of three cocoyam genotypes grown in Nicaragua. 10, 1 - 7.

Onokpise, M. (1999): Harvesting and Storage of Tubers and Corm. Tropical Sciences, 31, 122 – 127.

Onu, P.N. and Madubuike, F.N. (2006): Effect of Physical Properties of Wild Cocoyam on the Performance of Broiler Chicks. 39, 4 - 8.

Saxena, A. (1992): Viscous and Elastic Properties of Agricultural Produce, third Edition ASAE Michigan USA. 12, 5-6.

Schott, L. (2003): Mechanical and Physical Properties of Flour Extracted from Taro Colocasiaesculenta, 16: 12 – 14.

Tambong, J.K., Mittal, J.P. and Goswami, T.K. (1997): Evaluation of Cocoyam Plantation in Nicaragua as Source of Feed to Livestock. Journal of Agricultural Engineering Research, 64: 93 – 98.

Val Verde, K. (1997): Disease Affecting Agricultural Produce with Respect to Tubers in Africa. Agricultural Engineering journal. 16: 12 – 14.

Wilson, J. (1984): Physical and Climatic Factors Faced Growing Wild Cocoyam in the Tropical areas. Journal of Agricultural Engineering Research. 10: 13 – 14.

Zoerb, S. and Hall, K. (1993): Effect of Moisture Content and Variety on Selected Properties of Root and Stem Tubers. Agricultural Engineering International, 18: 5 – 4.

APPENDIXES

Presentation of Results on Physical Properties

Appendix 1.Moisture Contents of 30 Cocoyam samples

S/No	*Weight of Sample (Before Drying)* $W_i\ (g)$	*Weight of Sample (After Drying)* $W_f\ (g)$	*Weight Of Water removed* $W(g) = W_i - W_f$	*Moisture Content* $\frac{W_i - W_f}{W_i} \times 100$
1	108.03	29.17	78.86	73
2	107.43	32.23	75.20	70
3	105.23	29.46	75.77	72
4	102.11	27.57	74.54	73
5	100.77	29.22	71.54	71
6	96.48	27.02	69.46	72
7	94.38	27.38	67.00	71
8	91.24	27.37	63.87	70
9	87.30	23.57	63.73	73
10	82.89	23.20	59.69	72
11	81.67	23.68	57.98	71
12	78.07	21.86	56.21	72
13	77.81	23.34	54.47	70
14	75.61	22.69	52.92	70
15	72.46	21.01	51.45	71
16	67.73	18.97	48.76	72
17	65.43	16.79	48.64	74
18	63.04	17.03	46.01	73
19	60.81	17.63	43.18	71
20	59.52	17.86	41.66	70
21	59.10	17.14	41.96	71
22	56.49	16.38	40.11	71
23	54.38	16.34	38.07	70
24	45.34	12.24	33.09	73
25	44.31	12.41	31.90	72
26	37.04	10.75	26.29	71
27	36.91	9.60	27.31	74
28	33.19	9.30	23.89	72
29	29.5	8.26	21.24	72
30	27.0	7.02	19.98	74

Appendix 2.Mass, Major Diameter, Minor Diameter, Intermediate Diameter of measured parameters of 30 Cocoyam samples

Specimen	*Mass (g)*	*Major Diameter (mm)*	*Minor Diameter (mm)*	*Intermediate Diameter (mm)*
1.	108.03	95.2	40.8	42.6
2.	107.43	94.9	44.4	46.5
3.	105.23	94.6	45.5	47.0
4.	102.11	93.7	43.2	45.8
5.	100.77	112.3	44.0	47.2
6.	96.48	84.8	43.8	45.7
7.	94.38	80.6	43.6	45.7
8.	91.24	66.0	46.0	48.2
9.	87.30	65.4	44.8	46.9
10.	82.89	63.0	42.2	45.6
11.	81.67	85.0	40.2	42.2
12.	78.07	76.0	41.2	44.0
13.	77.81	80.0	39.2	42.7
14.	75.61	75.6	40.0	42.3
15.	72.46	76.2	40.2	42.1
16.	67.73	66.4	42.0	44.8
17.	65.43	62.1	40.9	44.2
18.	63.04	61.8	40.2	41.8
19.	60.81	60.4	40.8	40.5
20.	59.52	89.1	26.0	29.1
21.	59.10	69.2	38.0	40.8
22.	56.49	72.0	32.8	33.4
23.	54.38	55.0	44.4	47.1
24.	45.34	72.0	35.6	39.2
25.	44.31	72.6	38.0	40.7
26.	37.04	64.0	28.0	30.0
27.	36.91	63.0	27.6	29.0
28.	33.19	61.8	27.3	30.7
29.	29.5	61.2	32.4	34.6
30.	27.0	56.0	30.0	31.0

