African Journal of Food Science and Technology ((ISSN: 2141-5455) Vol. 4(10) pp. 211-220, December, 2013
DOI: http:/dx.doi.org/10.14303/ajfst.2013.050
Available online @http://www.interesjournals.org/AJFST

Full Length Research Paper

Effects of moisture content on some mechanical properties of Soybean (Glycine max) varieties

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ABSTRACT

The study examines the effect of moisture content on some mechanical properties of soybean. Two soybean varieties – TGx1987-10F and TGx1987-62F were conditioned at two moisture content level of 6.51% and 10.35%. The varieties were classified and identified as samples A_1, A2 and B_1, B_2 for the two varieties respectively. Experiment was conducted using a testometric machine, and values for the following mechanical properties were obtained apart from other parameters; Force at break (N) and Deformation at break (mm)for different conditioned moisture levels. At the moisture content of 6.51% values of the stated parameters for TGx1987-10Fare 1907N and 9.9929mm while forTGx1987-62F are 916N and 9.9622mm. Also at the moisture content of 10.35%, force at break is 429.6N for deformation of 9.9953mm for TGx1987-10F while that of TGx1987-62F are 287.7N and 9.9925mm respectively. The study concluded that for every increase in moisture content, less force is required to break the soybean seed. Hence, force at break and moisture content has a significant effect on the compressive strength of the soybean. There is also a significant difference in the values of compressive strength of the two varieties. The values are higher in TGx1987-10F variety than the TGx1987-62F variety at conditioned moisture levels.

Keywords: Mechanical properties, moisture content, force, energy, soybean.

INTRODUCTION

Soybean is a leguminous vegetable of the Pea family that grows in tropical, subtropical and temperate climates. Soybean has a high protein content of 40% by weight, 32% carbohydrate, 20% fat, 5% minerals, and 3% fiber and other trace substances. It is used as sources of protein in human food, animal feed and in industries (Adekunle et al., 2006). Approximately, 85% of the world's soybean crop is processed into soybean meal and vegetable oil (Endres, 2001).Soybean seed contains about 19% oil. In the extraction of soybean oil from seed, the soybeans are cracked, adjusted for moisture content, rolled into flakes and solvent extracted with commercial hexane (Hookgenkamp and Henk, 2005).Effective cracking of nut as reported by Eric et al 2009 is dependent on the stiffness modulus and the sizes of nuts. Cracking of palm nut under repeated impact load with the objective of minimizing kernel breakage was modeled by koya, 2006. The models were based on the conservation of energy impacted on the nut by a falling weight, on the kinetic energy of a moving nut and strain energy required in breaking the nut shell. Three parameters were identified by Ndukwu and Asoegwu, (2010) as influencing the performance of cracking operation, cracking speed, moisture content and the feed rate. The knowledge of compressive strength of grains is generally required by scientist, machine, designers and processors in the development of appropriate machines for harvesting, milling, and oil extraction from the seed (Ajibola et al., 1990). The compressive strength will indicate the yield, load required, for shearing to different moisture levels. Methods for achieving this depend on the composition of raw materials. For example, seeds and nuts are processed wet.

Oil processing is categorized into three stages of

Figure 1. Universal Testometric material testing machine

Figure 2. Graph of Force at Break (N) against Deformation at break (mm) for Variety TGx1987-10F at 6.51% MC

Figure 3. Graph of Force at Break (N) against Energy to break (NM) for Variety TGx1987-10F at 6.51% MC

