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Selected Physical and Mechanical Properties of NERICA Paddy.

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Abstract

The determination of the physical and mechanical properties of ERICA paddy (FARO's 4-l(SIPI), 51 (Isadanc), 52(WITA 40) and 57(TOX4004-43-1-2-1)) at different moisture contents were carried out. The paddy rice was studied under un-parboiled and parboiled states. The results indicate that the size ranges were 3.88mm to 5.14mm for FARO 51; 3.91mm to 4.98mm for FARO 57; 3.62mm to 4.61mm for FARO 52 and 3.10mm to 4.82mm for FARO 44. This explains that no single sample of NERICA paddy can effectively represent the size of the other samples. In mechanical properties, results indicate that FARO 51 had highest values of rupture force, 42.00N at 13% moisture content in longitudinal loading position and FARO 52 had lowest values of rupture force, 23.10N at 13% moisture content for un-parboilcd samples in lateral loading position. FARO 51 had highest values of rupture force, 39.50N at BOlo moisture content in longitudinal loading position and FARO 52 recorded lowest rupture force, I5.80N at15°h moisture content for parboiled samples in lateral loading position. It implies that force beyond these points at this moisture contents may cause damage to the NERICA paddy.

KEYWORDS: NERICA, rice, physical and mechanical properties, moisture content, size, force deformation.

INTRODUCTION

After harvest, agro raw materials are normally handled, transported, dried, stored and further processed into food, feed and fiber.

In some basic post harvest activities, separation processes such as sorting, grading and cleaning are involved.

In mechanized operations, these post harvest processes are supposed to be carried out with machines and equipments. The engineering design and efficient operation of the post harvest processing machines and equipments require adequate knowledge of engineering properties of the bio-materials to be handled. Knowledge of engineering properties such as physical and mechanical properties constitute important and essential engineering data in the design of machines; storage structures; processes and controls as well as in the analysis and determination of the efficiency of machines, development of new consumer products of plants and animal origins and in the evaluation of the quality of food products. (Mohsenin,1986; Oluka, 1991; Oluka and Nwuba, 2001).

NERICA, also known as New Rice for Africa (NERICA) is a hybrid of the local African rice variety with high disease resistant traits and the high yielding variety of Asia. The rice is quite new to Africa and is currently being adopted and tried across the continent.

As a new product, there are on-going research studies on ERICA rice varieties. Studies on the engineering properties of the new rice variety are one of them.

Physical and Mechanical handling of the post harvest processing operation of NERICA require adequate knowledge of the physical and mechanical properties. Knowledge of these properties will be valuable to Engineers, Food Scientists and Processors in designing of machines, storage structures, processes and controls as well as in the development of new products and quality assessment of food products.

Akintayo, et al (2010), reported that NERICA varieties, being an inter- specific crossing of two rice species (African and Asian) led to progenies that were not sterile, have favourable agronomic characteristics, significant widening genetic variation and allowing rice farmers to profit from the Oryza. glaberrima gene pool. They reported that NERICA varieties have good agronomic performance and resistance to Africa's harsh growth conditions, and especially short growth duration, much appreciated by farmers. They maintained that NERICA resist pests, tolerate drought and grow in infertile soils better than most rice varieties. Okello et al (2012) studied NERICA cultivation and its yield determinants based on upland rice system and stated that the response of NERICA rice yield to nitrogen is as high as 46kgjha of paddy per 1kgjha of nitrogen applied; 1kgjha of increase in seeds applied increases rice yield by 8kgjha and that continuous planting of NERICA on the field reduces its yield by 130kgjha for every additional season of continuous planting.

Therefore, the information obtained is essential in the processing of rice paddy (NERICA) and prevention of mechanical damages during handling, processing and storage of the paddy. Equally, the knowledge of these properties will serve as a guide to designers of processing, storage and general handling equipments.

MATERIALS AND METHOD:

The research materials include four NERICA paddy varieties of FARO 44, 51, 52 and 57. These rice paddy samples were obtained from the Ebonyi State Agricultural Development Programme (EBADEP) at an average moisture content of 11 % (wb). The rice paddy samples were hydrated to obtain three more different moisture content levels of13%, 15% and 18% (wb) at which the test experiments were conducted. A total of 1000 rice paddy were used for the experiments and they were taken to Civil Engineering Material's laboratory, University of Nigeria Nsukka (UNN), for compression tests while the physical tests were done at Agricultural and Bioresource Engineering processing laboratory, Enugu State University of Science and Technology.