Appendix 3.Lengths, volumes, and Mass of measured parameters of 30 Cocoyam samples

Specimen	*Mass (g)*	*Length (mm)*	*Initial Volume (ml)*	*Final Volume (ml)*	*Volume (ml)*
1.	108.03	95.2	145	259	114
2.	107.43	94.9	140	250	110
3.	105.23	94.6	140	248	108
4.	102.11	93.7	135	240	105
5.	100.77	112.3	130	230	100
6.	96.48	84.8	130	225	95
7.	94.38	80.6	125	220	93
8.	91.24	66.0	120	210	90
9.	87.30	65.4	115	203	88
10.	82.89	63.0	110	192	82
11.	81.67	85.0	100	180	80
12.	78.07	76.0	100	177	78
13.	77.81	80.0	100	176	76
14.	75.61	75.6	120	195	75
15.	72.46	76.2	120	193	73
16.	67.73	66.4	120	190	70
17.	65.43	62.1	130	197	67
18.	63.04	61.8	130	195	65
19.	60.81	60.4	130	192	62
20.	59.52	89.1	140	200	60
21.	59.10	69.2	140	198	58
22.	56.49	72.0	140	195	55
23.	54.38	55.0	140	190	50
24.	45.34	72.0	135	180	45
25.	44.31	72.6	135	178	43
26.	37.04	64.0	135	175	40
27.	36.91	63.0	130	165	35
28.	33.19	61.8	130	163	33
29.	29.5	61.2	130	160	30
30.	27.0	56.0	130	155	25

Appendix 4: Means, standard deviation and coefficients of variation of measured parameters of Cocoyam samples (measured)

S/No	*Measured Parameters*	*Unit*	*Maximum Value*	*Minimum Value*	*Mean*	*Standard Deviation*	*Coefficient of Variation (%)*
1.	Major Diameter	Mm	112.3	56.0	74.33	14.10	19.0
2.	Intermediate Diameter	Mm	48.2	29.0	41.04	6.09	14.8
3.	Minor Diameter	Mm	46.0	26.0	38.77	5.99	15.5
4.	Mass	G	105.23	27.70	70.44	24.69	35.1
5.	Volume	Ml	114	25	70.17	25.46	36.28

Appendix 5: Means, standard deviation and coefficients of variation of some physical properties of Cocoyam (calculated)

S/No	*Calculated Parameters*	*Unit*	*Maximum Value*	*Minimum Value*	*Mean*	*Standard Deviation*	*Coefficient Of Variation (%)*
1.	Arithmetic Mean Diameter	mm	68.83	37.00	51.38	8.73	16.4
2.	Geometric Mean Diameter	mm	62.91	34.82	49.09	8.01	16.3
3.	Square Mean Diameter	mm	65.30	35.75	50.07	8.30	16.4
4.	Equivalent Diameter	mm	65.48	35.86	50.18	8.34	16.4
5.	Sphericity	dec	0.56	0.62	0.66	0.57	0.86
6.	Aspect Ratio	dec	0.41	0.46	0.55	0.43	0.77
7.	Particle Density	g/cm^3	1.08	1.05	1.35	1.06	1.02
8	Weight	N	1.03	0.26	0.69	0.24	0.34
9	Surface Area	mm^2	12433.38	3808.96	7570.70	201.56	834.69