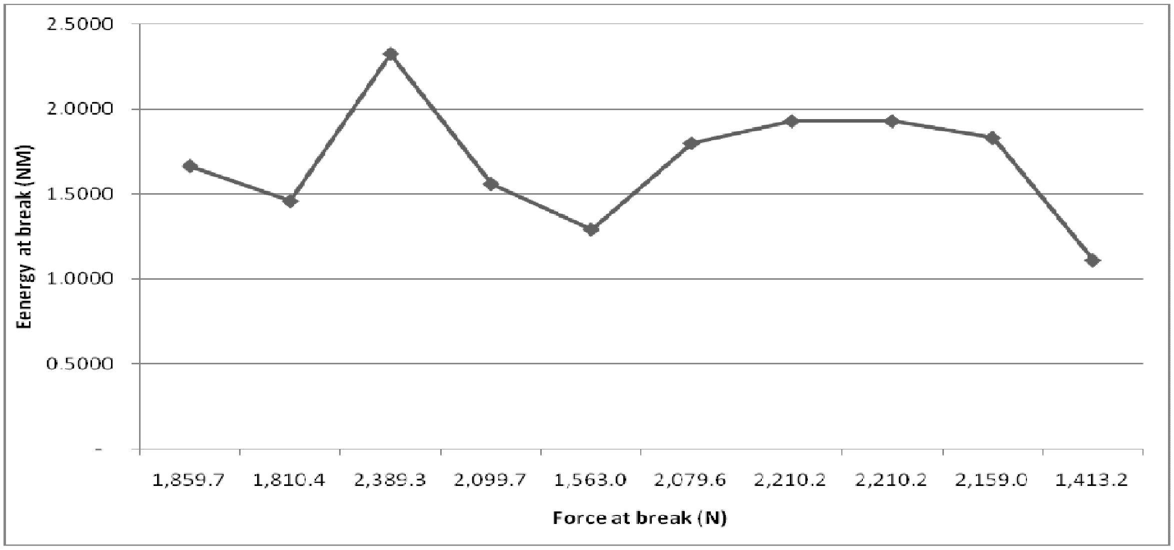
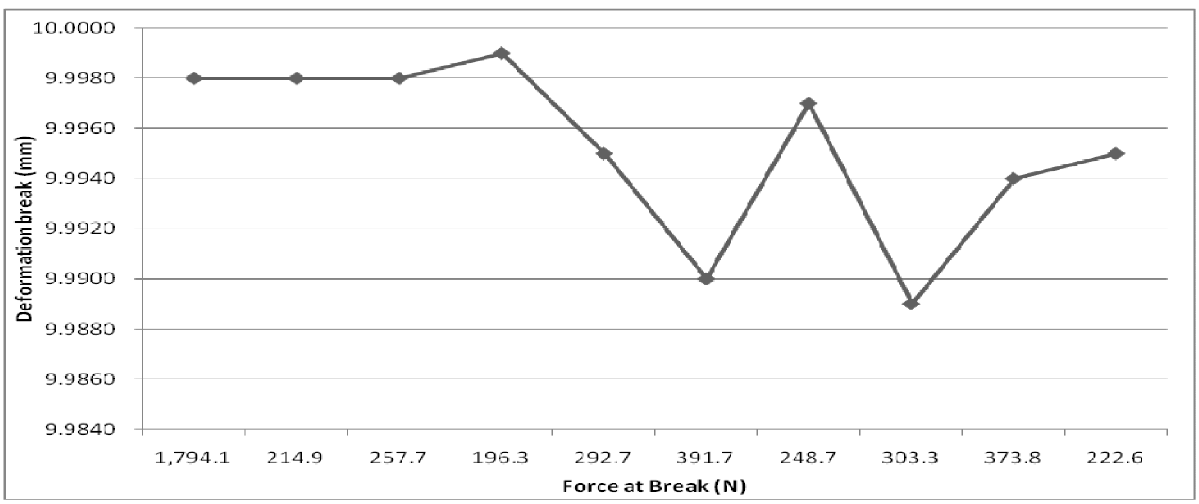


Figure 4. Graph of Force at Break (N) against Deformation at Break (mm) for Variety TGx1987-10F at 10.35% MC



preparation of raw material, extraction and storage. Akinoso (2006), revealed that particle size of the seed, applied pressure, moisture content, heating duration and duration processing are identified factors influencing the yield and quality of oil seeds using hydraulic press. It was reported that important variables in palm kernel pre-treatment are temperature, retention time and moisture content. High operational efficiency was recorded while pressing oil seeds with low moisture content (Patil and Sharman, 1998). Effects of processing parameters on mechanical expression of oil from melon seeds were also reported. The studied parameters were moisture content, particle size, pre-heating temperature and duration. Highest oil yield of 80% was recorded at a pressure of 25MPa and 5% moisture content. It was stated in the report that oil yield was mostly dependent on the amount of moisture reduction achieved during heating. Also the effects of thermal and hydro thermal pre-treatment on oil point of raw soybean extruded soybean and blanched soy split. Mechanical compression was carried out with the aid of carver press. The result showed that raw soybean required the highest pressure to reach the oil point and extruded soybean. Also, increasing moisture content increased the oil point pressure for all the samples (Kamal-din and Appeloquist, 1995).Nwagugu and Okonkwo (2009) reported the effect of moisture

