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# BIOPHYSICAL AND MECHANICAL PROPERTIES OF RICE VARIETIES: ATTRIBUTES TO LOSSES IN POST HARVEST PROCESSING.

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**Abstract**
***The work showcases that at moisture content range (15 – 18%) wb, the compressive force against natural position of the grains were also determined and consideration of variation in natural position of rice grain at rest during compression gave representative apparent compressive strength across the five varieties. It requires about 25N for the rice grain (IITA306) to fail at 0.7mm at horizontal and 150N to crack the rice grain in vertical position at 21.0mm, it takes 60N for the rice grain (MAS) to fail at 1.4mm and 150N to crack the rice grain at 22.5mm as well as 58N for the rice grain (R18) to fail at 1.2mm and 125N to crack the rice grain at 20mm, as such 13N for the rice grain (SML) to fail at 0.93mm and 110N to crack the rice grain at 23.5mm,as well as 21N for the rice grain (R15) to fail at 0.65mm and 200N to crack the rice grain at 22.5mm respectively. Therefore, losses during rice processing operations are specific. It is advisable to handle a particular rice variety uniquely since losses are variety specific.***

***Keywords:*** biophysical, mechanical properties, rice varieties, processing, post-harvest losses

## 1. Introduction

Food (rice production) may be produced in abundance at short duration but tends to decrease incoherently due to inability to process, store, preserve, handle, transport and/losses at post-harvest processes. These are some of the fundamental reasons for food shortage/scarcity and insecurity. Rice production as a cereal (grain) experiences a high level of processing, storage, handling, transportation and losses at 25% post-harvest every season. And this represents some tens of millions of metric tonnes of food [1]. Losses are attributed to a combination of factors affecting the way the rice crop is grown, harvested, cleaned, handled, dried, stored, milled, and marketed. These losses are either outright physical losses, or deterioration of quality which reduces the commercial value. Significant gains have been made in understanding the socio-economic environment under which the industry operates, and in understanding the post-harvest processes and the bio-chemical properties of the rice grain as it relates to maintaining the milled rice quality. The big gap has been in the development of technologies suitable to the conditions prevailing in Nigeria, and in the institutional arrangements to enable local farmers and processors to use technology to improve productivity in their operations. Once the paddy rice has left the farm, it enters the domain of the post-production sector. The people involved in the post-production sector are not usually farmers themselves (rice producers). They are entrepreneurs (private rice processors) who invest in technology. In Nigeria, most work as part of a small family business as seen in Abakaliki Rice Mill Complex in Ebonyi State-Nigeria. Where there are clusters of Rice processing Entrepreneurs. The key players in the post-production sector are the traders, the processors, the wholesalers and the retailers. These entrepreneurs are profit driven, and respond to market forces. They form a business network, and the marketing economists view this network as a marketing system. The post-production technologies are the tools of their trade. The development of technology in Nigeria to store and process rice, and deliver it from the farms to the consumers, has not kept pace with the developments in the farm production sector. This lag is attributed to a strategic misunderstanding of the target research beneficiaries in the post-production sector. Public-sector (government sponsored) research cannot seem to accept entrepreneurs as the direct beneficiary of research results. This

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perhaps is due to the fact that most researches come from a culture of incoherency marked with random field of interest and thoughts instead of problem-solution basis. However, this work provide solutions for both government and private sectors (entrepreneur) as means of evaluating quantitatively the level of post-harvest losses in rice production in Nigeria. It is expected to determine the effect of Force-deformation (stress-strain relationship) considering the variation of the natural contact surface of rice which lead to losses during milling operation. However, it is necessary to appraise logically the processing techniques and technologies involved (both imported and local), the physical and mechanical properties of rice varieties (improved) as well as post harvest handling and storage with precision to minimize post harvest losses during rice production.

## 2. Material and methods

### *2.1 Rice varieties*

Available unprocessed rice grains samples that are processed were collected for laboratory testing and experiments. In a sample space of over thirty common rice varieties available at the site (Abakaliki rice mill Ltd), five most common available rice varieties were isolated, collected with auger in a cellophane therein covered air tight, which are used to carry out this work as a representative sample. Such common Rice varieties includes: IITA306 (Faro37), R5 (Faro23), RI8, SML, MAS. Each rice grain variety was pigmented with indelible ink for ease of identification, laboratory testing and processing.

### *2.2 Instrumentation.*

The instruments used to carry out this work includes Digital analytical weighing balance, Digital vernier caliper, oven, INSTRON model 3339 (universal testing machine), Beaker, water, Electric burner, hand glove, indelible ink, pencil, pen and paper.

