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Mechanical Behaviour of Rubber Seed under Compressive Loading

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Abstract **- In this study, the mechanical behaviour of rubber seed was determined in terms of compressive force, stress, energy, deformation and elastic modulus at four levels of moisture content ranging from 9.1 to 14.8 % (w.b.), using the Universal Tensile Testing Machine, under compressive loading, with loading range (0-500 N), chart speed (50 rpm/mm) and cross head speed (1.5 mm/min) as testing conditions. The optimum peak values of force, stress, energy, deformation and elastic modulus at 14.8 % (w.b.) moisture content were 164.35±66.09 N, 2.09±0.59 N/mm^2, 0.27±0.07 Nm, 2.74±0.51 mm and 7.77±3.85 N/mm^2, respectively. Beyond elastic limit, the force of compression decreased quadratically with increase in deformation with high coefficient of determination (significant p <0.05). Predictive equations were derived to relate the force and deformation at peak and break stages of compression. It was deduced from these equations that rubber seed will continue to flow pass 2.40 mm peak with decrease in force until 3.10 mm when it is expected to break. The results showed that rubber seed combined the properties of viscosity and elasticity when subjected to compressive loading.**
Keywords **- compressive loading, elasticity, mechanical behaviour, moisture content, rubber seed**

1. INTRODUCTION

The economic importance of rubber tree (*Hevea brasiliensis*) in Nigeria has largely focused on the rubber latex while little or no attention is being paid to its by-products namely, wood and seed. Although, the latex is more important than the wood or seed, yet the prospects of the seed is high because of the oil contained in it. Haque *et al.* [9] reported oil yield as high as 38.9 % for rubber seed which is more than the yields in jatropher (32.4 %) and karanj (31.8 %) seeds and thus has great potential in the production of biodiesel.

However, in order to meet the increasing demand for biodiesel in the renewable energy industry study on the mechanical properties of agricultural materials are essential. Such study will enable oil extraction machines be developed [5]. Moreover, according to [11] and reported by [12], knowledge of physical and mechanical properties constitutes important and essential engineering data in the design of machines, storage structures, processes and control. These are basic information of great value not only to the engineers, but also useful to those who may exploit these properties and find new uses for the plant material.

Roos [14] reported that the macromolecules of agricultural and food materials are generally in an amorphous state at low moisture content. This property makes them hard, brittle and are said to be in the glassy state. As the moisture content increased the molecules become more mobile and consequently softer as they enter the rubbery stage thus making the material to become ductile and flow.

The mechanical properties of biological materials represent their strength under various loads in terms of several parameters such as rupture force, deformation and toughness [2, 13]. The physico-mechanical properties of rubber seed shell carbon filled natural rubber compound have been studied by Ekebafe *et al.* [4]. However, the technical information and data on the mechanical behaviour of rubber seed are sparse in the literature. The aim of this study was to determine mechanical behavior of rubber seed such as rupture force, deformation and energy absorbed.

2. MATERIAL AND METHODS

2.1 Sample Preparation

Rubber seeds were obtained from Rubber Research Institute of Nigeria (RRIN), Benin City. The seeds were subjected to manual cleaning to remove broken tree branches, leaves, sands and stones. The initial and final moisture contents of the seed were determined using the AOAC [1] standard procedure. The initial moisture content was found to be 9.1 % (w.b.) and the final moisture contents were found to be 11.3 %, 12.4 % and 14.8 % (w.b.) [6].

2.2 Methods

Eight (8) randomly selected rubber seeds from samples of different moisture content were subjected to compression test, using the Universal Tensile Testing Machine with loading range (0-500 N), chart speed (50 rpm/mm) and cross head speed (1.5 mm/min) as testing conditions, to determine the mechanical properties. The mechanical behaviour of the seed was expressed in terms of the force and energy absorbed at peak, yield and break; and the seed specific deformations. The applied force at bioyield and oil points and their corresponding deformation for each seed sample was read directly from the force-deformation curve. The force at break was determined as the force on the digital display when the seed under compression makes a clicking sound.

The average values and standard deviations were determined for the samples of different moisture content as the mechanical properties of rubber seed.

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3. RESULT AND DISCUSSIONS

Table 1 shows the average values of force, stress, energy and deformation obtained from the experiment at different compression stages. The response of rubber seed to compression load depended on the moisture content.

The loading orientation that gave the least resistance to the mechanical behaviour of the seed was the yield stage. The force measured in loading at peak and break stages of compression decreased from 214.06 to 164.35N and from 210.86 to 152.64N with increasing moisture content from 9.1 to 14.8% (w.b.), respectively. However, this force increased with increasing moisture content from 69.70 to 73.54N at yield stage of compression. This may be due to the fact that at low moisture content the seeds are hard and brittle; but as the moisture content increased the molecules become more mobile and consequently enter the rubbery stage where they tend to flow. They therefore required less loads for maximum compression. This suggests that the hardness of the seed decreases as the moisture content increased from the initial value of 9.1 to 14.8% (w.b.), beyond which it becomes easy to break.

