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EFFECT OF MOISTURE CONTENT AND PROCESSING PARAMETERS ON THE STRENGTH PROPERTIES OF BRACHYSTEGIA EURYCOMA SEED

Ndubisi A. Aviara[1], Michael Y. Edward[1] and John O. Ojediran[2]
[1]Department of Agricultural and Environmental Resources Engineering, University of Maiduguri, Maiduguri, Nigeria.
[2]Department of Agricultural Engineering, Landmark University, Omu-Aran, Nigeria.

Abstract

Brachystegia Eurycoma seed is an important food thickening agent with seed gum that has potential as binding agent in the pharmaceutical industry in Nigeria. Presently, the kernel is obtained by manually dehulling the seed and the operation is not only time consuming and tasky but also wasteful. In order to overcome the above problems associated with the processing of the seed, there is the need to development a mechanical device for handling and processing the crop. The development of such device requires knowledge of the mechanical properties of the seed. To provide the needed data, investigation of the mechanical properties of the seed under different processing conditions of soaking, parboiling and roasting and moisture content levels of 8.90, 14.02, 20.90 and 26.30% (w.b) was carried out using the Testometric Universal Testing Machine (UTM). The properties studied include bioyield point, yield point, rupture point, bioyield strength, compressive strength and rupture strength, modulus of elasticity, modulus of stiffness, modulus of resilience and modulus of toughness. Results showed that all the above mechanical properties of Brachystegia Eurycoma seed decreased with increase in moisture content. Highest values of the properties were obtained from unprocessed seeds followed by parboiled seeds except for the compressive strength which was highest on unprocessed seeds and followed by soaked seeds. Roasting gave the lowest values of the properties except on modulus of stiffness at the highest moisture level and modulus of toughness that was lowest on soaked seeds. From the results obtained, it could be taken that the Brachystegia Eurycoma seeds subjected to roasting operation prior to dehulling, would require less energy to handle.

Keywords: Brachystegia eurycoma, mechanical properties, compressive tests, moisture content, roasting, soaking, parboiling, processing.

Introduction

Brachystegia eurycoma is an economic tree crop that grows in the tropical rainforest of West Africa. It belongs to the caesalpiniaceae family, the spermatophyte phylum and of the order of fabaceae. The crop is classified as legume with its pod containing seeds (Figure 1a) that are dicotyledonous (Figure 1b). Brachystegia eurycoma seed contains 56% carbohydrate, 15% crude fat, 9% protein, 4.5% ash and 2.9% crude fiber (Uhegbu et al., 2009). In Nigeria, the seed flour is used as soup thickening and stabilizing agent (Uhegbu et al., 2009) and as emulsifying agent in food systems (Ikegwu et al., 2009). Onimawo and Egbekun (1998) reported that the seed helps in maintaining the body temperature when consumed. The seed gum from Brachystegia eurycoma compared favourably with commercial gums used in the food industry (Uzomah and Ahiligwo, 1999) and can be used as a binding agent in medicinal tablet formulation (Olayemi and Jacob, 2011).

The processing of Brachystegia eurycoma seeds to obtain the cotyledonous kernels and flour normally involves such operations as parboiling, soaking or roasting prior to dehulling and size reduction. The hulls are removed by running a bottle or stone tangentially on the surface of the seeds spread on a flat surface. The kernels are ground or pounded in a mortar using pestle, to obtain the flour. These processes presently carried out, are not only labor intensive with low output but also time consuming. In order to appropriate the full economic potentials of Brachystegia eurycoma seed, there is the need to develop machine and equipment for use in carrying out the dehulling and other handling operations that will be efficient in terms of energy consumption and time. The development of such machine and equipment requires knowledge of the mechanical properties of the seeds. Uhegbu et al. (2009) investigated the effect of processing methods on the nutritional and antinutritional properties of the seed and Ikegwu et al. (2009) noted that the viscosity of the seed flour increased with increase in roasting time and palm oil concentration but decreased with increase in sodium chloride concentration. Ndukwu (2009) determined some physical properties of Brachystegia eurycoma seed at the moisture content of 12.9% (d.b) but did not address the variation of the properties with moisture content and processing methods.

Mamman et al. (2005) investigated the variation of some mechanical properties of the balanites aegyptiaca nuts relevant in bulk handling and processing with moisture contents and loading orientations. Nut moisture content and loading orientation were found to have significant effects on the properties. Similar findings were reported on cumin seed (Singh and Goswami, 1998), sheanut (Olaniyan and Oje, 2002), walnut cultivars (Altuntas and Ozkan, 2008; Aviara and Ajikashile, 2011), barley grains (Tavakoli et al., 2009a), jatropha seeds and kernels (Karaj and Muller, 2010), shea kernel (Manuwa and Muhammad, 2011) and mucuna flagellipes nut (Aviara et al., 2012). Khazaei and Mann (2004a, b) noted that the rupture force and modulus of elasticity of sea buckthorn berries respectively decreased with the increase in temperature. Burubai, et al. (2007a, b) reported that the compressive force needed to initiate seed coat rupture of African nutmeg decreased with an increase in both pre-heating temperature and moisture content and noted that the energy demanding and time consuming unit operation of cracking the nut to extract the kernel can be positively manipulated by varying the loading rate and pre-heating time used to condition the nut for mechanical cracking. Dobrzanski and Szot (1997) earlier investigated the resistance of pea seed coat to tension when the seed was dried at different temperatures. Gates and Talja (2004) studied the effects of temperature and moisture content on the mechanical properties of oat and observed that the stiffness of the seed decreased with the increase in temperature and increased with the increase in moisture content.

Davis et al. (2009) noted that the compressive force, strain energy and elastic modulus of different groundnut varieties decreased as the blanching time increased, while deformation increased linearly with the increase in blanching time. Data on the mechanical properties of Brachystegia eurycoma seed and their variations with moisture content and processing methods, however, appear to be scanty. The objective this study, therefore, was to determine the mechanical properties of Brachystegia eurycoma seed and investigate their relationship with moisture content and processing parameters. The mechanical properties include bioyield point, yield point, rupture point, bioyield strength, rupture strength, compressive strength, modulus of elasticity, modulus of stiffness, modulus of resilience and modulus of toughness.

Materials and Methods

Sample Preparation

Bulk quantities of freshly harvested Brachystegia eurycoma seeds were purchased at the Gombe main market in Gombe, Gombe State, Nigeria. The seeds were cleaned and sampled for the good and viable ones using a raffle box divider. The clean and viable seeds were collected together until the needed quantity required to carry out the experiment was obtained. The seeds were aerated and conditioned to different moisture contents. The seeds at different moisture contents labelled A, B, C and D, were then divided into three groups or sub samples each. Each sub sample was subjected to the different preprocessing treatments of soaking, parboiling and roasting respectively for 6 min and used in carrying out the investigations.