### *2.3 Sampling.*

The techniques adopted for this work is that of random sampling on the survey plot (Abakaliki Rice mill complex) which is characterized by regimented classified division of labour based on different unit of operations in the processing of rice.

For data collection, efforts were made fervently to extract information from legitimate staff of the Rice mill through the help of the Chairman – Abakaliki Rice mill Ltd.

#### *2.3.1. Experimentation.*

The five rice varieties each were graded and sorted (free from deformations) for their physical properties, placed in beakers containing water (soaked for 10mins) and steamed at the same time at 100°C for 20minutes, thereafter allowed to cool (temper), air dried, before oven-dried to moisture content range (14-18) percent wet basis, the modified seeds were allowed to equilibrate at room temperature for at least 48hours before testing [2, 3]. However, rice husk were hand removed and the grain taken for compressive (mechanical) testing. The experiments were designed in 2x5 factorial in completely randomized design (CRD) that is two-way ANOVA with no blocking. whereby, there are five varieties of rice as factor A and Heat treatment(parboiling) as factor B. meanwhile, the measured values of the parameters (physical properties) of grains were replicated three times.

*(a) Determination of physical properties of these Rice varieties:* Measurements of three major linear dimensions of the rice structure, namely, length (L), width (W) and thickness (T) were determined using a digital vernier caliper with an accuracy of 0.01 mm

. Also the kernel weights were also measured using electronic weighing balance, model P1210 and 0.001g sensitivity. The aspect ratio (Ra) was determined by using the formula below:

$$R_a = L/W \quad (1)$$

The equivalent diameter ($D_p$) of the rice kernel was calculated as [3]:

$$D_p = \left[\frac{L(W+T)^2}{4}\right]^{1/3} \quad (2)$$

Surface area(S) of the rice kernel was calculated with the equation (3) below

$$S = \frac{\pi D L^2}{(2L-D)} \quad (3)$$

where $D = (WT)^{1/2}$

Also, sphericity (ψ) also calculated with the following formula

$$\psi = \frac{(LwT)^{1/3}}{L} \quad (4)$$

*(b.) Moisture Content Determination of Rice Kernel.*

Oven-dry method of determining moisture content was used to determine the moisture content wet basis of the grains using an electric oven model Y147893/17.

The weight of air-dried samples and the weight of oven-dried samples were determined and the moisture content evaluated using the expression:

$$M_c = \frac{W_S - D_W}{D_W} \times \frac{100}{1} \quad (5)$$

In equation (5), $W_S$ is the weight of rice parboiled sample, $D_W$ is the dried weight sample, and $M_C$ is the moisture content (%)

*2.3.2 Determination of the Mechanical (compressive) properties of the Rice Kernel Variety.*

Rice grains are usually subjected to forces, which affect the final quality of the processed rice especially during husking and milling such forces includes impact shear forces and frictional forces at the natural position [4]. The force of impact of the natural position of the rice kernel in terms of resistance of the grain compressive force with respect to the grain dimensions at natural position evaluated using universal testing machine ISTRON model 3339 connected to a computer. The grain behaviour to the compression was shown graphically with the aid of the computer software interface which shows the collapse of the grain and variation of the force during deformation across the grain dimension at the natural rest position.

## 3. Results and Discussions.

### *3.1 Results from the experiments.*

For rice grain to undergo any form of processing, handling, and storage, its moisture content must be determined. Table 1 shows the moisture content (wet basis) for the five varieties of rice that are used in this study. The experiment was carried out at the Engineering Material Testing and Development Institute Akure, Ondo state.

*Table 1: The Moisture Content of the five rice varieties.*

| Rice Varieties | Unit weight (g) | Can weight + Rice (g) | Weight of Can After Drying (g) | Moisture Content | PercentageMoisture Content (%) (wet basis) |
|---|---|---|---|---|---|
| IITA306 | 0.035 | 9.035 | 9.029 | 0.006 | 17.1 |
| RI8 | 0.029 | 10.029 | 10.024 | 0.005 | 17.2 |
| MAS | 0.028 | 9.028 | 9.023 | 0.005 | 17.8 |
| SML | 0.029 | 9.029 | 9.024 | 0.005 | 17.2 |
| R5 | 0.026 | 9.026 | 9.022 | 0.004 | 15.3 |