Figure 5. Graph of Force at Break (N) against Energy to break (NM) for Variety TGx1987-10F 10.35% MC

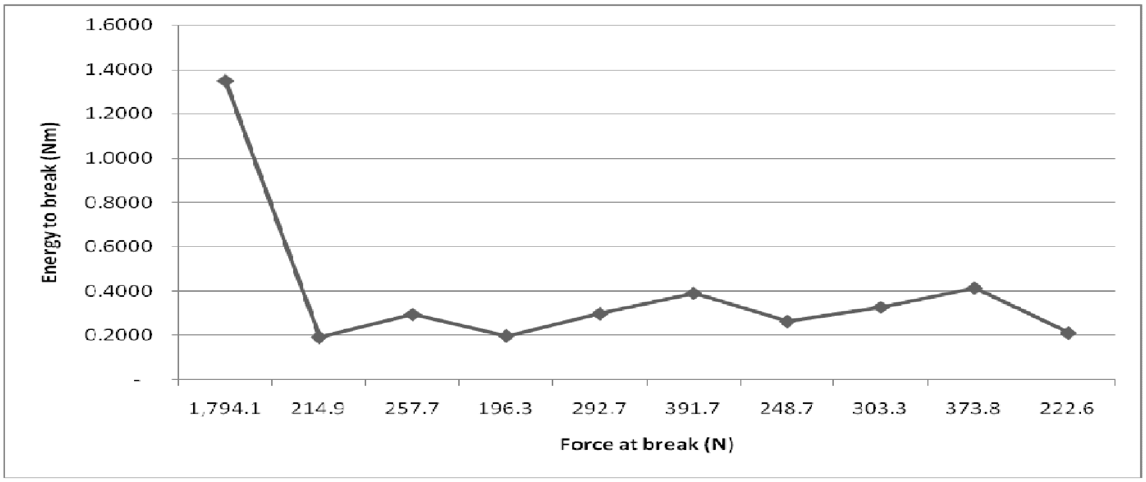


Figure 6. Graph of Force at Break (N) against Deformation at break (mm) for Variety TGx1987-62F at 6.51% MC

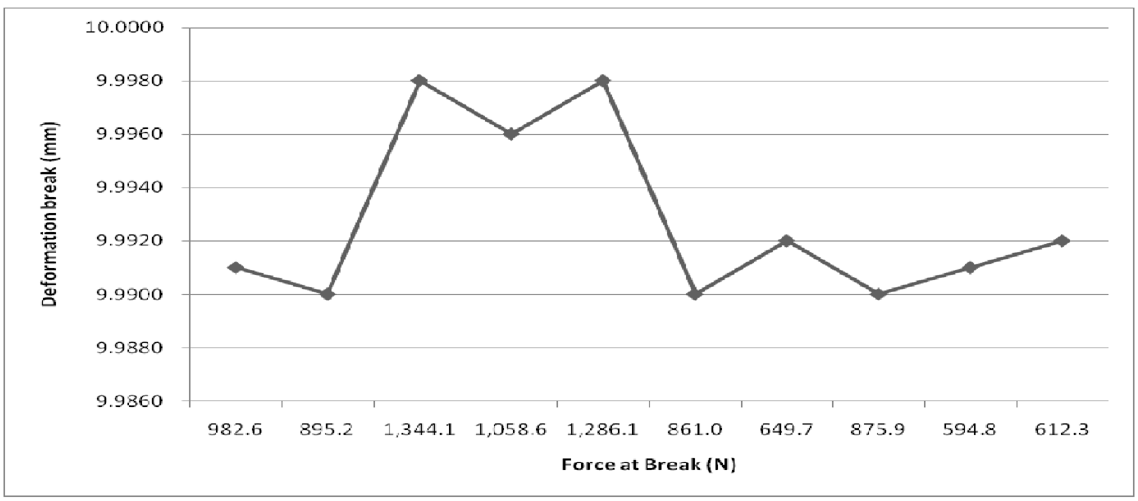


Figure 7. Graph of Force at Break (N) against Energy to break (NM) for Variety TGx1987-62F 6.51% MC