Experimental Procedure

Conditioning Brachystegia eurycoma seeds to different moisture levels

The conditioning of Brachystegia eurycoma seeds to different moisture levels was carried out using the method described by Asoegwu (1995). This involved the reduction of moisture by sun drying the seeds for different periods of time. The seeds were subjected to sun-drying by spreading them in thin layer on a flat surface and exposing them to sun shine. After every 24 hours, a sample was taken from the seeds and stored in a polyethylene bag for 12 hours to attain uniform moisture content (Oluwole et al., 2007). The sun-drying exercise lasted for 72 hours and four samples at different moisture levels were obtained.

Determination of the moisture contents of seed samples

The method described by Asoegwu (1995) was used to determine the moisture content of each seed sample. This involved the oven drying of seed at 105°C for 6 hours. The weight of the seed sample was measured and recorded before and after oven drying and moisture content was calculated as percentage loss in weight. The experiment was replicated three times for each samples and the average value of the moisture content obtained was recorded.

Determination of processing variables

Brachystegia eurycoma seeds treated to different processing parameters were obtained by subjecting samples at different moisture contents to the following unit operations.

Soaking in water

Seed samples were soaked in clean water contained in a metal bucket for a period of 5 min. After this time, the seeds were removed from the water and the surface water was cleaned off. The seeds were then sealed in polyethylene bags and stored at the ambient condition for 24 h before they were used in carrying out experiments.

Roasting in an open pan

Samples of Brachystegia eurycoma seed at different moisture contents were heated in an open pan for 5 min with continuous stirring. After this, the seeds were spread in thin layer to cool in natural air. The cooled seeds were then collected in polyethylene bag and stored for used in carrying out experiments.

Parboiling

This process involved heating of water to boiling point in a bowl and immersing the Brachystegia eurycoma seeds at specified moisture content into the boiled water for a period of 5 min. Thereafter the water was drained completely from the seeds. Then, the sample obtained was poured into a polyethylene bag and stored at ambient condition for use in carrying out experiments.

Unprocessed condition

Samples of the seeds at different moisture contents were left without subjecting them to any processing pretreatment. These samples were used in carrying out experiments in order to determine the effects of subjecting the seeds to various processing variables on the strength properties.

Evaluation of the compressive strength properties of Brachystegia eurycoma seed

Compressive tests were carried out on Brachystegia eurycoma seeds at different moisture contents and processing pretreatments under lateral loading, using the Testometric Universal Testing Machine (UTM) controlled by a micro-computer shown in Figure 2. Test results, statistics and force-deformation curves were automatically generated. The seeds were compressed at the rate of 20mm/min. As compression began and progressed, a force-deformation curve was plotted automatically in relation to the response of each sample of seed to compression. A typical force-deformation curve of Brachystegia eurycoma seed under compression on the lateral axis is shown in Figure 3. The force-deformation curves obtained were analysed for bioyield point, yield point, rupture point, bioyield strength, compressive strength, rupture strength, modulus of elasticity, modulus of stiffness, modulus of resilience and modulus of toughness.

The bioyield point was taken as the point on the force-deformation curve at which the compressed seed hull weakened and failed internally without cracking outwardly. At this point, an increase in deformation resulted from either a decrease or no change in force (Mohsenin, 1986), and the seed could be said to have failed in its internal cellular structure (Anazodo, 1982, Mamman et al., 2012). The yield point was the point on the force-deformation curve at which the visible failure of seed hull became initiated and the hull just began to tear (Aviara et al., 2007 and Aviara et al., 2012). Rupture point was the point on the force-deformation curve at which the seed hull completely became broken and torn with the kernel exposed (Mohsenin, 1986; Anazodo, 1982). The bioyield strength was taken as the stress at which the seed hull failed in its internal cellular structure. The compressive strength was the stress at which the visible failure of the seed hull was initiated so that it began to tear. The rupture strength was taken as the stress at which the seed hull got completely broken. Modulus of elasticity was taken as the ratio of the stress to the strain up to bioyield. Modulus of resilience was taken as area under the force-deformation curve up to bioyield (Aviara et al., 2007) and was determined from the force-deformation curve of the seed using the method that of Haque et al. (2001). Modulus of stiffness was the ratio of the average maximum force to the average maximum deformation of the seed at failure (Dinrifo and Faborode, 1993; Aviara and Ajikashile, 2011). It was calculated from the force-deformation data of the seed following the method employed by Mamman et al. (2005) and Aviara et al. (2007). Modulus of toughness was taken as area under the force-deformation curve up to failure (Aviara et al., 2012) and was determined from the force-deformation curve using the method that was followed by Haque et al. (2001). The compression test was replicated ten times at each moisture content and processing pretreatment and the mean of each property obtained under lateral loading was recorded. The variations of the properties with moisture content and processing parameters were plotted.

Results and Discussion

Moisture content

The average moisture content of the four samples A, B, C and D were found to be 8.90%, 14.02, 20.9 and 26.30% respectively. Sample D with moisture content level of 26.30% was the moisture content at harvest.

Mechanical Properties of Brachystegia Eurycoma Seed

Bioyield point

The variation of the bioyield point of unprocessed and processed Brachystegia eurycoma seed with moisture content variables under compression at lateral loading orientation is represented in the Figure 4. The figure shows the bioyield point decreased with increase in moisture content for both the processed and unprocessed samples. The unprocessed seed exhibited the highest bioyield point while the lowest values were obtained on roasted seed. Unprocessed and parboiled seeds exhibited similar trend in the variation of their bioyield point with moisture content, while soaked and roasted seeds exhibited similar trend. Roasting may have resulted in the formation of more brittle cell walls that became easily broken down on application of force. The implication of the above result is that the force needed in compression to initiate failure in the intercellular structure of the seed is dependent on the moisture content and the method of processing to which the seed is subjected. Minimum force would be needed when the seed is roasted at higher moisture levels.

Yield point

Variation of the yield point of Brachystegia eurycoma seeds with moisture content when subjected to compressive loading on the lateral orientation is represented in Figure 5. From Figure 5, it can be seen that the yield point of processed and unprocessed seeds decreased with increase in moisture content and followed a similar trend with the bioyield point of the seeds. The unprocessed seeds required the highest amount of force to initiate the breakage of the seed hull, while the roasted seeds required the lowest amount of force. At all the conditions employed, minimum force requirement was obtained at higher moisture level.

Rupture point

The variation of rupture point of unprocessed and processed Brachystegia eurycoma seeds with moisture content when subjected to compressive loading on the lateral orientation is represented in Figure 6. The figure shows that the rupture point of the seeds decreased with increase in moisture with the unprocessed seeds exhibiting the highest values and the roasted seeds exhibiting the lowest values. This indicates that the roasted seeds would require lower level of force to shell than the unprocessed, parboiled and soaked seeds. Rupture point of both processed and unprocessed seeds exhibited similar trend with moisture content.

The decrease in rupture point with increase in moisture content was not expected as the hull was expected to be less brittle with increase in moisture content. The lowest value for rupture point was higher than that of cumin seed (Singh and Goswami, 1998, Saiedirad et al. 2008), barley grain (Tavakoli et al, 2009a), soybean (Tavakoli et al, 2009b), conophor nut (Aviara and Ajikashile, 2011), mucuna flagellipes (Aviara et al., 2012) and balanites aegytiaca seeds (Mamman et al., 2012).