*Table 2: Shows the Biophysical Parameters of the Five Varieties.*

| Variety | Repli cation | Length (mm) | Width (mm) | Thickness (mm) | Sphericity | Surface Area (mm2) | Aspect Ratio | Volume (mm³) | Equivalent. Dia. (mm) | Weight (g) | True Density (g/mm³) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IITA306 | 1 | 7.92 | 1.87 | 2.50 | 0.310 | 31.155 | 4.235 | 19.800 | 2.052 | 0.022 | 0.001 |
| IITA306 | 2 | 7.9 | 1.88 | 2.05 | 0.311 | 31.185 | 4.202 | 19.841 | 2.052 | 0.018 | 0.000 |
| IITA306 | 3 | 7.92 | 1.86 | 2.51 | 0.309 | 31.130 | 4.423 | 19.800 | 2.052 | 0.022 | 0.001 |
| RI8 | 1 | 8.99 | 2.00 | 2.55 | 0.291 | 36.476 | 4.495 | 24.365 | 2.170 | 0.028 | 0.000 |
| RI8 | 2 | 8.99 | 2.00 | 2.55 | 0.291 | 36.476 | 4.495 | 24.365 | 2.170 | 0.027 | 0.000 |
| RI8 | 3 | 8.88 | 1.88 | 2.6 | 0.287 | 35.228 | 4.723 | 23.332 | 2.150 | 0.029 | 0.000 |
| MAS | 1 | 7.91 | 2.00 | 2.5 | 0.317 | 32.360 | 3.955 | 20.969 | 2.072 | 0.03 | 0.000 |
| MAS | 2 | 7.69 | 1.98 | 2.54 | 0.322 | 31.717 | 3.883 | 20.568 | 2.055 | 0.03 | 0.000 |
| MAS | 3 | 7.39 | 2.00 | 2.53 | 0.332 | 30.803 | 3.695 | 19.853 | 2.030 | 0.031 | 0.001 |
| SML | 1 | 8.94 | 2.39 | 1.76 | 0.310 | 32.537 | 3.740 | 20.157 | 2.101 | 0.039 | 0.001 |
| SML | 2 | 8.06 | 2.26 | 1.79 | 0.326 | 29.098 | 3.566 | 17.307 | 2.013 | 0.036 | 0.001 |
| SML | 3 | 8.78 | 2.31 | 1.99 | 0.310 | 33.686 | 3.800 | 21.253 | 2.113 | 0.038 | 0.001 |
| RI5 | 1 | 7.92 | 1.87 | 2.5 | 0.310 | 31.155 | 4.235 | 19.800 | 2.052 | 0.022 | 0.000 |
| RI5 | 2 | 7.90 | 1.84 | 2.53 | 0.308 | 31.012 | 4.293 | 19.750 | 2.051 | 0.018 | 0.000 |
| RI5 | 3 | 7.92 | 1.86 | 2.51 | 0.309 | 31.130 | 4.258 | 19.800 | 2.052 | 0.022 | 0.000 |

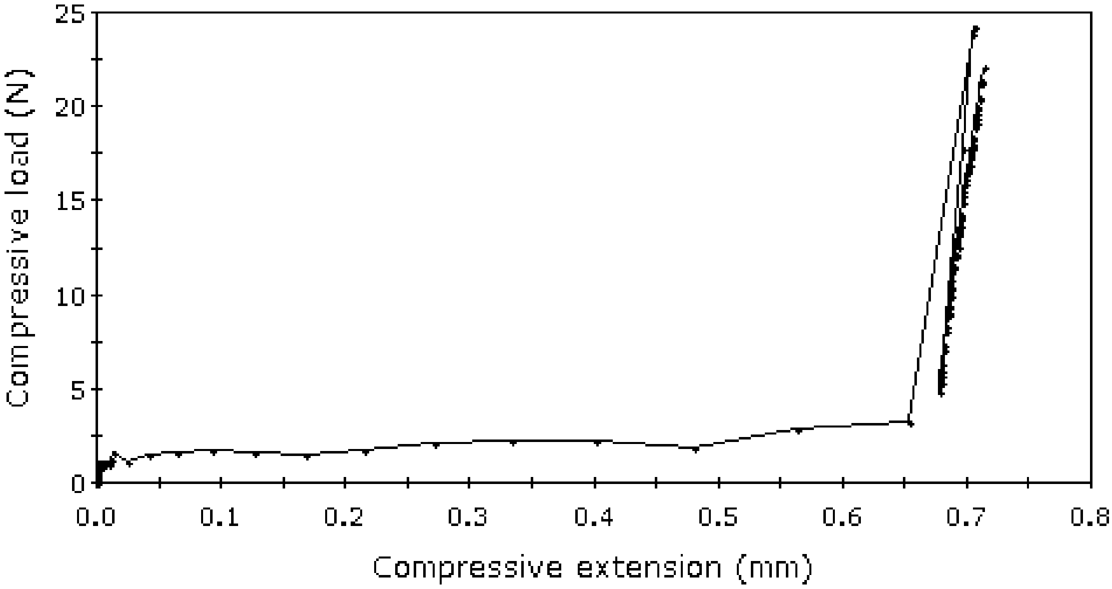


*Figure 1a: Graph of compressive force against the flat/horizontal position of rice grain (IITA306).*