The apparatus used to carry out the research include; venire caliper of 0.0lmm accuracy used to measure the major, minor diameters and the thicknesses of the various rice paddy samples; metler electronic weighing balance model P1210 of 0.05kg sensitivity used for weight measurements; an electric oven of model number N30C Genlab, used to determine the moisture contents of the rice paddy.

The Honsfield Monsanto Tensometer model number S/W L8889 of ± 0.1 % accuracy having a maximum loading rate of 1350± 160N/S with a testing speed of 2.Smmj min used for compression test of the rice paddy for both parboiled and un-parboiled paddy under longitudinal and lateral loading positions. Relevant physical properties of NERICA paddy such as size, weight and volume were determined. The dimensions of the randomly selected NERICA paddy samples were measured at the different moisture contents of 13%,15% and 18% (wb) using venire caliper and a melter electronic weighing balance model number P1210 of 0.05kg sensitivity. The geometric mean diameter (GMO) and sphericity where calculated as follows (Mohsenin, 1986):

$$GMD = (abc)^{1/3} \ldots\ldots\ldots..(1)$$

$$S = \frac{GMD}{a} \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The quasi-static parallel plate compression tests were carried out using Monsanto Tensometer to determine the force-deformation characteristics of parboiled and un-parboiled NERICA paddy samples in longitudinal and lateral loading positions at three different moisture contents of 13%, 15% and 18% (wb).The NERICA paddy samples at different conditions (parboiled and un-parboiled) where placed in two loading positions on the compression jaws, making sure that the center of the tool was in alignment with the peak of the curvature of the NERICA paddy sample. Force was applied by turning the load arm of the testing machine at 2.5mmj min and the paddy loaded to a point of maximum break (rupture). This was accompanied by the corresponding drop on the force-deformation graph, which was plotted concurrently by the cursor and its attached needle, which punctured the graph sheet at frequent intervals thereby recording the force and the corresponding deformation. The resultant graph produced by joining the successive punctures shows the force-deformation curve, indicating bio-yield points and rupture force points which were measured at different loading positions and moisture contents. Thirty replications of the test were taken for each variety of NERlCA rice grain used. The test room temperature was maintained at 29°C.

After the experiments, the rupture force, deformation, modulus of deformability, toughness and stiffness of the tests samples were determined.

The rupture force was obtained at rupture point at which failure in micro-structure of the NERICA sample occurred. The modulus of deformability wsa determined from equation (1) (Mohsenin, 1986);

$$E = (1.13(1-r^2 (f^2 / D^3 d)^{1/2} \ldots\ldots\ldots\ldots\ldots (3)$$

where E= Modulus of deformability (Pa) r = Poisson's ratio (0.32, for agricultural materials)

f = Force in Newton (N)

D = Deformation in millimeter (mm)

d = diameter of the material in millimeter (mm) Toughness is the amount of work or energy required to bring about rupture in material. It was determined by computation of the area under the force-deformation curve before rupture, expressed as obtained in equation (2.0) (Mohsenin, 1986

$$\text{Toughness} = \frac{\text{Rupture Energy}}{\text{Volume of Material}} \ldots\ldots\ldots\ldots\ldots (4)$$

Stiffness was computed using equation (3.0) as reported by Maduako and Faborode (1994).

$$\text{Stiffness modulus} = \frac{\text{Maximum breaking force}}{\text{Maximum deformation at breaking (mm)}} \ldots\ldots\ldots\ldots (5)$$

Data Analysis

The experimental design was randomized complete design with factorial layout in which four varieties and two treatments at three levels of moisture content. The heat treatment effects were analyzed as well using the ANOVA and the least significant difference (LSD) test was used for means comparison of data.

RESULTS AND DISCUSSION

The data collected from the experiments were presented and analyzed using tables with descriptive statistical methods and graphs. These data were obtained from the measurements of the dimensions of the NERICA paddy; calculations of some properties and compression test results

Each value is the mean of 30 test samples. Values in parenthesis are the standard deviation (SD)

Table 2: The Physical Properties of Un-parboiled NERICA Paddy at Three Moisture Contents (% wb).

Each value is the mean of 30 test samples. Values in parenthesis are the standard deviation (SD)

Table 3: The Size Characteristics of Parboiled NERICA Paddy at Three Moisture Contents (%wb)

Each value is the mean of 30 test samples. Values in parenthesis are the standard deviation (SD)

Table 4: The Physical Properties Of Parboiled NERICA Paddy At Three Moisture Contents (% wb

Each value is the mean of 3n test samples. Values in parenthesis are the standard deviation (SD)

Table 5: Mechanical Properties Of Unparboiled NERICA Paddy At 13% Moisture Content (% wb).