Bioyield strength

The variation of bioyield strength of processed and unprocessed Brachystegia eurycoma seeds with moisture content when subjected to compressive loading at the lateral orientation is represented in the Figure 7. As expected, the bioyield strength decreased with increase in moisture content with the unprocessed seeds exhibiting the highest values and the roasted seeds showing the lowest values. Minimum bioyield strength was obtained for the unprocessed and processed seeds at the highest moisture level. The trend of bioyield strength with moisture content for Brachystegia eurycoma seeds subjected to different processing treatments appeared to be similar and to resemble that of balanites aegytiaca nuts (Mammam et al., 2005).

Compressive strength

The variation of compressive strength of Brachystegia eurycoma seeds with moisture content when subjected to compressive loading under lateral orientation as presented in the Figure 8. The figure shows that the compressive strength of the seeds decreased with increase in moisture content. Similar finding was reported for wheat by Kang et al. (1995). Unprocessed seeds yielded the highest values of compressive strength while roasted seeds exhibited the lowest values. Soaked seeds however, displaced the parboiled seeds and yielded the second highest compressive strength. Minimum compressive strength for both processed and unprocessed seeds was obtained at higher moisture level. This indicates that the roasted seeds would require the least compressive pressure to dehull under compression. The higher the moisture content of the seed prior to roasting would be the lower the required dehulling pressure.

The minimum compressive strength of Brachystegia eurycoma seeds is higher than that of paddy grain (Prasad and Gupta, 1973), corn cobs (Anazodo and Norris, 1981), orange fruit (Haque et al, 2001), balanites aegyptiaca nuts (Mamman et al., 2005 and 2012), guna fruits (Aviara et al., 2007) conophor nut (Aviara and Ajikashile, 2011) and mucuna flagellipes nut (Aviara et al., 2012).

Rupture strength

The variation of rupture strength of processed and unprocessed Brachystegia eurycoma seeds with moisture content when subjected to compressive loading under lateral orientation is represented in Figure 9. The figure shows that the rupture strength of the seeds decreased with increase in moisture content for all the three processing methods and in the unprocessed condition. Roasting shows the least rupture strength at all the moisture levels employed, while the unprocessed seeds exhibited the highest values.

Minimum rupture strength of Brachystegia eurycoma seeds is lower than that of soya bean (Tavakoli et al, 2009b), sheanut (Olaniyan and Oje, 2002, Manuwa and Muhammad, 2011), orange fruit (Haque et al., 2001) and balanites aegyptiaca nuts (Mamman et al., 2005 and 2012).

Modulus of elasticity

The variation of modulus of elasticity of processed and unprocessed brachystegia eurycoma seeds with moisture when subjected to compressive loading under lateral orientation is presented in Figure 10. The figure shows that the modulus of elasticity the seeds decreased with increase in moisture content and varied with method of pretreatment. Unprocessed seeds exhibited the highest modulus of elasticity at all the moisture levels employed, while roasted seeds showed the lowest values. The trend of the modulus of elasticity of unprocessed seeds with moisture content appears to be similar to that of the soaked seeds, while that of the parboiled and roasted seeds followed a similar trend which is entirely different from that of the unprocessed and soaked seeds. Modulus of elasticity of Brachystegia eurycoma seed is higher than that of orange (Haque et al., 2001), soya bean (Tavakoli et al, 2009b), conophor nut (Aviara and Ajikashile, 2011) and mucuna flagellipes nut (Aviara et al., 2012). Minimum modulus of elasticity for both processed and unprocessed Brachystegia eurycoma seeds was within the same range as that of African nutmeg (Burubai et al., 2007a).

Modulus of stiffness

The variation of modulus of stiffness of processed and unprocessed Brachystegia eurycoma seeds with moisture content under compressive lateral loading is represented in the Figure 11. The figure shows that the modulus of stiffness decrease with increase in moisture content for both processed and unprocessed seeds and after a certain moisture level it began to converge. Highest modulus of stiffness was displayed by the unprocessed seeds followed by the soaked seeds. The lowest modulus of stiffness was maintained by the roasted seeds. However, beyond the moisture content of 25%, the modulus of stiffness of the soaked seeds became lower than that of both the parboiled and roasted seeds.

Minimum modulus of stiffness of Brachystegia eurycoma seeds is higher than that of corn cobs (Anazodo and Norris, 1981), soya bean (Tavakoli et al., 2009b), conophor nut (Aviara and Ajikashile, 2011) and mucuna flagellipes nut (Aviara et al., 2012), but within similar range as the minimum value for balanites aegytiaca nuts (Mamman et al., 2005).

Modulus of resilience

The variation of modulus of resilience of processed and unprocessed Brachystegia eurycoma seeds with moisture content under lateral compressive loading is represented in Figure 12. The figure shows that like other strength properties so far examined, the modulus of resilience of Brachystegia eurycoma seeds decreased with increase in moisture with the unprocessed seeds exhibiting the highest modulus of resilience and the roasted seeds having the lowest values at all the moisture levels employed.

The trend of the modulus of resilience of Brachystegia eurycoma seeds with moisture content can best be described as non-linear. Modulus of resilience the seeds were higher than that of corn cob (Anazodo and Norris, 1981), soya bean (Tavakoli et al., 2009b) and sheanuts (Olaniyan and Oje, 2002).

Modulus of toughness

The variation modulus of toughness with moisture content for processed and unprocessed Brachystegia eurycoma seeds at lateral compressive loading is represented Figure 13. The figure shows that the modulus of toughness of both processed and unprocessed seeds decreased with increase in moisture content and differed with pretreatment up to the moisture level of 25%. After this moisture level of 25%, the modulus of toughness of both processed and unprocessed seeds converged to a similar value. While unprocessed seeds exhibited the highest modulus of toughness, the soaked seeds exhibited the minimum values.

The trend of modulus of toughness with seed moisture content was similar for unprocessed and parboiled seeds and same for roasted and soaked seeds.

Conclusions

The investigation of the strength properties of Brachystegia eurycoma seeds revealed the following:

1. The strength properties of the seeds namely bioyield point, yield point, bioyield strength, rupture point, rupture strength, compressive strength, and modulus of elasticity, modulus of stiffness, modulus of resilience and modulus of toughness, all decreased with increase in moisture content.
2. The properties varied with such processing pretreatments as parboiling, soaking and roasting and were of highest values for unprocessed seeds.
3. Minimum values of the properties were obtained on roasted seeds except for the modulus of stiffness at the highest moisture content and modulus of toughness that yield the lowest values on soaked seeds.
4. Roasted Brachystegia eurycoma seeds appear to require minimum amount of energy to achieve the dehulling operation.