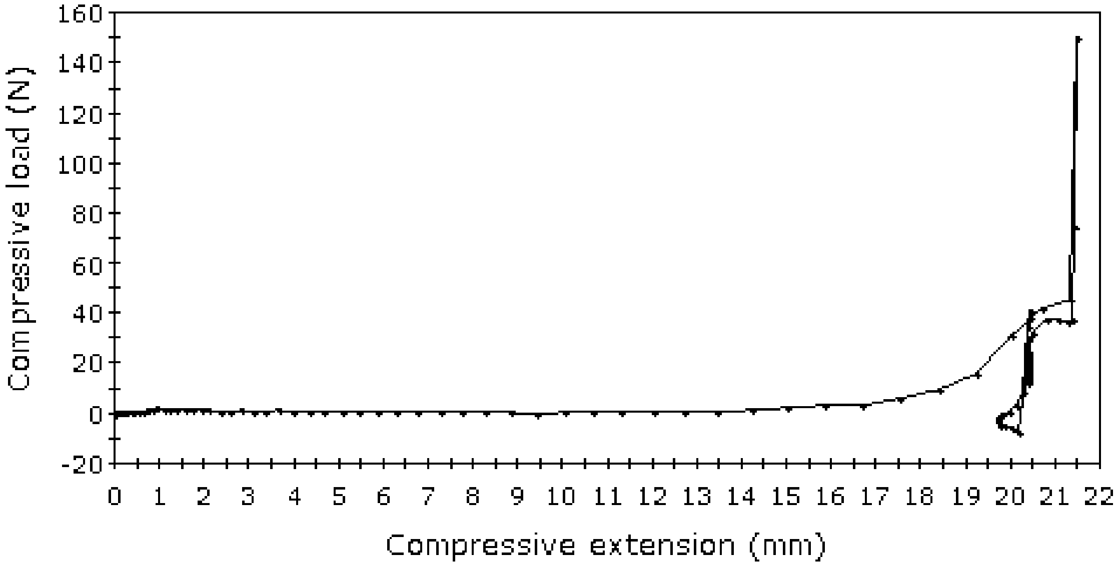


*Figure 1b: Graph of compressive force against the Vertical/ standing position of rice grain (IITA306).*

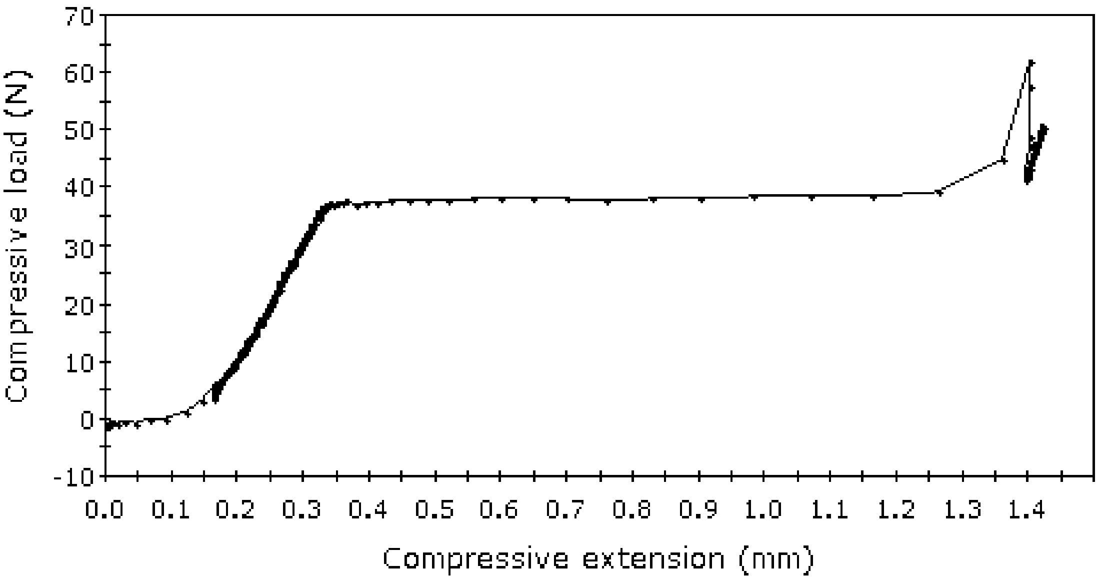


*Figure 2a: Graph of compressive force against the Flat/ Horizontal position of rice grain (MAS).*