Each value is the mean of 30 test samples. Values in parenthesis are the standard deviation (SD).

Table 6: Mechanical Properties Of Un-parboiled NERICA Paddy At 15% Moisture Content (% wb).

MECHANICAL PROPERTIES/LOADING POSITIONS	FARO 44	FARO 51	FARO52	FARO 57	MEAN
RUPTURE FORCE (N)					
LONGITUDINAL	36.05(6.58)	37.00(6.76)	30.01(5.48)	40.02(7.31)	35.77(6.53)
LATERAL	37.80(6.90)	30.20(5.51)	25.80(4.71)	39.90(7.29)	33.43(6.10)
DEFORMATION (mm)					
LONGITUDINAL	0.39(0.07)	0.61(0.11)	0.42(0.08)	0.60(0.10)	0.51(0.09)
LATERAL	0.41(0.08)	0.35(0.06)	0.45(0.08)	0.54(0.09)	0.44(0.08)
COMPRESSIVE STRENGTH (N/mm^2)					
LONGITUDINAL	5.73(1.05)	5.20(0.95)	5.87(1.07)	4.68(0.86)	5.37(0.98)
LATERAL	6.01(1.10)	4.24(0.77)	5.05(0.92)	4.67(0.91)	4.99(0.91)
MODULUS OF DEFORMABILITY ($l \times 10^6$)					
LONGITUDINAL	12.33(2.25)	6.44(1.18)	8.95(1.63)	7.22(1.32)	8.74(1.60)
LATERAL	11.10(2.03)	12.10(2.21)	6.94(1.27)	8.43(1.54)	9.64(1.76)
TOUGHNESS (N/mm^3)					
LONGITUDINAL	6.93(1.27)	5.87(1.07)	5.46(0.10)	5.80(1.06)	6.02(1.10)
LATERAL	7.27(1.33)	4.79(0.88)	4.69(0.86)	5.78(1.05)	5.63(1.03)
STIFFNESS (N/mm)					
LONGITUDINAL	41.54(7.58)	26.72(4.88)	32.38(5.91)	34.17(6.24)	33.70(6.15)
LATERAL	59.76(10.91)	48.03(8.77)	28.67(5.23)	59.44(10.85)	48.98(8.94)
FORCE AT BIO-Yield POINT(N)					
LONGITUDINAL	16.20	16.30	13.60	20.50	16.65
LATERAL	24.50	16.81	12.90	32.10	21.58

Each value is the mean of 30 test samples. Values in parenthesis are the standard deviation (SD)

Table 7: Mechanical Properties Of Un-parboiled NERICA Paddy At 18% Moisture Content (% wb).

Table 8: Mechanical Properties Of Parboiled NERICA Paddy At 13% Moisture Content (% wb

Ea ... tion (SD).

Table 9: Mechanical Properties of Parboiled NERICA Paddy At 15% Moisture Content (% wb).

MECHANICAL PROPERTIES/LOADING POSITIONS	FARO 44	FARO 51	FARO 52	FARO 57	MEAN
RUPTURE FORCE (N)					
LONGITUDINAL	33.05(6.03)	34. 70(6.34)	20.50(3.74)	22.90(4.18)	27.79(5.07)
LATERAL	25.90(4.73)	25.50(3.74)	15.80(2.89)	24.50(4.4 7)	22.93(4.19)
DEFORMATION (mm)					
LONGITUDINAL	0.52(0.09)	0.42(0.08)	0.57(0.10)	0.40(0.12)	0.48(0.09)
LATERAL	0.41 (0.07)	0.45(0.08)	0.35(0.06)	0.53(0.10)	0.44(0.08)
COMPRESSIVE STRENGTH (N/mm^2)					
LONGITUDINAL	4.03(0.74)	3.57(0.65)	2.86(0.52)	1.96(0.36)	3.11(0.57)
LATERAL	3.16(0.58)	2.62(0.48)	2.21 (0.40)	2.09(0.38)	2.52(0.46)
MODULUSOF DEFORMABILITY(l $x10^6$)					
LONGITUDINAL	7.88(1.44)	11.68(2.13)	4.16(0.76)	8.32(1.52)	8.01(1.46)
LATERAL	8.82(1.61)	7.74(1.41)	6.67(1.22)	5.84(1.07)	7.27(1.33)
TOUGHNESS (N/mm^1)					
LONGITUDINAL	6.12(1.12)	5.10(0.93)	3.54(0.65)	3.18(0.58)	4.49(0.82)
LATERAL	4.80(0.88)	3.75(0.69)	2.72(0.50)	3.40(0.62)	3.67(0.67)
STIFFNESS (N/mm)					
LONGITUDINAL	38.46(7.02)	59.52(10.87)	14.04(2.56)	47.00(8.58)	39.76(7.26)
LATERAL	58.78(10.73)	30.00(5.48)	28.86(5.27)	23 .02(4.20)	35.17(6.42)
FORCE AT BIO-YIELD POINT(N)					
LONGITUDINAL	20.00	25.00	8.00	18.80	17.95
LATERAL	24.10	13.50	10.10	12.20	14.98