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Figure 1a: Brachystegia eurycoma seeds (Source: Ndukwu, 2009)

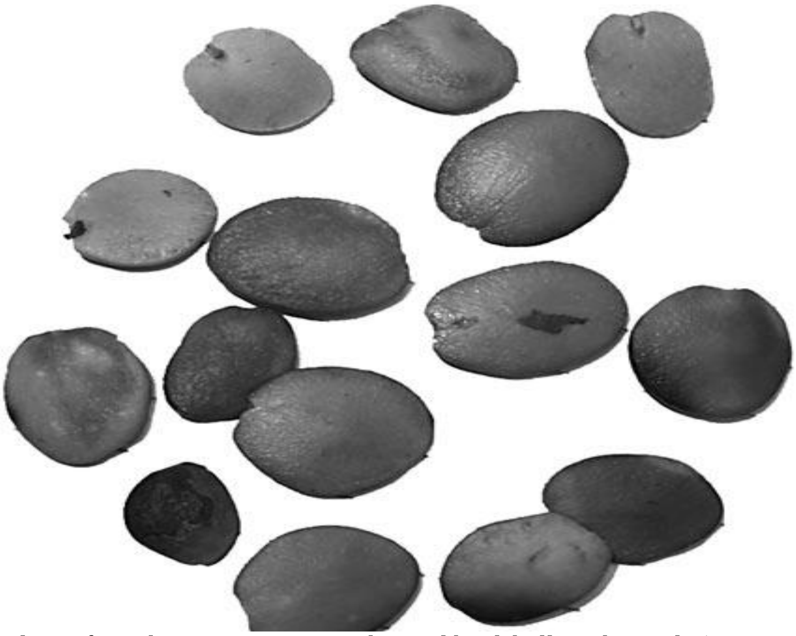

Fig 1b: Cotyledons of Brachystegia eurycoma obtained by dehulling the seeds (Source: Ndukwu, 2009)

Figure 2: Universal Testing Machine with Brachystegia Eurycoma seeds loaded in the lateral Orientation

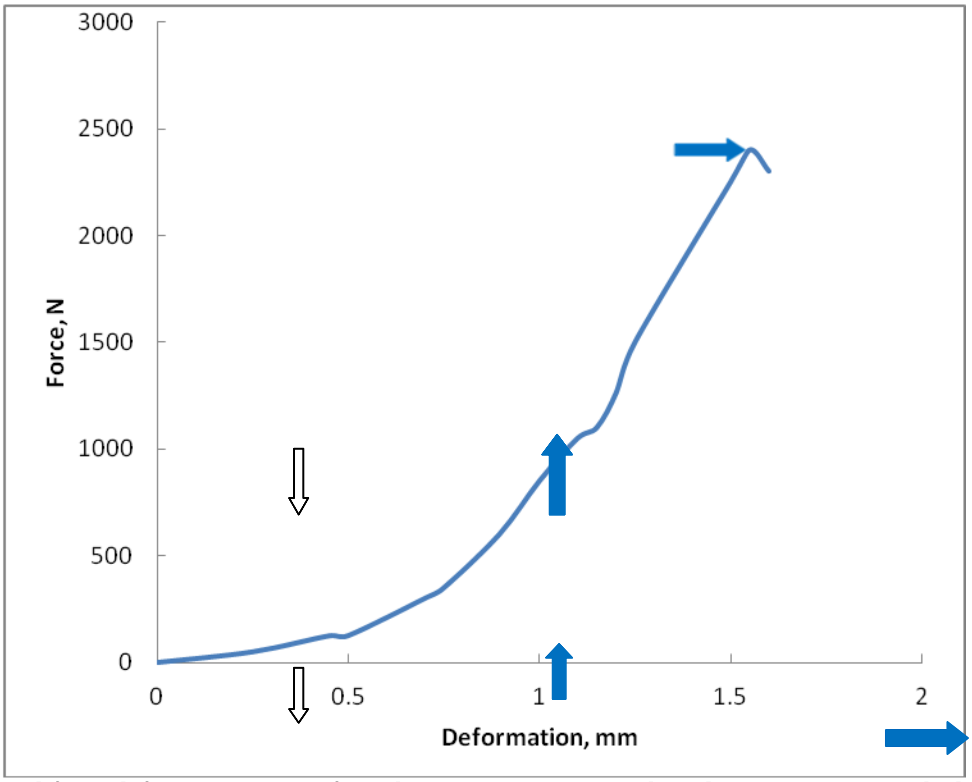

Figure 3: Typical force-deformation curve of Brachystegia Eurycoma seeds under compression on the lateral loading orientation, is the bioyield point, is the yield point and is the rupture point

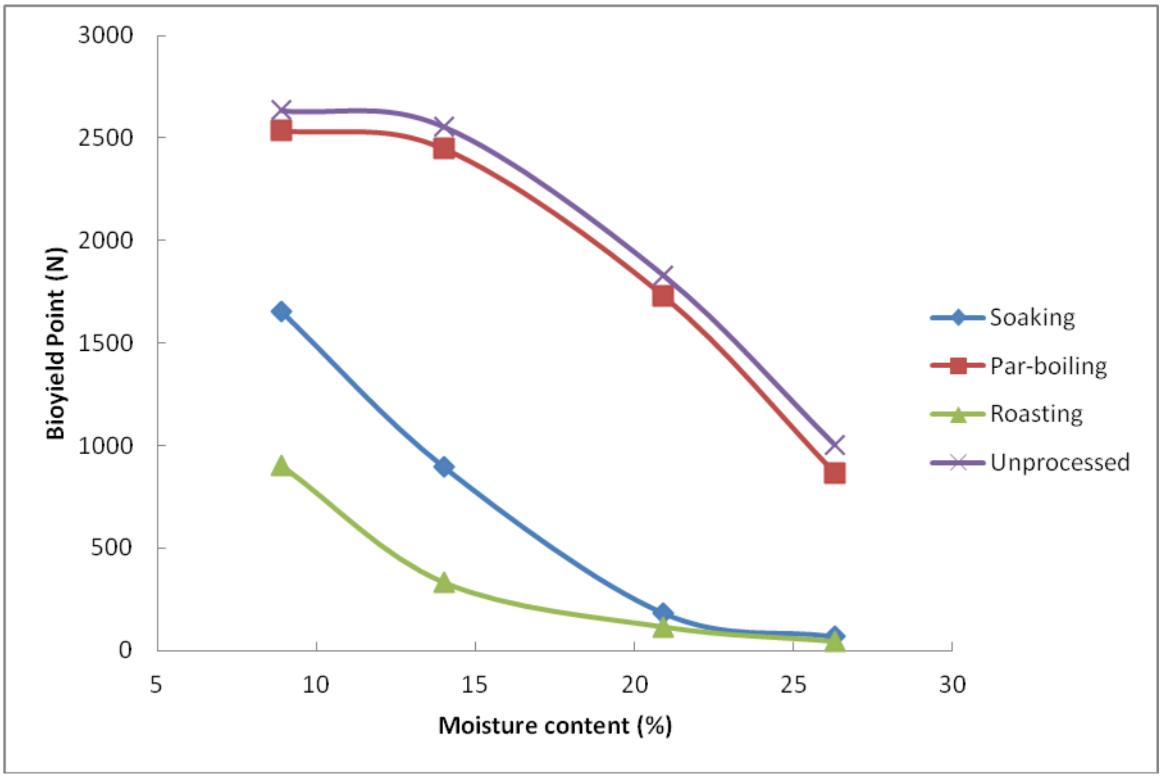

Figure 4: Effect of moisture content on bioyield point of Brachystegia eurycoma seeds under lateral compressive loading