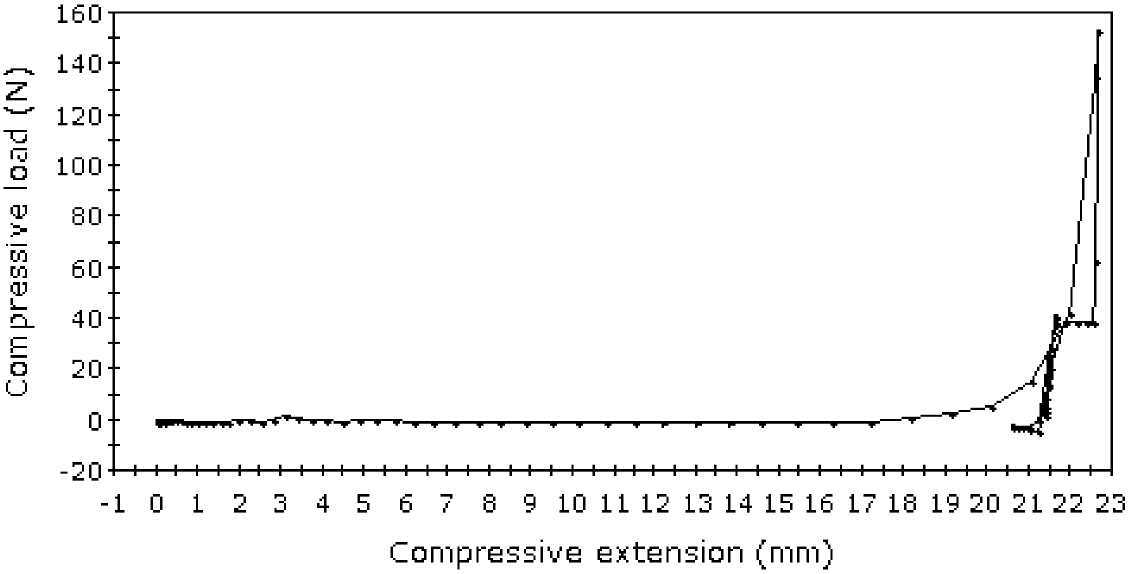


*Figure 2b: Graph of compressive force against the Vertical/ Standing position of rice grain (MAS).*

For rice grain to be subjected to forced-deformation resulting from handling, processing, heat treatments and storage, it is necessary to determine the biophysical parameters of the five rice varieties. Table 2 shows the biophysical parameter which includes: length, width, thickness, weight, Aspect ratio, Equivalent Diameter, Sphericity, Surface area, True density, volume.

However, the Mechanical (stress-strain) properties of the Rice Varieties were carried out bearing in mind the natural positions of the grains during milling operations (vertical/standing or flat/horizontal positions) as well as normal storage conditions which may be either in length, width or thickness whether vertical or horizontal position.

Figures 1a-5b shows graphs of rice varieties subjected to stress (compressive load) at different natural positions of rice grains (with respect to their dimension at Natural positions that are involved during milling and storage operation).

These are some the factors responsible for breakages during milling, handling and storages. From the graph shown in Figures 1a and 1b, it can be seen that the material obeyed Hooke's law until the point of failure (bio-yield point) that is the point of breakage or crack. At horizontal position, it requires about 25N for the rice grain (IITA306) to fail at 0.7mm. Meanwhile, it takes about 150N to crack the rice grain at a vertical position at 21.0mm.