Presentation of Results on Mechanical Properties

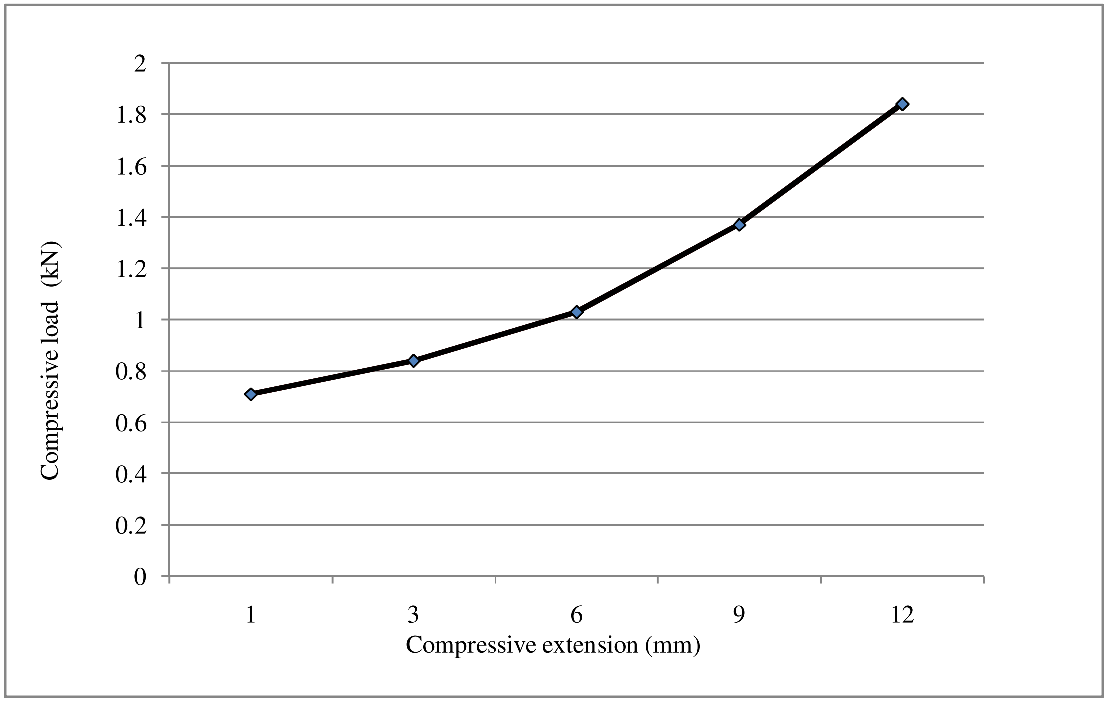

Figure 1.Compressive Load against Compression Extension of Cocoyam (Horizontal)

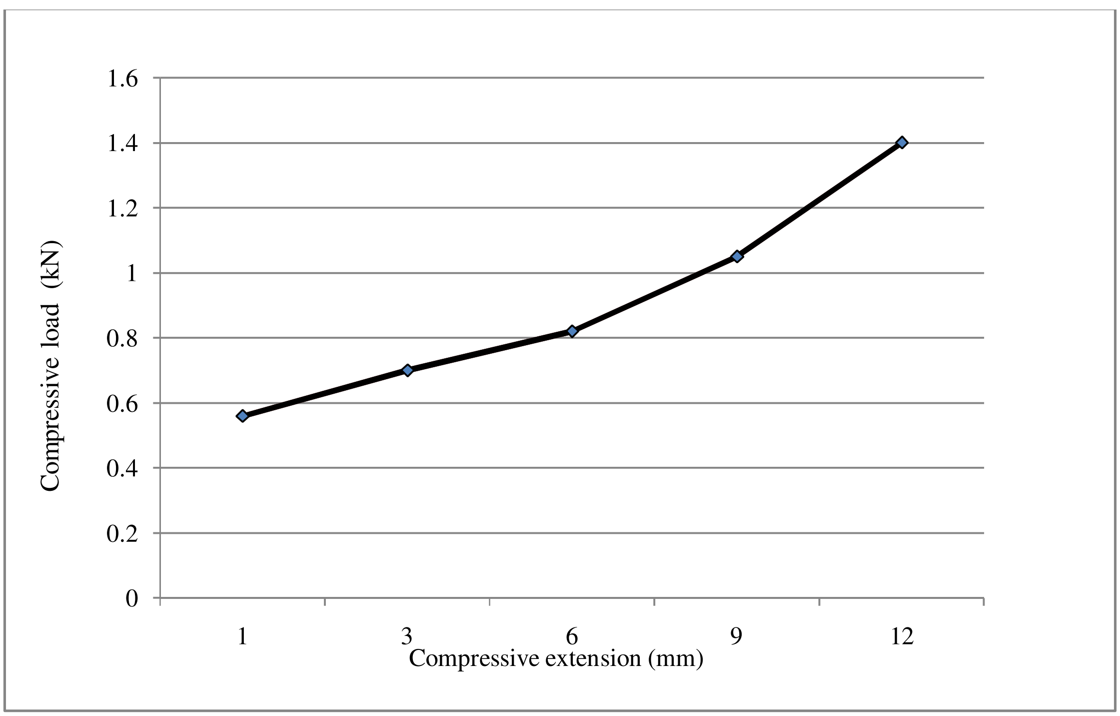

Figure 2.Compressive Load against Compression Extension of Cocoyam (Vertical)