Each value is the mean of 30 test samples. Values in parenthesis are the standard deviation (SD)

Table 10: Mechanical Properties Of Parboiled NERICA Paddy At 18% Moisture Content (% wb).

MECHANICAL PROPERTIES/LOADING POSITIONS	FARO 44	FARO 51	FARO 52	FARO 57	MEAN
RUPTURE FORCE (N)					
LONGITUDINAL	25.91(4.73)	35.90(6.55)	25.00(4.56)	38.10(6.96)	31.23(5.7)
LATERAL	20.10(3.67)	30.10(5.50)	29.00(5.30)	20.00(3.65)	24.48(4.5)
DEFORMATION (mm)					
LONGITUDINAL	0.51 (0.09)	0.39(0.07)	0.70(0.13)	0.48(0.09)	0.52(0.10)
LATERAL	0.40(0.07)	0.43(0.08)	0.41(0.08)	0.22(0.04)	0.37(0.07)
COMPRESSIVE STRENGTH (N/mm^2)					
LONGITUDINAL	2.82(0.52)	2.91(0.53)	3.09(0.56)	3.58(0.65)	3.10(0.57)
LATERAL	2.19(0.40)	2.44(0.45)	3.58(0.65)	1.88(0.34)	2.52(0.46)
MODULUS OF DEFORMABILITY($lx10^6$)					
LONGITUDINAL	6.67(1.22)	13.79(2.52)	3.97(0.73)	10.64(1.94)	8.77(0.81)
LATERAL	7 .44(1.36)	9.99(1.82)	10.26(1.87)	18.01(3.29)	11.43(2.0)
TOUGHNESS (N/mm)					
LONGITUDINAL	4.39(0.80)	3.96(0.72)	3.85(0.70)	4.89(0.89)	4.46(0.81)
LATERAL	3.41 (0.62)	67.69(12.36)	4.46(0.81)	2.56(0.47)	3.60(0.66)
STIFFNESS (N/mm)					
LONGITUDINAL	43.22(7.89)	4.72(0.86)	14.29(2.61)	50.83(9.28)	44.01(8.0)
LATERAL	38.75(7.08)	55.35(10.11)	36.83(6.72)	73.64(13.45)	51.14(9.3)
FORCE AT BIO -YIELD POINT(N)					
LONGITUDINAL	22.04	26.40	10.00	24.40	20.71
LATERAL	15.50	23.80	15.10	16.20	17.65

Each value is the mean of 30 test samples. Values in parenthesis are the standard deviation (SD).

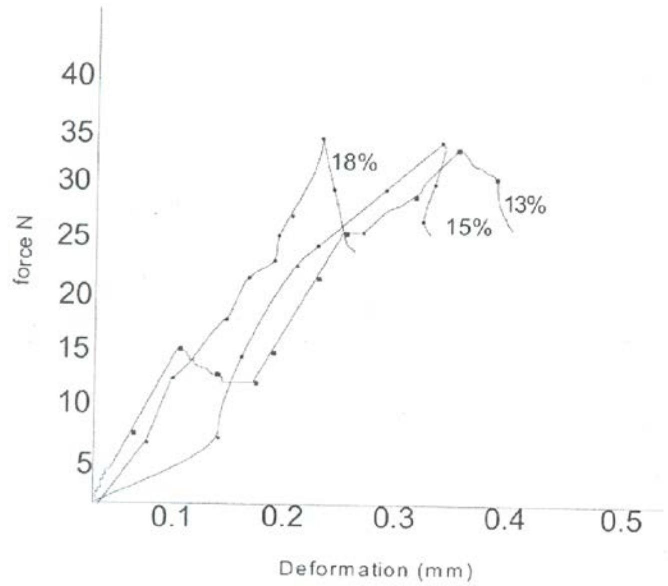

Fig 1: Force - Deformation Curve for Un-parboiled FARO 44 NERICA Paddy (Longitudinal loading position) at Three Moisture Content levels (% wb).