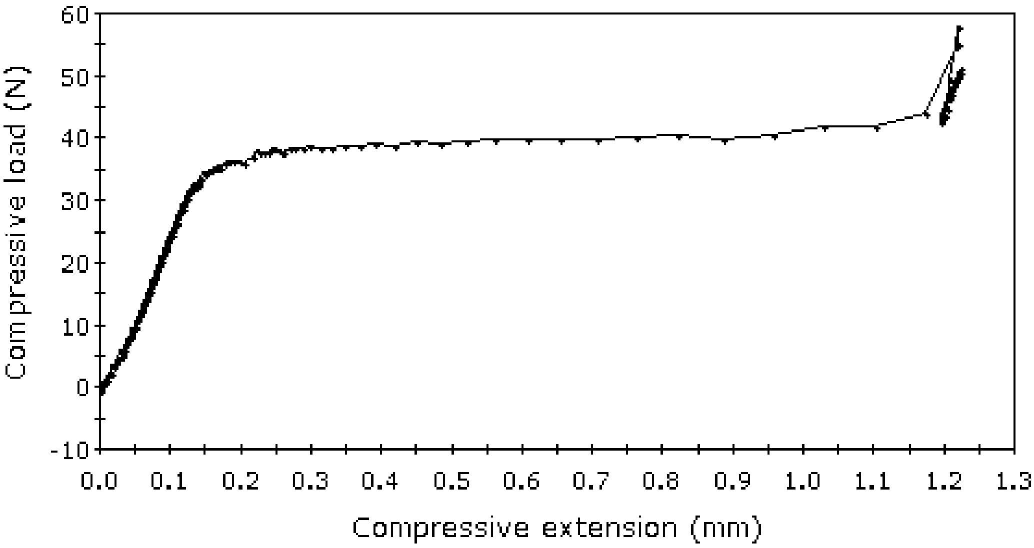


*Figure 3a: Graph of compressive force against the flat/horizontal position of rice grain (RI8).*

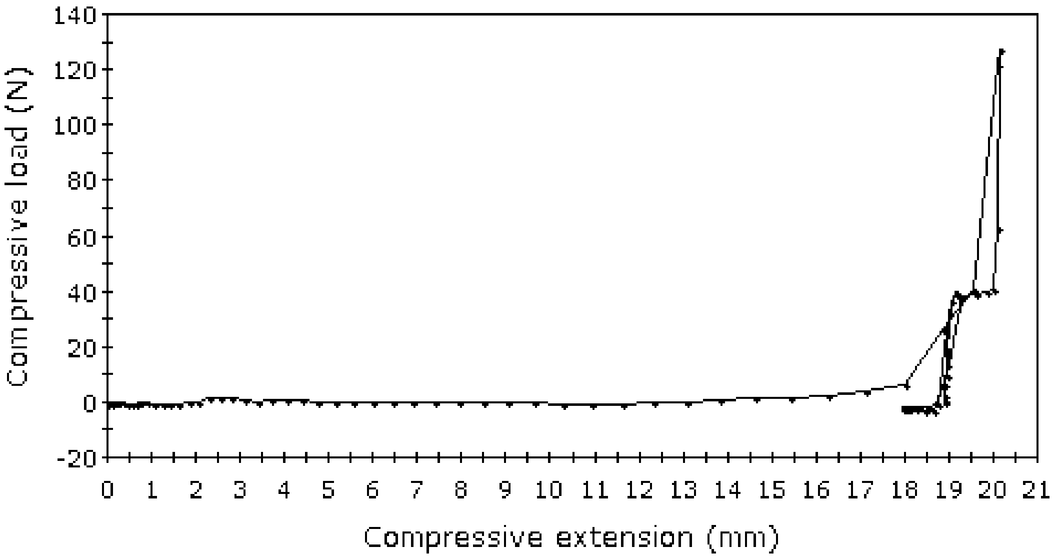


*Figure 3b: Graph of compressive force against the Vertical/ Standing position of rice grain (RI8).*

The moisture content of the rice variety at point of these tests is as shown in Table 1.

From the graph shown in Figures 2a and 2b, it can be seen that the material obeyed Hooke's law until the point of failure (bio-yield point) that is the point of breakage or crack. At horizontal position, it requires about 60N for the rice grain (MAS) to fail at 1.4mm. Meanwhile, it takes about 150N to crack the rice grain at a vertical position at 22.5mm. The moisture content of the rice variety at point of these tests is as shown in Table 1.

From the graph shown in Figures.3a and 3b, it can be seen that the material obeyed Hooke's law until the point of failure (bio-yield point) that is the point of breakage or crack. At horizontal position, it requires about 58N for the rice grain (R18) to fail at 1.2mm. Meanwhile, it takes about 125N to crack the rice grain at a vertical position at 20mm. The moisture content of the rice variety at point of these tests is as shown in Table 1.

From the graph shown in Figures 4a and b, it can be seen that the material obeyed Hooke's law until the point of failure (bio-yield point) that is the point of breakage or crack. At horizontal position, it requires about 13N for the rice grain (SmL) to fail at 0.93mm. Meanwhile, it takes about 110N to crack the rice grain at a vertical position at 23.5mm. The moisture content of the rice variety at point of these tests is as shown in Table 1