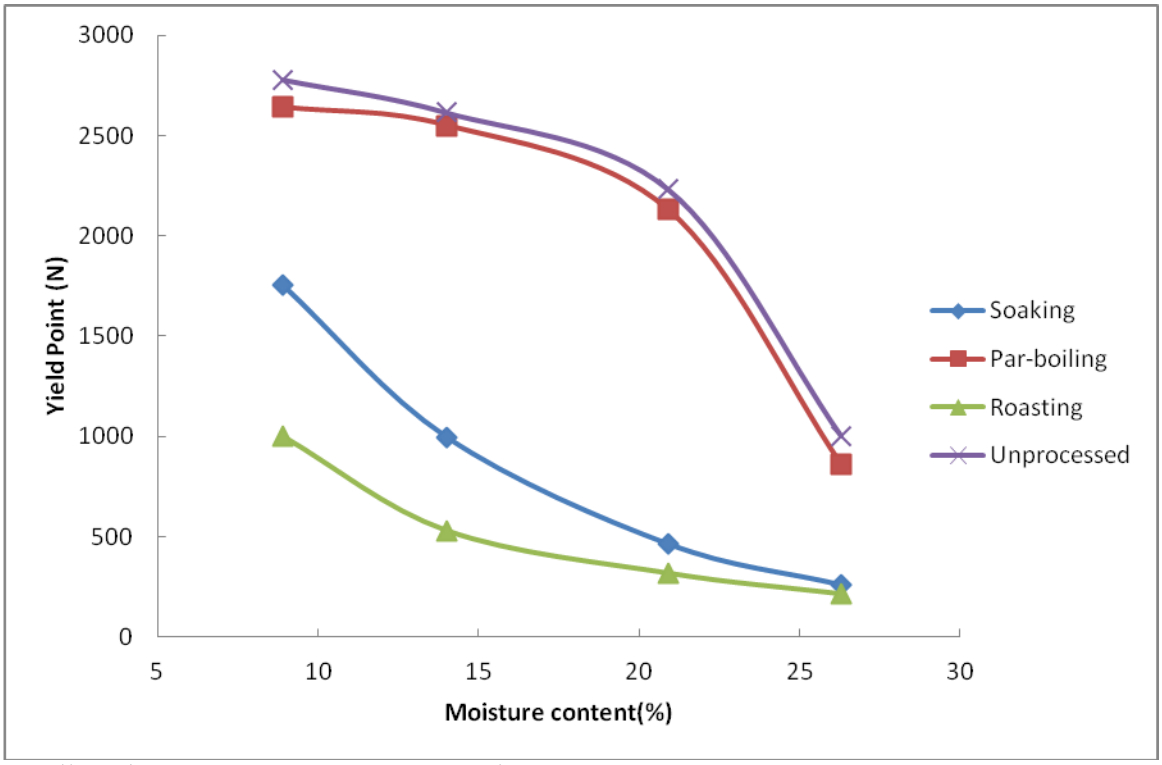

Figure 5: Effect of moisture content on yield point of Brachystegia eurycoma seeds under compression on lateral loading orientation

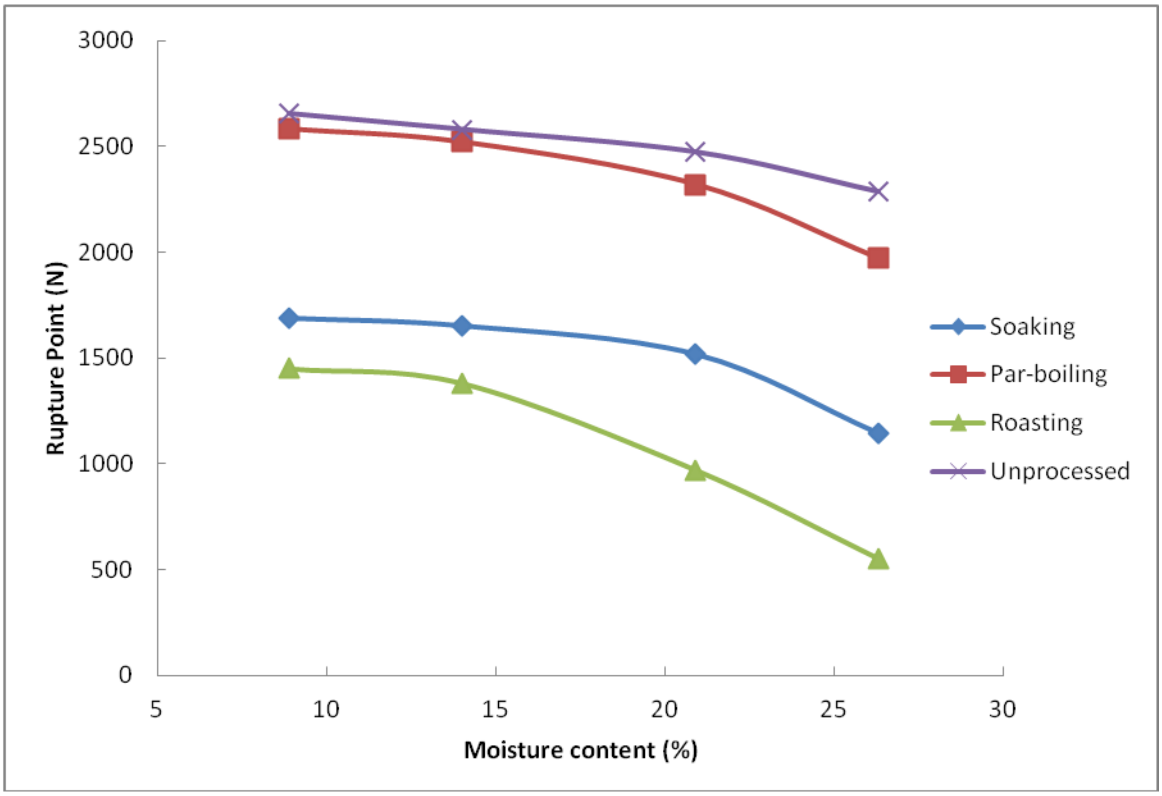

Figure 6: Effect of moisture contents of Brachystegia eurycoma seeds under lateral compressive loading