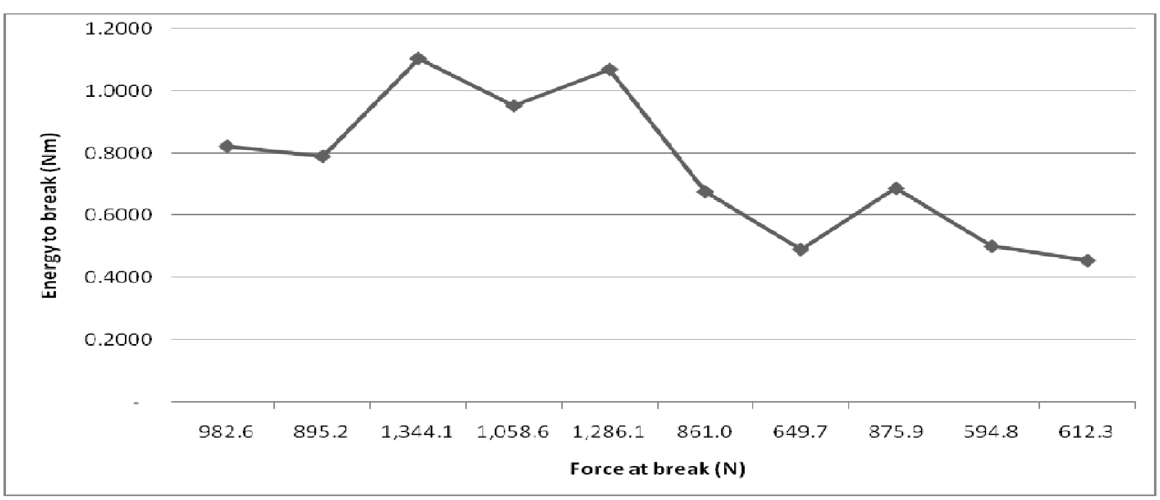


Figure 8. Graph of Force at Break (N) against Deformation at break (mm) for Variety TGx1987-62F at 10.35% MC