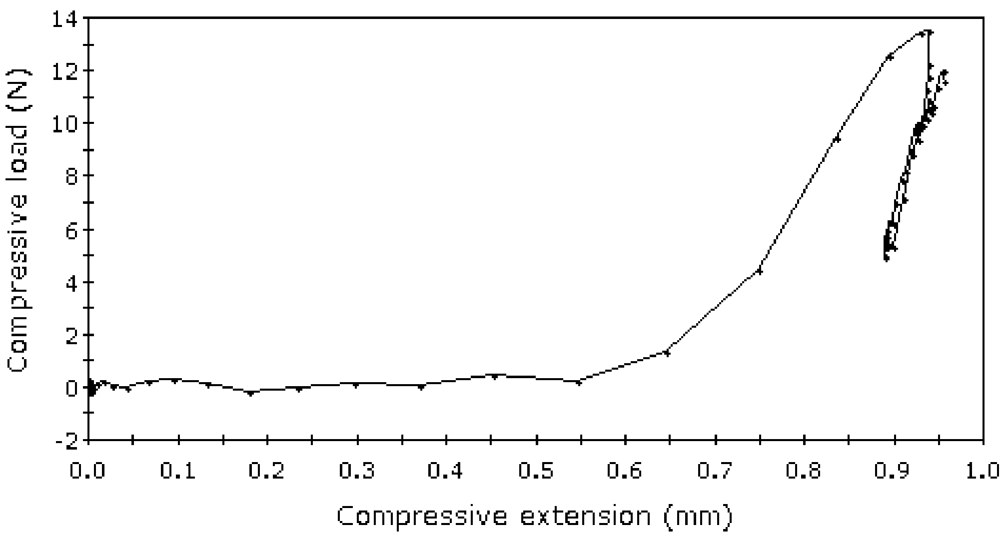


*Figure 4a: Graph of compressive force against the flat/horizontal position of rice grain (SML).*

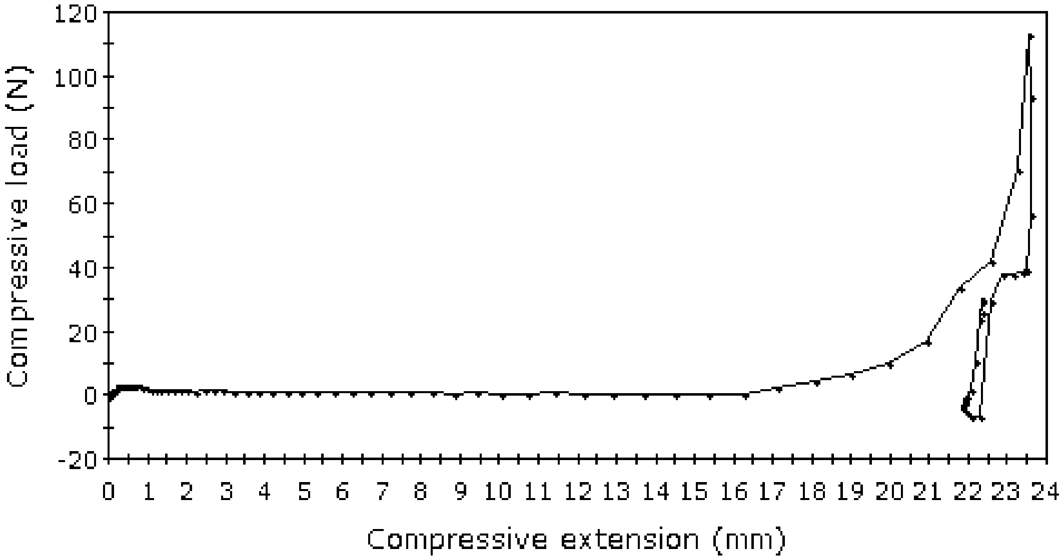


*Figure 4b: Graph of compressive force against the Vertical/ Standing position of rice grain (SML).*