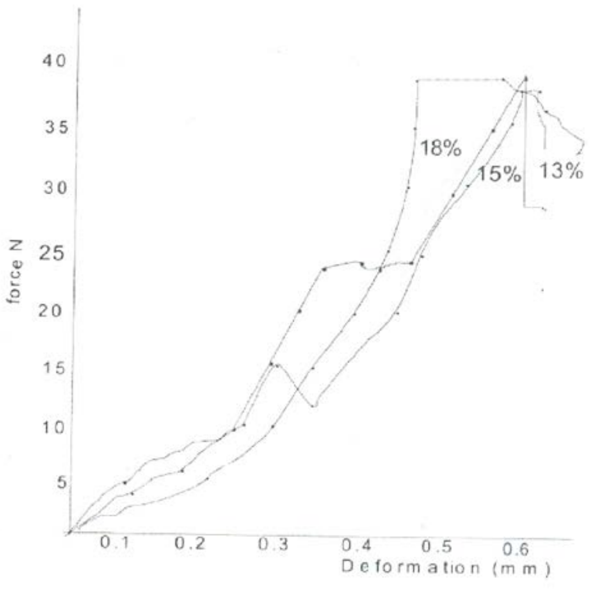

Fig 2: Force - Deformation Curve for Un-parboiled FARO 51 NERICA Paddy (Longitudinal loading position) at Three Moisture Content levels ('% wb).

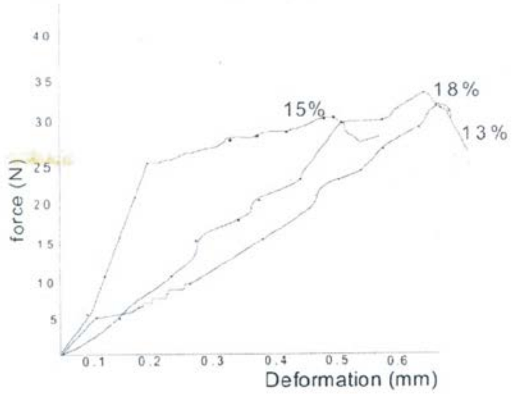

Fig 3: Force - Deformation Curve for Un-parboiled FARO 52 NERICA Paddy (Longitudinal loading position) at Three Moisture Content levels (%wb).

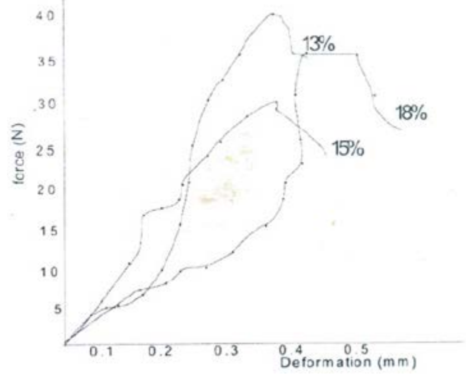

Fig 6: Force - Deformation Curve for Un-parboiled FARO 51 NERICA Paddy (Lateral loading position) at Three Moisture Content levels (%wb).

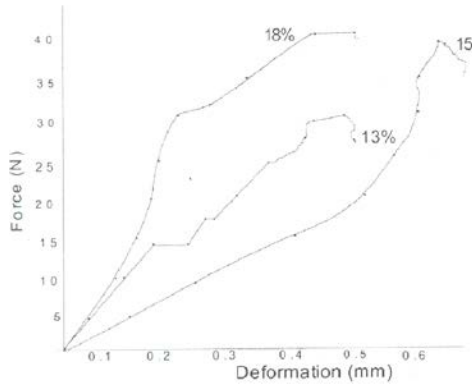

Fig 4: Force - Deformation Curve for Un-parboiled FARO 57 NERICA Paddy (Longitudinal loading position) at Three Moisture Content levels (%wb).