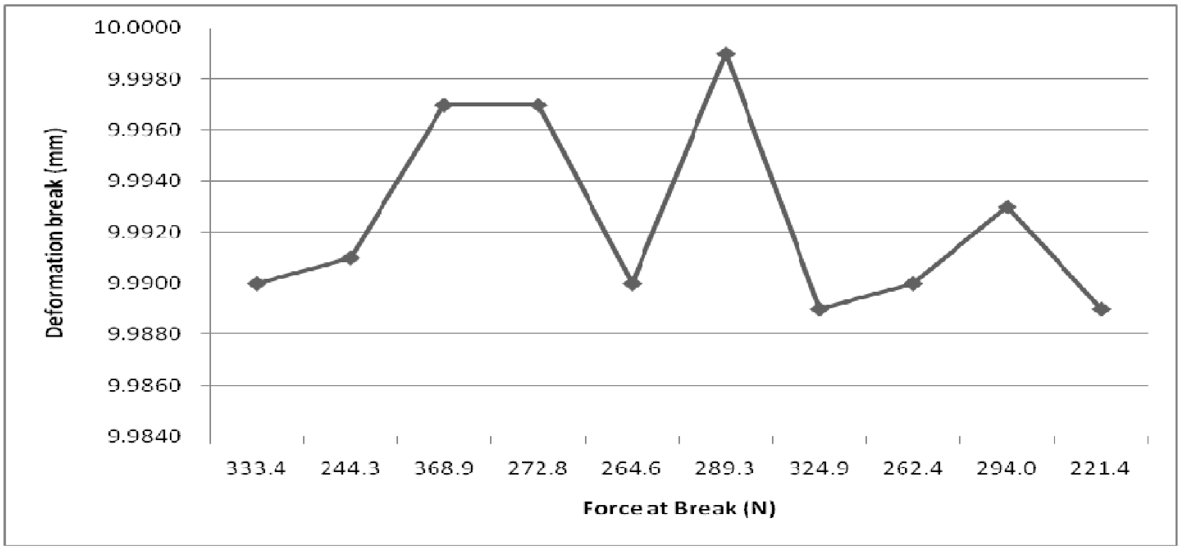
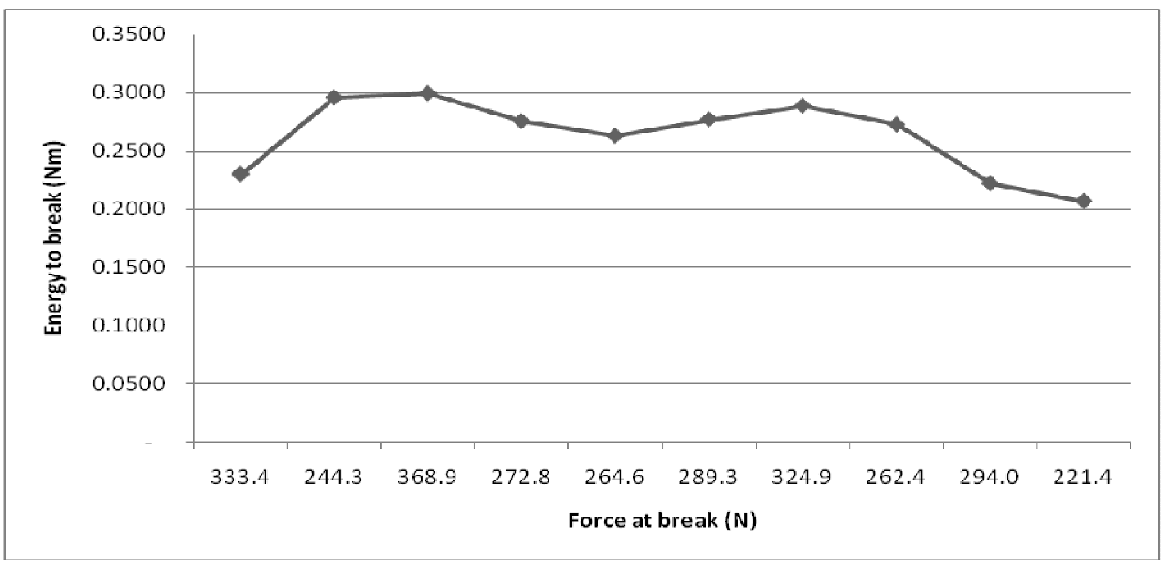


Figure 9. Graph of Force at Break (N) against Energy to break (NM) for Variety TGx1987-62F 10.35% MC



content on compressive strength of sweet cassava (Manihot Esculenta).

The comprehensive strength of the cassava decreased with increasing moisture content from 67 to 71%. The head, centre and tail compressive strengths are 558N, 466N and 374N respectively. The compression position and moisture content also affect the rupture of Macadamia nut. Previous work also reported that variation in moisture content, variety and axis of orientation of castor nut as it affects the force deformation behaviour of the seed. The effect of hydro thermal treatment on mechanical oil expression from soybean was also investigated. The report revealed that boiled splits soybean, produces high yield after drying to 7% moisture content and soaked split, produces yield at 8% moisture content. Energy consumption, decreases with an increase in moisture content in boiling treatment but temperature remained high in soaked beans (Singh and Bargala, 1990). Sakuniaran and Singh (1987), worked on oil expression characteristics of rape seed under uniaxial bulk compression and developed mathematical expression that correlates effects of moisture content, rates of deformation and pressure on oil expression characteristics. Oil recovery efficiency for degree of