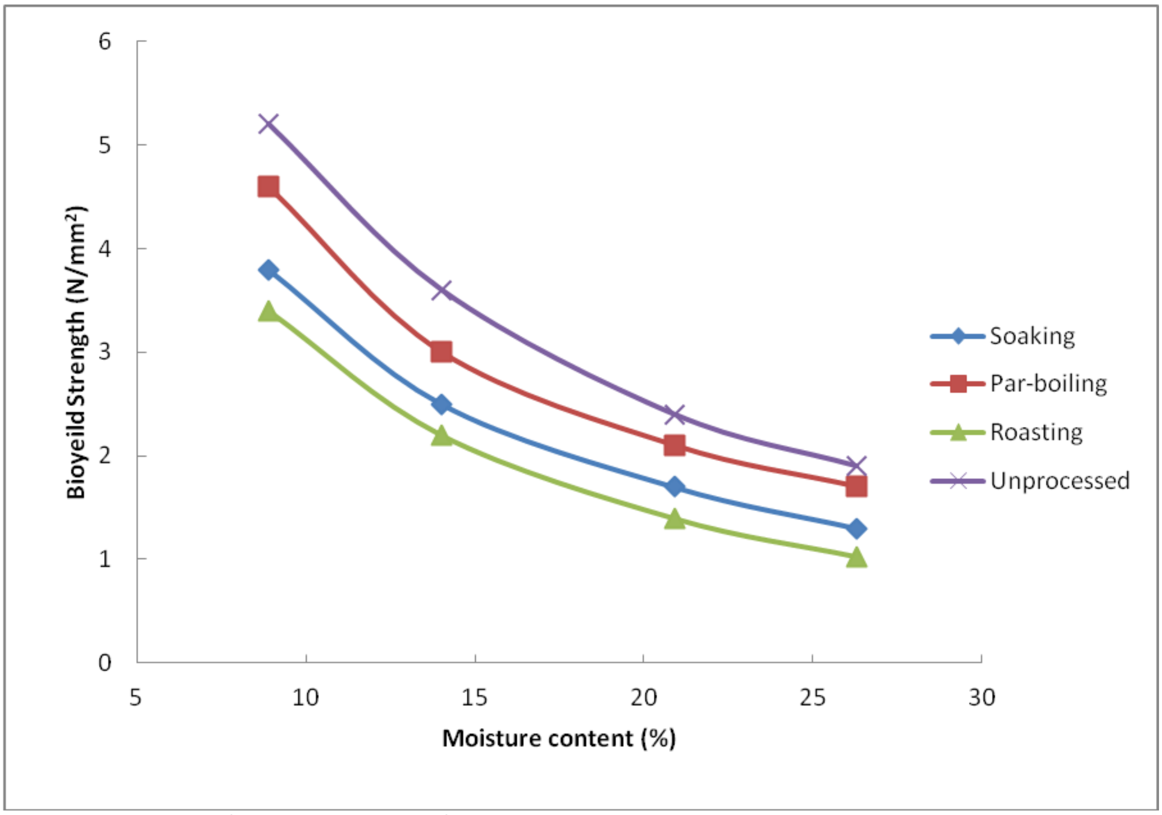

Figure 7: Variation of bioyield strength of Brachystegia eurycoma seeds with moisture contents under lateral compressive loading

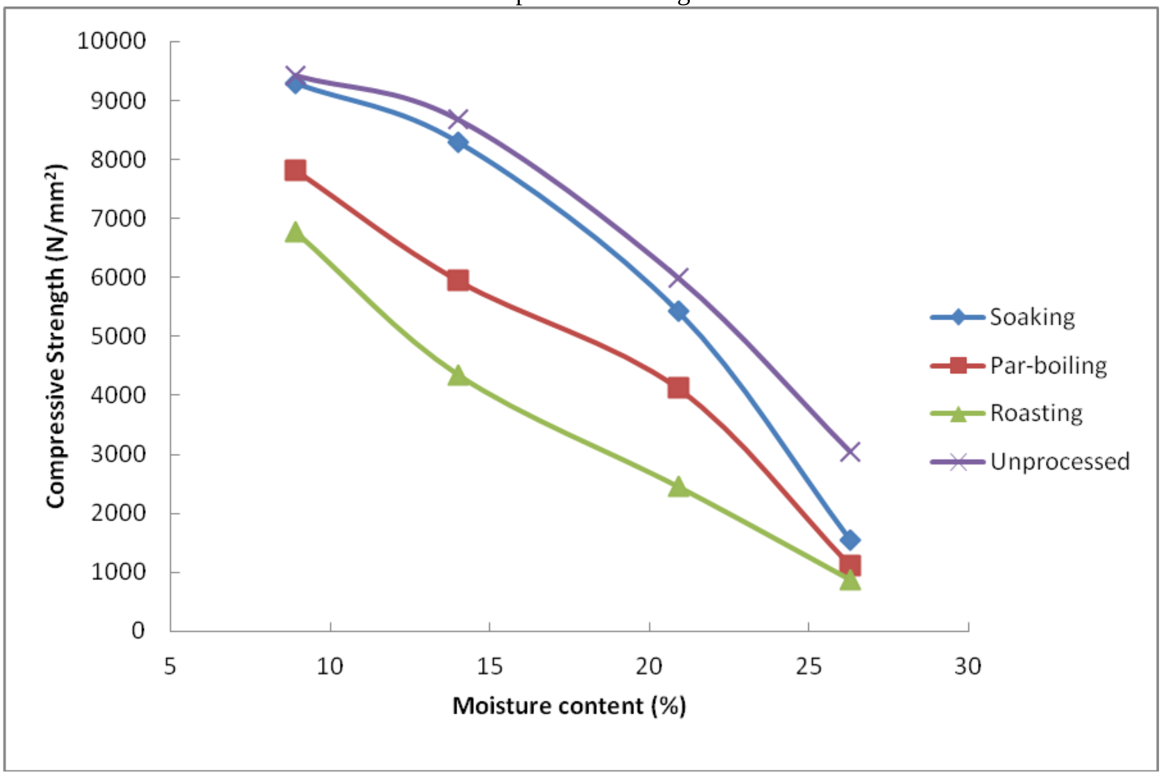

Figure 8: Variation of compressive strength of Brachystegia eurycoma seeds with moisture under lateral loading