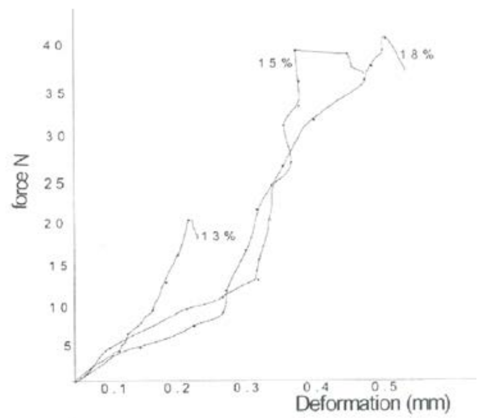

Fig 7: Force - Deformation Curve for Un-parboiled FARO 52 NERICA Paddy (Lateral loading position) at Three Moisture Content levels (%wb).

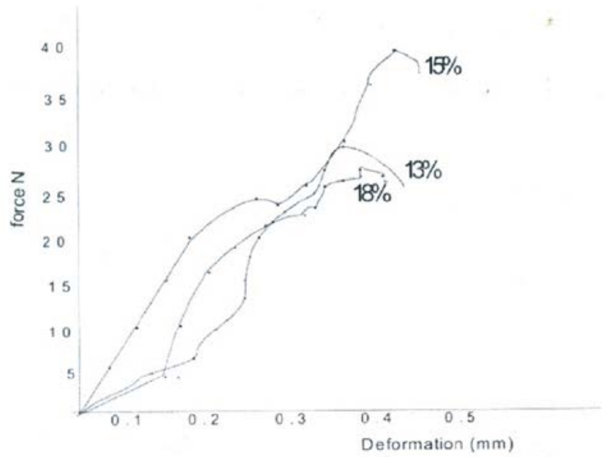

Fig 5 force - Deformation Curve for Un-parboiled FARO 52 NERICA Paddy (Lateral loading position) at Moisture Content levels (%wb).

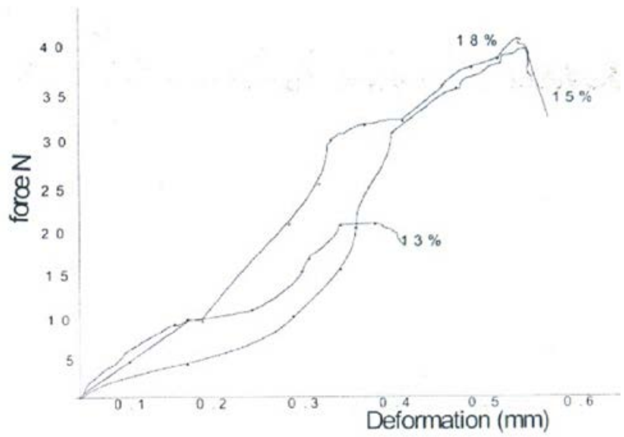

Fig 8: Force - Deformation Curve for Un-parboiled FARO 57 NERICA Paddy (Lateral loading position) at Three Moisture Content levels (%wb).

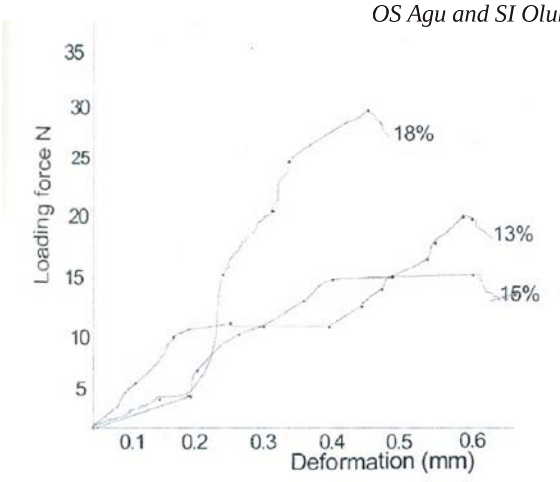

Fig 15: Force - Deformation Curve for Parboiled FARO 52 NERICA Paddy (Lateral loading position) at Three Moisture Content levels (%wb).