Stress was measured as a function of rupture force and area of cross section of the seed. The stress measured in loading at peak and break stages of compression decreased from 2.73 to 2.09 N/mm^2 and from 2.68 to 1.94 N/mm^2 with increasing moisture content from 9.1 to 14.8 % (w.b.), respectively. The observed stress at yield stage of compression increased from 0.88 to 0.94 N/mm^2 with increasing moisture content from 9.1 to 14.8 % (w.b.). Similar trends were reported by Haddad *et al.* [8] and Kang *et al.* [10] for wheat kernels in their works on mechanical properties of wheat kernels.

Absorbed energy was measured as a function of rupture force and deformation on the surface of the seed. The energy absorbed at peak, break and yield stages of compression increased from 0.18 to 0.27 Nm, 0.18 to 0.24 Nm and 0.022 to 0.057 Nm respectively, with increasing moisture content up to 14.8 % (w.b.). This shows that rubber seed required less energy to deform at low moisture content than at high moisture content because of their level of brittleness.

The deformation values at the peak and break stages of compression were found to increase from 1.66 to 2.74 mm and 1.65 to 2.98 mm with increasing moisture content from 9.1 to 14.8 % (w.b.), respectively. It is important to note that the deformation values of rubber seed compressed at peak stage were higher than those compressed at break stage. The seed produced an initial high deformation under loading up to peak stage after which it decreased as it entered the break stage. This shows that rubber seed combined the properties of viscosity and elasticity when subjected to compressive loading. Similar trend were reported by Fathollahzadeh and Rajabipour [7] and Bamgboye and Adejumo [3] in their study on barberry and roselle seeds, respectively. They attributed this behaviour to the flexibility and viscoelasticity of the seeds at high moisture content.

The elastic modulus decreased from 18.54 to 7.77 N/mm^2 with increasing moisture content from 9.1 to 14.8% (w.b.). The increase in tensile stress was less than the accompanying increase in the strain as the seed absorbed moisture, hence the high value of elastic modulus at lower moisture content. Haddad *et al.* [8] reported a decreasing trend in this property in their work on wheat kernel.

Furthermore, Figs. 1 and 2 showed the force- deformation curves of rubber seed at peak and break stages of compression, respectively. The force at peak and break decreased quadratically with increasing deformation as the seed absorbs moisture with high coefficient of determination (significant $p< 0.05$). Hence, once elastic limit is exceeded small force will produce greater deformation. The seed will continue to flow with decreasing force pass 2.40 mm peak until 3.10 mm when it is expected to fail completely. This further confirms the viscoelastic behaviour of rubber seed.

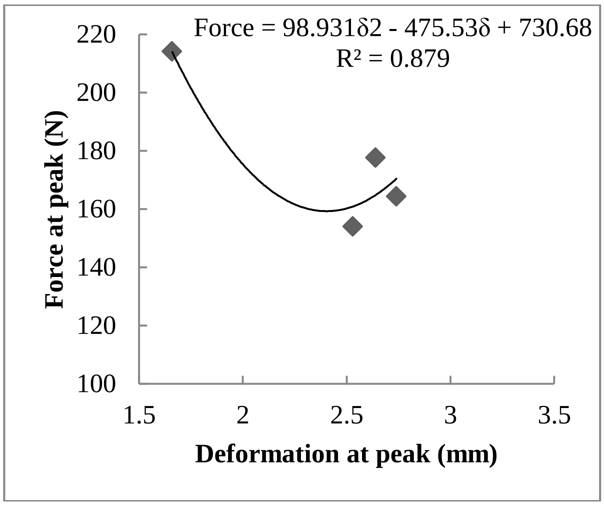

Fig.1. Force-Deformation Curve at peak

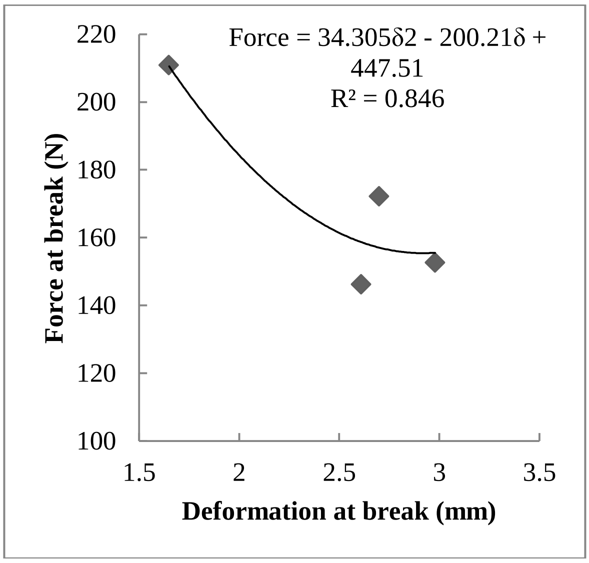

Fig.2. Force-Deformation Curve at Break

4. CONCLUSIONS

1. The force and stress at peak and break stages of compression decreased with increase in moisture content. Their values at yield stage increased with increasing moisture content of rubber seed.
2. The absorbed energy at peak, break and yield stages increased with increasing moisture content of rubber seed.
3. The deformation increased with increasing moisture content at peak and break stages of compression.
4. The elastic modulus decreased with increase in moisture content of rubber seed.
5. Beyond elastic limit, the force of compression decreased quadratically with increase in deformation with high coefficient of determination (significant $p < 0.05$).
6. From the predictive equations on the force-deformation curves it was shown that rubber seed will continue to flow pass 2.40 mm peak with decrease in force until 3.10 mm when it is expected to break.
7. Under compressive loading, rubber seed combined the properties of viscosity and elasticity.