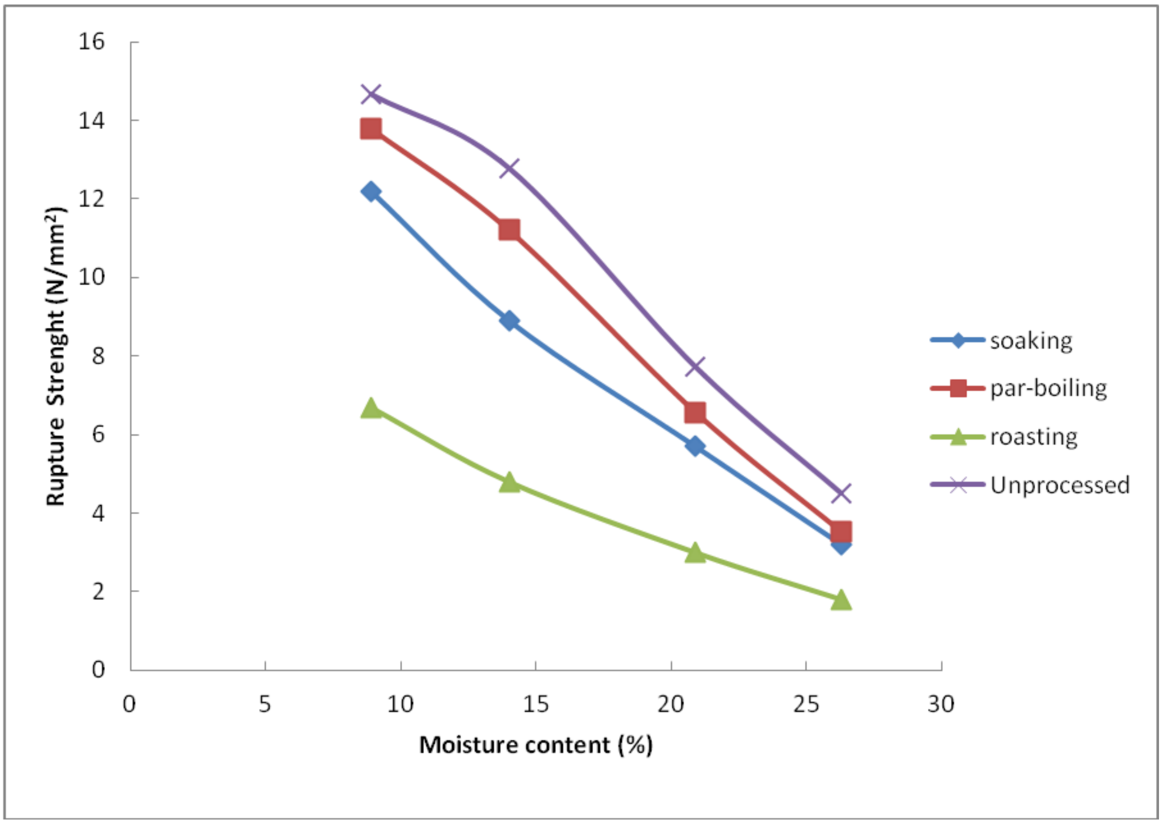

Figure 9: Variation of rupture strength of Brachystegia eurycoma seeds with moisture content under lateral compressive loading

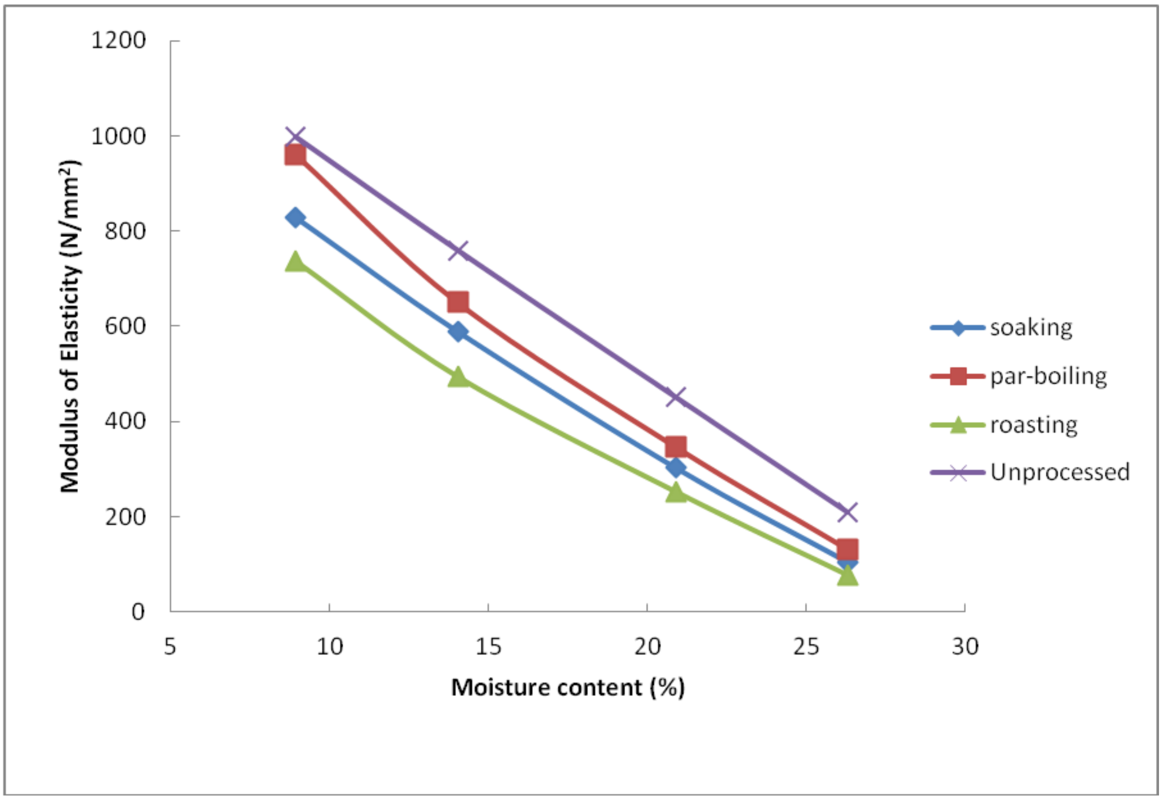

Figure 10: Variation of modulus of elasticity of Brachystegia eurycoma seeds with moisture content at lateral compressive loading