Table1. Sample variety: TGx1987-10F AT 6.51% MC

Test No	Cylinder Length mm	Inner Diameter, mm	Outer Diameter mm	Force @peak N	Def. @peak Mm	Energy to peak Nm	Force@ Break N	Def. @ Break mm	Energy at Break Nm	Force@ Yield N
1	6,0000	2,0000	4,0000	1928.6	9,9830	1.6498	1859.7	9.9910	1.6649	-
2	8,0000	2,0000	4,0000	1864.4	9.9860	1.4554	1810.4	9.9880	1.4591	-
3	6,0000	2,0000	4,0000	2389.3 •	9.9930	2.3227	2389.3	9.9930	2.3227	-
4	6,0000	2,0000	4,0000	2187.3	9.9820	1.5685	2099.7	9.9930	1,5921	-
5	7,0000	2,0000	4,0000	1563.0	9.9910	1.2924	1563.0	9.9910	1.2924	-
6	7,0000	2,0000	4,0000	2155.8	9.9800	1.7671	2079.6	9.9950	1.7989	-
7	7,0000	2,0000	4,0000	1557.3	9.9780	1.9280	2210.2	9.9980	1.9280	-
8	6.0000	2,0000	4,0000	2210.2	9.9980	1.9280	2210.2	9.9980	1.9280	-
9	6,0000	2,0000	4,0000	2159.0	9.9960	1.8303	2159.0	9.9960	L8303	-
10	8,0000	2,0000	4,0000	1413.2	9.9880	1.1119	1413.2	9.9880	1.1119	-

Statistical data evaluation of results

Min	6,0000	2,0000	4,0000	1413.2	9.9780	1.0909	1413.2	9.9880	1.1119	0
Mean	6,0000	2,0000	4,0000	1942.8	9.9875	1.6017	1907.1	9.9929	1.6119	0
Max.	6,0000	2,0000	4,0000	2389.3	9.9980	2.3227	2389.3	9.9980	2.3227	0
S.D.	0.0000	0.0000	0.0000	333.7	0.3840	0.3840	333.2	0.3815	0.3815	0

compression was found to be an exponential function of these factors.

MATERIALS AND METHODS

Sample Preparation

The study was conducted on two varieties of soybean, TGx1987-10F and TGx1987-62F obtained from Ibadan, south west Nigeria and observed to be free from bruises and deformation for qualitative analytical work. The samples were grouped into two for each of the varieties as $A_1$and $A_2$for the TGx1987-10F variety and B_1 and B_2 for the TGx1987-62F variety. The samples from the two varieties were conditioned to the desired moisture content of 6.51% and 10.35% wet basis using the method developed by Visvananthan et al., (1996). Ten numbered replicate from each group samples A_1, A_2 and B_1, B2 were picked at random and weighed in an electronic analytical balance. These samples were oven dried in a digital temperature oven at 103^{o}C for 6 hours until the equilibrium moisture content is attained. The moisture content of the soybean was determined using standard method specified by Mohsenin (1986). The initial moisture content (mc) of the samples was estimated from the relationship;

$$\% MCwb = \frac{wo-wf}{wo} x\ 100 \quad (1)$$

MC(wb) = moisture content (%) wet basis
wo= initial weight of sample (g)
wf=weight of dried sample after t minutes of oven drying(g)

Soybean Compression Test

The compressive test employed the method of Guan and Hanna (2004) and Guan et al (2005).The compressive forces were measured with the Testometrics Universal Testing Machine (UTM of Serial No. 500 – 689, 175kg and 0.6kw at the material testing laboratory of Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos State (Figure 1).The internal and outside diameter of the seed was measured for the ten replicates of the grouped varieties for different moisture condition. The samples were subjected to loading with the Universal Testing Machine (UTM). At these condition the grouped varieties and the parameters describing the behavior of the seed under compressive load were measured and recorded. Testing conditions for the materials is at speed of 25.00 mm/min pre-load off. The two varieties of soybeans grouped into four samples A1, A2 and B1, B2 were tested