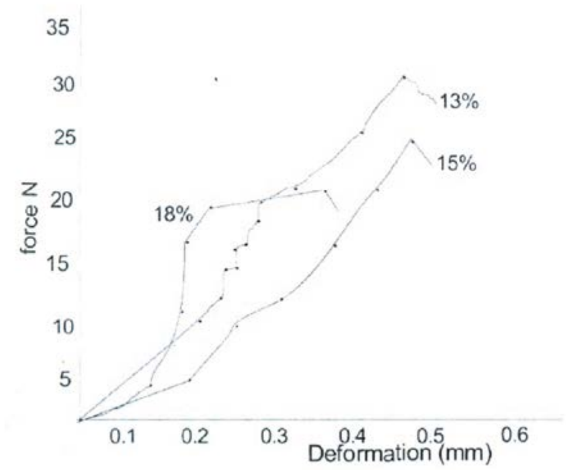

Fig 16: Force - Deformation Curve for Parboiled FARO 57 NERICA Paddy (Lateral loading position) at Three Moisture Content levels (%wb),

Size/Dimensional Properties

Tables 1 and 3 show the size characteristics of the ERICA paddy at different moisture contents of un-parboiled and parboiled conditions, The dimensions increased with increase in moisture content and the differences between the values were statistically significant at P > 0.01. This shows that there is an increase in the dimensions which contributed to expansion as a result of moisture intake within the paddy rice.

The size observations show that FARO 57 recorded highest value on GMD; ranged from 3.91mm to 4.42mm and the least was FARO 52 ranged from 3.62mm to 4.24mm for un- parboiled condition. While FARO 51 recorded highest value in GMD in table 3; ranged from 4.70mm to 5.14mm and the least was FARO 44 ranged from 3.10mm to 4.82mm for parboiled condition all at 13%, 15% and 18% moisture content. These indicate that NERICA paddy rice has a wide size ranges and no single sample of the paddy can effectively represent the other. This indication is in line with Oluka and Nwuba (2001) that no single variety can be effectively use to represent the size characteristics of other varieties in design and post harvest handling of the crop.

Sphericity

The sphericity of NERICA paddy in Tables 2 and 4 increased with increasing moisture content, indicating that sphericity of the paddy rice was statistically significant (P > 0.01) as the moisture increased. In Table 2 at 18% moisture content, FARO 52 recorded highest value of sphericity 0.409 (0.075) and the least was FARO 44; 0.366 (0.067) at 13% moisture content. While in Table 4 at 18% moisture content FARO 57 recorded highest value of 0.432(0.079) and FARO 44 was the least at 13% moisture content 0.298 (0.054).This indicates that relative proportional changes occurred in the dimensions of the NERICA paddy samples. A similar report by Asoegwu et al (2006) said that sphericity increased with decrease in seed size with the small sized seeds having the highest sphericity.

Volume:

The NERICA paddy volume increased with the increase of moisture content in Tables 2 and 4. The volume increased from 5.00 mm to 7.80mm^3 at 13% to 18% moisture contents in Table 4.1n table 2, it increased from 4.40 mm to 7.60mm^3 at 13% to 18% moisture contents (statistically significant at P > 0.01) This increase in volume may be attributed to expansion in size dimensions which was as a result of weight increase of the rice paddy that resulted to the displacement of more liquid. (Moshenin, 1986).

Bulk Density and Specific Gravity:

In Table 2, the bulk density of NERICA paddy varied front 0.0064g/ mm at 13% moisture content to 0.0051g/ mm at 18% moisture content and in Table 4, the values were 0.0068g/mm^3, O.0062g/mm', O.0063g/mm^3 at 13%, 15% and 18% moisture contents for FARO's 51, 52 and 57 respectively. This result indicates a decrease in bulk density and specific gravity with an increase in moisture content (P > 0.01). This implies that there was an increase in mass of the sample owing to the moisture in the paddy which was lower than the volumetric expansion of the bulk agro-material, as reported by Mwithiga and Sifuna (2006) for Sorghum seeds.

Surface Area:

In Table 2, the surface area of the NERICA paddy increased from 4.870mm^2 to 8.584mm^2 and in table 4; 5.985mm^2 to 12.321mm^2 when the moisture content increased from 13% to 18% moisture contents (P > 0.01). The results indicate that the increase in the values may be attributed to their dependence on the size dimensions of the NERICA paddy which can be linked to Oluka and Nwuba (2001) report for cowpeas. Tables 5 to 10 and Figures 1 to 16 represent the mechanical properties of NERICA paddy at three (13%, 15% and 18%) moisture contents for two loading positions (longitudinal and lateral) and in two states of unparboiled and parboiled.