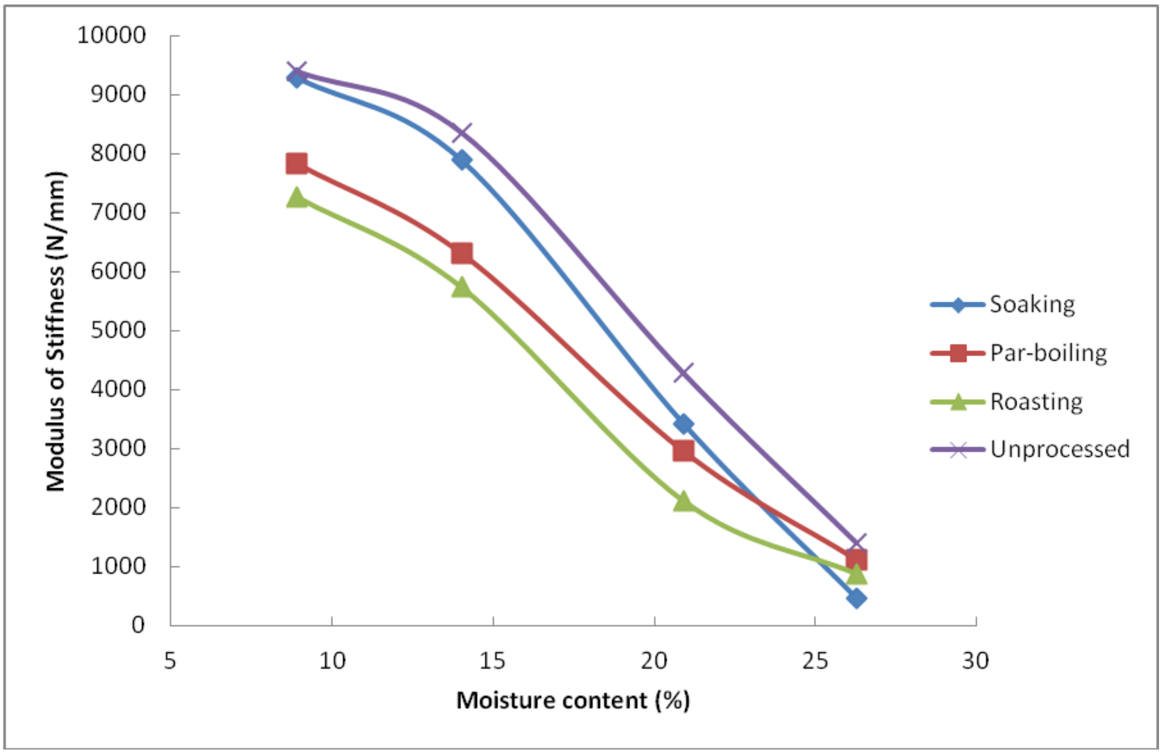

Figure 11: Variation on modulus of stiffness of Brachystegia eurycoma seeds with moisture content under lateral compressive loading

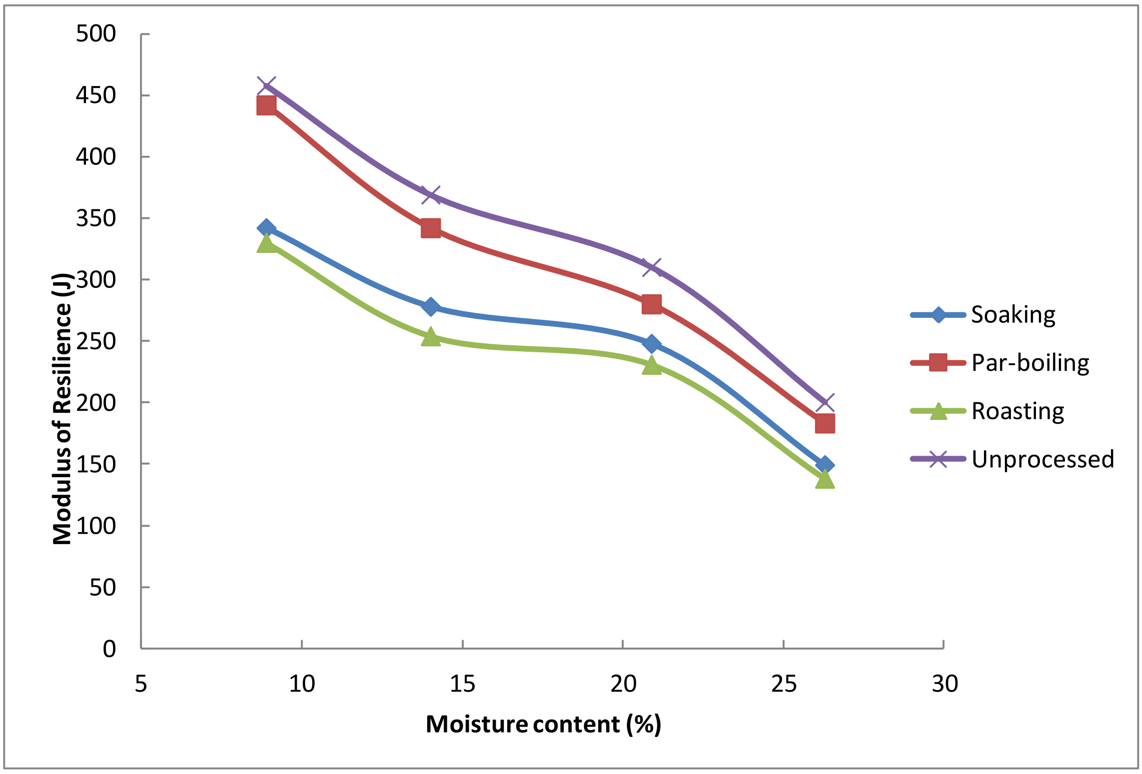

Figure 12: Variation of modulus of resilience of Brachystegia eurycoma seeds with moisture content under lateral compressive loading

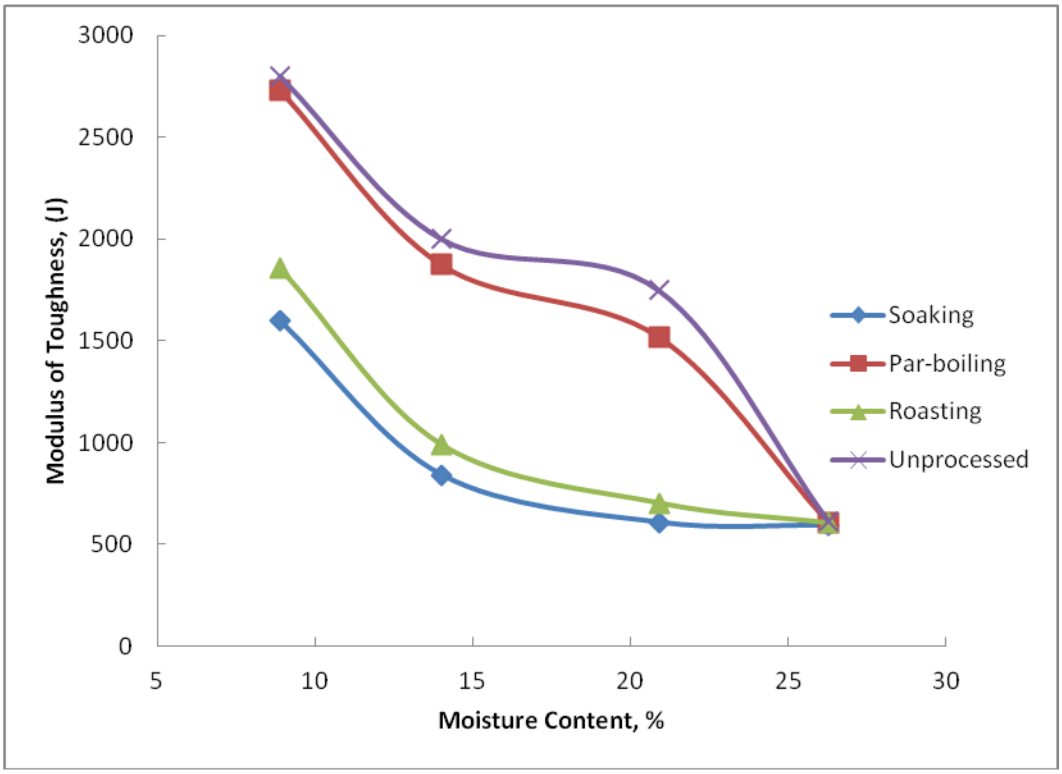

Figure 13: Variation of modulus of toughness of Brachystegia eurycoma seeds with moisture content under lateral compressive loading