Table 2. Sample Variety: TGx1987-10F AT 10.35%

Test No	Cylinder Length mm	Inner Diameter mm	Outer Diameter mm	Force @peak N	Def. @ peak mm.	Energy to peak Nm	Force @ Break N	Def Break mm	Energy to Break Nm	Force @ yield N
1	6.000	2.0000	4.0000	1794.1	9.9980	1.3480	1794.1	9.9980	1.3480	-
2	7.000	2.0000	4.0000	214.9	9.9980	0.1934	214.9	9.9980	0.1934	47.10
3	6.000	2.0000	4.0000	257.7	9.9980	0.2956	257.7	9.9980	0.2956	87.30
4	7.000	2.0000	4.0000	196.3	9.9980	0.1992	196.3	9.9990	0.1992	79.10
5	7.000	2.0000	4.0000	300.7	9.9810	0.2943	292.7	9.9950	0.2985	62.10
6	6.000	2.0000	4.0000	411.1	9.9850	0.3891	391.7	9.9900	0.3911	124.30
7	6.000	2.0000	4.0000	248.7	9.9970	0.2641	248.7	9.9970	0,2641	88.80
8	8.000	2.0000	4.0000	317.0	9.9880	0.3271	303.3	9.9890	0.3280	111.00
9	5.000	3.0000	5.0000	386.3	9.9810	0.4098	373.8	9.9940	0.4148	80.70
10	11.000	3.0000	5.0000	233.0	9.95.10	0.2089	222.6	9.9950	0.2121	55.10

Statistical data evaluation of results

Min	5.000	2.0000	4.0000	196.3	9-.9810.	0.1934	196.3	9.9890	0.1934	0.00
Mean	6.400	2.2000	4.2000	436.0	9.9904	0.3930	429.6	9.9953	0.3945	81.73
Max.	11.000	3.0000	5.0000	794.1	9.9990	1.3480	1794.1	9.9990	1.3480	24.30
S.D.	1.647	0.4216	0.4216	482.4	0.0073	0.3438	483.8	0.0031	0.3435	25.13

to determine the force at peak (N), deformation at peak (mm), energy at peak (Nm), force at yield (N) and they recorded and compared the results. The procedure was also repeated for the other conditioned varieties at 6.51% and 10.35% moisture content wet basis for ten replicates each to determine all the above listed parameters; and the result is presented in the tables 1, 2, 3, 4.

RESULTS AND DISCUSSION

Effect of Moisture Content on Mechanical Behavior during Loading

The following mechanical properties were obtained from test results as presented in tables 1, 2, 3 and 4: Force at peak, deformation at peak, energy to peak, force at break, deformation at break, energy at break and force at yield. The mean and standard deviation of these values were computed. Graphical presentation shows the relationship between deformation at break and the force at break for the two varieties at the conditioned moisture contents of 6.51% and 10.35%. These relationships are presented in figures 2,3,4,5,6,7,8 and 9. In figures 2 and 3 the force and energy required to break decreases with corresponding increase in moisture content. This observation is consistent for both varieties tested and is in line with the observation of Adejumo et al., (2011).At moisture content of 10.35% the force at break decreases from 334.40N to 221.40N for the TGx1987-62Fvariety, and from 391.7N to 222.6N for the TGx1987–10F variety. The basic reason for this observation is due to the fact that the seed absorbs moisture faster and the fibre becomes weaker, hence, it decreases in force and energy at break when the seed is undergoing compressive loading.

Table 3. Sample variety, TGx1987-62F AT6.51%MC

Test No	Cylinder Length mm	Inner Diameter mm	OuterDiameter mm	Force@peak N	Def.@ peak mm	Energyat peak Nm	Force@ Break N	Def. @ Break mm	Energy to Break Nm	Force@ yield N
1	7.0000	2,0000	4.0000	1019.0	26.278	0.8177	982.6	9.983	0.8227	_
2	8.0000	2.0000	4.0000	925.8	0.986	0.7867	895.2	9.990	0.7904	-
3	7.0000	2.0000	5.0000	1344.1	9.998	1.1053	1344.1	9.998	1.1053	-
4	7.0000	2.0000	4./0000	1058.6	9.996	0.9533	1058.6	9.996	0.9533	-
5	8.0000	2.0000	4.000.0	1286.1	9.998	1.0704	1286.1	9.998	1.0704	-
6	7.0000	2,0000	4,000.0	897.2	9.981	0.6644	861.0	9.995	0.6767	-
7	6.0000	2.0000	4.0000	682.5	9.983	0.4849	649.7	9.992	0,4909	-
8	7.0000	2.0000	4.0000	909.3	9.986	0.6836	875.9	9.990	0.6872	-
.9	6.0000	2.0000	4.0000	617.6	9.984	0.4968	594.8	9.991	0.5010	-
10	7.0000	2.0000	3.0000	612.3	9.992	0.4552	612.3	9.992	0.4552	-