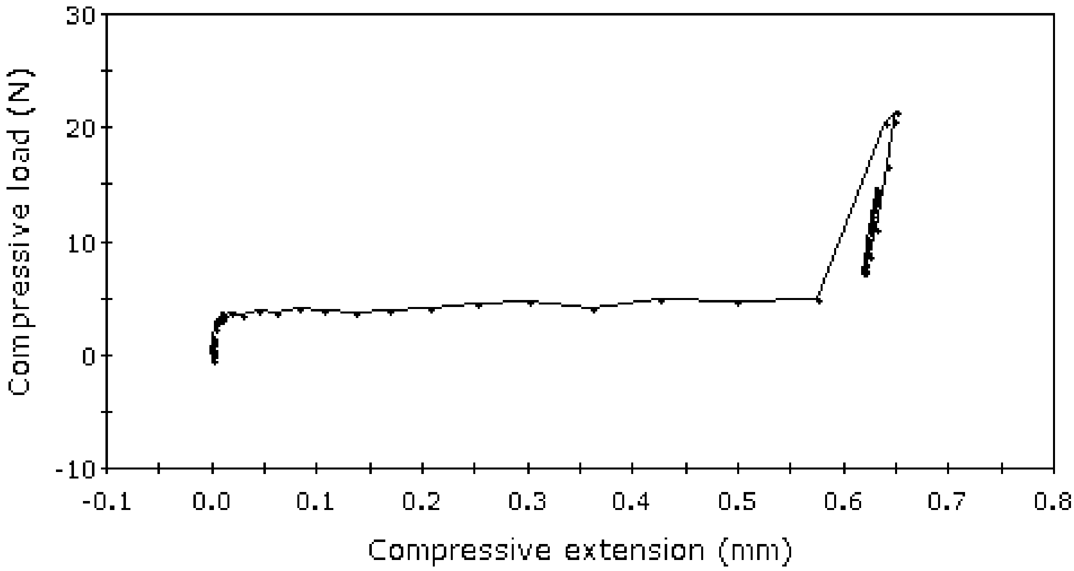


*Figure 5a: Graph of compressive force against the flat/horizontal position of rice grain (RI5).*

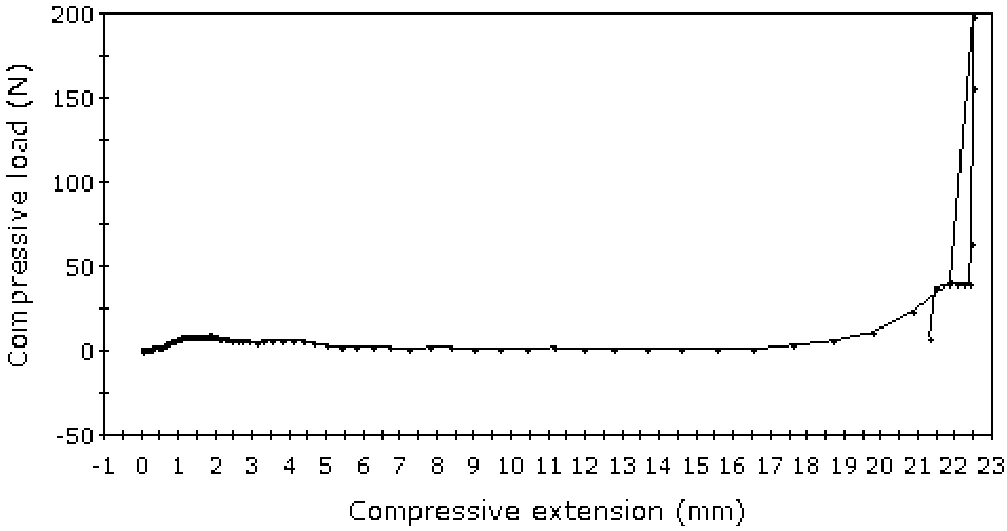


*Figure 5b: Graph of compressive force against the Vertical/ Standing position of rice grain (RI5)*

From the graph shown in Figures 5a and 5b, it can be seen that the material obeyed Hooke's law until the point of failure (bio-yield point) that is the point of breakage or crack. At horizontal position, it requires about 21N for the rice grain (R15) to fail at 0.65mm. Meanwhile, it takes about 200N to crack the rice grain at a vertical position at 22.5mm. The moisture content of the rice variety at point of these tests is as shown in Table 1.

## 4. Conclusion

The biophysical and mechanical properties of the rice grain (varieties) were also identified as the inherent causes of these losses especially during processing, handling and storage. It is one of the major sources of damage to rice grain during rice processing because it will affect other units of operation. From the results obtained, it can be concluded that rice grains subjected to compressive load at variation of contact area/ surfaces absorbed the shock, obeyed Hooke's law but yield at different compressive loads per areas /dimensions. Therefore, the modulus of elasticity for different rice varieties are specific and unique to each variety, at the moisture content range (15-18%) wb.

## 5. Recommendations

- Rice processing at mill complex should evolve from manually processed to integrated mechanized system with high precision of operation to reduce largely the quantity of rice lost during processing.
- Government should assist the private sector – the entrepreneurs who are involved in these activities with available finance/ logistic so that they can improve on the working conditions of the rice milling complex as well as expose the personnel to the latest technological breakthrough in post harvest technologies.
- Researches that are targeted for private sector usage should be encourage so that solutions can be provided to the group that need them to flourish capacity building that are private sector driven as seen at the mill complex.
- Rice production in Nigeria should leave the position of domestic consumptions to the stage of producing for the nation as well as exporting to earn foreign exchange.

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