5. REFERENCES

[1] A O A C. Official methods of analysis: Association of official analytical chemists, 2002, Gathersburg, ML, USA.
[2] Altuntas, E., and Yildiz, M. Effect of moisture on some physical and mechanical properties of faba bean (*vicia faba* L.) grains. Journal of Food Engineering, 78, 174-183, 2007.
[3] Bamgboye, A.I., & Adejumo, O.I. Mechanical properties of Roselle (*Hibiscus sabdariffa* L) seeds. Agricultural Science Research Journal, 1(8): 178-183, 2011.
[4] Ekebafe, L.O., Imanah, J.E., and Okiemen, F.E. Physico-mechanical properties of rubber seed shell carbon-filled natural rubber compounds. Chemical industry and Chemical engineering quarterly, 16(2): 149-156, 2010.
[5] Fadeyibi, A. Influence of moisture content on some engineering properties of rubber seed. Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria. An unpublished Master of Engineering Dissertation. Pp. 33-38, April, 2012.
[6] Fadeyibi, A., and Osunde, Z.D. Thermo-physical properties of rubber seed useful in the design of storage structure. International Journal of Agriculture & Biological Engineering, 5(2): 62-66, June, 2012.
[7] Fathollahzadeh, H., and Rajabipour, A. Some mechanical properties of barberry. International Agrophysics, 22, 299-302, 2008.
[8] Haddad, Y., Benet, J.C., Delenne, J.Y., Merme, A., and Abecassis, J. Rheological behaviour of wheat endosperm-proposal for classification based on rheological characteristics of endosperm test samples. Journal of cereal Science, 34:105 – 113, 2001.
[9] Haque, M.A., Islam, M.P., Hussain, M.D., and Khan, F. Physical, mechanical properties and oil contents of selected indigenous seeds available for biodiesel production in Bangladesh: Agricultural Engineering Institute. CIGR Ejournal; Manuscript 1419: 11(1), 2009.
[10] Kang, Y.S., Spillman, C.S., Steele, J.S., and Chung, D.S. Mechanical properties of Wheat. Transactions of the American Society of Agricultural Engineers, 38(2):573 – 578, 1992.
[11] Mohsenin, N.N. Physical properties of plant and animal material. Gordon and Breach Publications. New York, 1978.
[12] Olaoye. Some physical properties of castor nut relevant to the design of processing equipment. Journal of Agricultural Engineering Research, 77(1): 113-118, 2000.
[13] Polat, R., Tarhan, S., Cetin, M., and Atay, U. Mechanical behaviour under compressive loading and physical parameters of Japanese quail (*Coturnix coturnix japonica*) eggs. Czech Journal of Animal Science, 52(2): 50-56, 2007.
[14] Roos, Y.H. Phase Transitions in Foods. Academic Press Inc., San Diego, California, p.350, 1995.

Table 1: Some Mechanical Properties of Rubber Seed

		Moisture content, % (w.b.)			
Parameter	**Unit**	**9.1**	**11.3**	**12.4**	**14.8**
Force at peak	N	214.06±66.09	177.63±42.30	153.94±30.23	164.35±66.09
Force at break	N	210.86±69.97	172.11±39.35	146.18±34.38	152.64±46.68
Force at yield	N	69.97±25.20	64.08±11.85	90.32±62.87	73.54±65.66
Stress at peak	N/mm^2	2.73±0.84	2.26±0.54	1.96±0.38	2.09±0.59
Stress at break	N/mm^2	2.68±0.89	2.19±0.25	1.86±0.44	1.94±0.59
Stress at yield	N/mm^2	0.89±0.32	0.82±0.15	1.15±0.80	0.94±0.84
Energy to peak	Nm	0.18±0.09	0.29±0.14	0.24±0.06	0.27±0.07
Energy to break	Nm	0.18±0.09	0.27±0.12	0.23±0.01	0.24±0.17
Energy to yield	Nm	0.022±0.01	0.030±0.01	0.077±0.09	0.057±0.01
Def at peak	mm	1.66±0.65	2.64±0.79	2.53±0.69	2.74±0.51
Def at break	mm	1.65±0.65	2.70±0.87	2.61±0.69	2.98±0.30
Young's Modulus	N/mm^2	1.84±0.64	7.36±2.00	6.70±2.85	7.77±3.85

parameter presented in the form: Value ± standard deviation