Statistical data evaluation of results

Min	6.0000	2.0000	3.0000	612.3	9.681	0.4552	594,8	9.990	0.4552	0
Mean	7.0000	2.0000	4.1000	935.2	11.681	0.7518	916.0	9.993	0.7553	0
Max	8.0000	2.0000	2.0000	1344.1	26.278	1.1053	1344.1	9.883	1.1053	0
S.D.	0.6667	0.0000	0.4216	254.7	5.151	0.2378	261.7	0.0051	0.2362	0

Effect of Variety on the Compressive Loading of the Samples

Figure 2, 3, 4 and 5 shows the behaviour of TGx1987-10F variety under compressive loading, at moisture content of 6.51% and 10.35% respectively. Figure 6, 8, 7 and 9 presented the behavior of TGx1987–62F under both moisture contents. While both varieties showed decrease in the force at break and load at yield with increase in moisture content, the average values of force to break and energy at yield are higher at 1907N and 1.6119Nm for the variety of TGx1987–10F than the TGx1987–62F variety at 287.7N and 0.2627Nm under the same conditions respectively. The reason is because the TGx1987–10F variety seed can absorb and accommodate water than the TGx1987–62F variety. The compressive force decreases further to obtain similar deformation with the same moisture level of 10.35% and showing that less force is required to cause deformation of the biomaterial as the moisture content increases. There is no significant difference in the deformation of the bio-material between the two varieties for less than 0.05 uniformity levels. The study showed that higher force is required for the deformation of the soybean seed for low moisture content.

CONCLUSION

The following are the conclusions from the research

Table 4. sample variety, TGx1987-62F AT 10.35% MC

Test No	Cylinder Length	Inner Diameter mm	Outer Diameter mm	Force@peakN	Def. @peak mm	Energy to peak Nm	Force@ Break N	Def. @ Break mm	Energy to Break Nm	Force@ yield N
1	11.000	4.0000	5.0000	334.40	9.9900	0.2296	334.40	9.9900	0.2296	68.60
2	11.000	3.0000	5.0000	254.00	9.9860	0.2942	244.30	9.9910	0.2954	64.20
3	11.000	3.0000	5.0000	385.40	9.9790	0.2922	368.90	9.9970	0.2989	67.40
4	11,000	3.0000	5.0000	272.80	9.9970	0.2751	272.80	9.9970	0.2751	59.00
5;	11.000	3.0000	5.0000	277.50 -	9.9860	0.2615	264.60	9,9900	0.2625	63.30
6 ..	11.000	3.0000	5.0000	289.30	9.9990	0.2767	289.30	9.9990	0.2767	67.30
7	11.000	3.0000	5.0000	340.10	9.9870	0.2875	324.90	9.9890	0.2882	80.40
8	11.000	3.0000	5.0000	275.60	9.9850	0.2710	262.40	9.9900	0.2723	63.00
9	11.000	3.0000	5.0000	294.00	9.9930	0.2218	294.00	9.9930	0.2218	81.20
10	11.000	3.0000	5.0000	221.40	9.9890	0.2066	221.40	9.9890	0.2066	63.60

Statistical data evaluation of results

Min	11,000	3.0000	5.0000	221.40	9.9790	0.2066	221,40	9.9890	0.2066	59.00
Mean	11.000	3.0000	5.0000	294.45	9.9891	0.2616	287.70	9.9925	0.2627	27.25
Max	11.000	3.0000	5.0000	385.40	9.9990	0.2942	368.90	9.9990	0.2989	35.20
S.D.	0.000	0.0000	0.0000	475.21	0.0,041	0.0313	44.57	0.0068	0.0323	23.81

studies:

(i) Different varieties of soybeans have different behavior towards compressive behaviour.

(ii) The soybean of high moisture content breaks faster.

(iii) Moisture content was observed to have influence on the compressive strength of soybeans as the mechanical properties exhibit linear increase with increase moisture content.

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How to cite this article: Ashaolu M. O and Noibi A.O (2013). Effects of moisture content on some mechanical properties of Soybean (Glycine max) varieties. Afr. J. Food Sci. Technol. 3(10):211-220