Tables 5 to 10 and Figures 1 to 16 showed a significant effect on mechanical properties. FARO's 51 and 57 had significant higher values in all the properties in Tables 5 to 7. FARO 51 had highest values of rupture force 42.00N and 40.00N at 13% and 18% moisture contents and FARO 52 at 13%, 15% and 18% moisture contents had lowest rupture force values 32.20N, 30.01N and 33.98N in longitudinal loading position. In lateral loading position, FARO 51 had the highest values of rupture force, 39.98N at 13% moisture content and the lowest was FARO 52(23.10N) at 13% moisture content.

FARO 51 had significant highest values in all the properties in tables 4.8 to 4.10. At rupture point, FARO 51 recorded highest values; 39.50Nand 34.70N at 13% and 15% moisture contents and FARO 52 was the lowest, 20.50N at 15% moisture content in longitudinal loading position. FARO 51 had highest values of rupture force; 35.00 at13% moisture content and recorded lowest value; I5.80N at 15% moisture content for FAR0 52 in lateral loading position.

In Table 5 to 7, the compressive strength of NERICA paddy sample was more in FARO 44 (7.17N/mm2) longitudinal loading position at 13% moisture content and the least was FAR057 (3.37N/ mm^3) at 13% moisture content for lateral loading position.

Compressive strength in Tables 8 to 10 indicate highest at 13% moisture content in longitudinal loading position for FARO 44 (5.35/mm^2) and lowest at 18% moisture content for FARO 57 (1.88N/ mm") forlateralloading position.

These indicate that little force is required to cause rupture on the NERICA paddy as reported by Maduako et al (2001) on bambara nuts. The modulus of deformability was experienced more at 18% moisture content of un-parboiled NERICA paddy sample for FARO 57 (18.01Mpa) in lateral loading position and in unparboiled at 13% moisture content for FARO 44 (17.99Mpa) longitudinal loading position.

In tables 5 to 7 and figures 1 to 8, the bio yield force falls from 26.10N at 13% moisture content for FARO 57 to 5.70N at 18% moisture content for FARO 52 in longitudinal and lateral loading positions. In tables 8 to 10 and figures 9 to 16, the bio-yield force falls from 26.40N at 18% moisture content for FARO 51 to 8.00N for FARO 52 at 15% moisture content longitudinal loading position. It was discovered that the interactions between NERICA paddy samples, speeding of loading and position had significant effects on the compressive strength while the loading position and loading speed had significant effect on the rupture force and modulus of deform ability, respectively at the 99% probability level.

From the results of this research work, the following findings were made;

1. There is significant effect (P = 0.01) in the sizes of the NERICA varieties. This

indicates that no single variety can be used to represent effectively the size of the other varieties in terms of physical and mechanical properties. (Olukaand Nwuba, 2001).

2. The effect of heat treatment on the rice paddy has a significant effect of the physical and mechanical structure of the NERICA paddy samples on different least significant difference at different moisture contents.
3. FARO 57 has the highest size values of 4.98mm in parboiled and 4.42mm in unparboiled in all the moisture contents.
4. The deformation of NERICA paddy was affected significantly with increase in moisture content irrespective of the variety at different moisture contents.
5. The force at breaking occurred highest in unparboiled state at 18% moisture content (25.20N) for FARO 51 and rupture point occurred highest at the force of 42.00N; 40.02N and 40.00N at 13%, 15% and 18% moisture content while in parboiled state, the force at breaking occurred highest at 18% moisture content (26.40N) for FARO 51 and rupture point occurred highest at the force of 39.50N at13% moisture content for FARO 51. This indicates that any force beyond these points at this moisture contents may cause damage to the NERICA paddy.
6. In generally, the effects on the size for rupture force, deformation and toughness indicate that the force required to initiate paddy rupture was greater at longitudinal loading position of un-parboiled NERICA paddy than in lateral loading position of parboiled NERICA paddy samples.

CONCLUSION

This research study has identified some physical and mechanical properties of NERICA paddy and these can be used in the design of post harvest handling machines for NERICA varieties. The distinctive shapes and sizes of the various NERICA paddy as identified by the values of surface area and size distribution can be effectively utilized for the selection of sizes and shapes of screens used in the mechanical separation of NERICA paddy.

It also noticed that the mean rupture force required in breaking the paddy increased as the moisture content increases. The deformation of the NERICA paddy also increased as the moisture content increases in the four varieties of ERICA paddy studied under un-parboiled and parboiled states. The bio-yield force for both states (un-parboiled and parboiled) is affected significantly by moisture content, size and loading positions. These indicate that rupture force and toughness of NERlCA paddy at both states are necessary in choosing design parameters for the estimation of maximum power requirement in equipment / machine design and operation.

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