DETERMINATION OF SOME MECHANICAL PROPERTIES OF MELON FRUIT

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ABSTRACT

The processing of egusi melon fruits has been mostly traditional and where processing machine exists, the efficiency is usually low and the machine therefore not economical. Thus, there is a great need to determine some mechanical properties of melon fruits that are relevant for its seed extraction, washing and shelling. In this work, points of linear limit (POLL), bioyield point (BYP) and rupture point (RP) were determined by subjecting the melon fruit to compression test and shear stress. Based on the compression test, the maximum force required to deform melon fruit is 2531N and the corresponding deformation is 35mm.while, the minimum force is 506N and the corresponding deformation is 16mm. The maximum shear force and the corresponding deformation is 608N and 26mm, respectively, while the minimum shear force and the corresponding deformation is 297N and 8mm, respectively. The results from this work are therefore recommended for use in the design consideration of melon processing equipment.

KEYWORDS: Melon fruit, rupture, shear force, deformation, mechanical properties.

1. INTRODUCTION

In West Africa, Egusi melon *(colocynthis citrullus L.)* seeds (Fig. 1a) obtained from egusi melon plant (Fig. 1b) are a common component of daily meals. Egusi melon is popular in Nigeria because of its edible seeds, which have been used in the preparation of local soup. It is one of the members of the family *cucurbitaceae,* which has bitter fruit pulp. Basically, the seeds are small or large with thin, thick or encrusted seed coats, the seed edges may be flat or moulded (Oyolu, 1977).

Figure 1a, Egusi melon seed

Figure 1b, Egusi melon plant

Melon fruit is slender, hairy and grown annually over the ground with a very extensive and superficial root system when matured. The stems are rather thin, angular, grooved and 1.5 to 5 meters long, with white hairs; the fruit is hard, bitter and inedible. The seeds are generally sown at the beginning of the rains (May/June) or towards the end of the raining season (August / September).The fruits get ripe after 3 months, they are identified as ripe fruits when the stem is dried, and over-ripe when the fruits changes from green to yellowish / brown colour. The seeds are white inside the pulp if they are not properly ripe. The harvest is preferred when they are yellowish /brownish. The origin of melon is Africa, and other areas where they are widely cultivated include the Caribbean and Indonesia. In Nigeria, the existence of melon dates back to the 17th century. Statistics shows that 100,000 and 488,000 metric tons of melon were produced in Nigeria in 1992 and 1997 respectively (Federal Office of Statistics, 1999) as referenced by Oloko and Adetoye (2006).

Egusi melon seed is oil bearing and contains about 20-40% by weight of oil. Oyenuga (1968) reported that melon contains 30-50% of oil which is comparable to other oil plants. Egusi seed oil contains a high level of unsaturated fatty acids, which has a wide use both for domestic and industrial purposes. Domestic use of egusi oil include cooking soup, frying, while industrially it can be used for production of soap, pomade, metal polish, lubricant adhesive, candles and animal feed.

As reported by Nwagugu and Okonkwo (2009), various methods of determining mechanical properties of agricultural materials exists (tensometer, uniaxial tension test, shear test, etc.). However, compression test seemed to provide an objective result (Moshenin, 1984). Compression test of agricultural materials requires the production of a complete force – deformation curve from which force and deformation at linear limit, bioyield point, and rupture point can be determined. The objective of this study is therefore to determine the maximum force and deformation required for ripped melon fruit.

2. RESEARCH METHODOLOGY

The mechanical properties studied are compression and shear forces required to deform melon fruit. This aids the determination of the power required to crush melon fruits during the extraction of its seeds. The tests were performed at the National Centre for Agricultural Mechanization (NCAM) Ilorin, Kwara State. The machine used was a 50kW capacity automated universal testing machine (Testometric, Series 500-532) (2006).

2.1 Materials

The melon fruits were obtained from a farm in Nasarawa town, Nasarawa state. The local type variety of melon fruits referred to as, thick edge and the white big size variety was used. Twenty (20) melon fruits were selected randomly and grouped into five groups of four fruits each base on the size. From each group two were used in the determination of shear stress, and the remaining two were selected for compression testing.

2.2 Methods

Compression test: using the method of Guan et al., (2005) as given by Fayose (2009) compression forces were measured. Melon fruits were placed between the flat steel compression tool of the machine ensuring that the centre of the foot was in alignment with the peak of the curvature of the fruits as shown in Fig 2a. The test speed was set at 25mm / min (Moshenin, 1984). Each fruit was loaded to the point of rupture; hence, the force and deformation at linear limit, Bioyield and rupture points were all recorded.

Shear Test: The conduct of the shear test was similar to the compression test method. However, during the shear test, the flat steel compression tool at the top was replaced with shear tool in a knife form to shear the melon fruit (Fig.2b). The fruit was placed in the machine under the steel knife ensuring that the centre of the sharp knife was in alignment with the peak of the curvature of the fruits. The fruit was loaded to point of shearing, and a force deformation curve was produced automatically from which point of linear limit (POLL), bioyield point (BYP), and rapture point (RP) were determined.

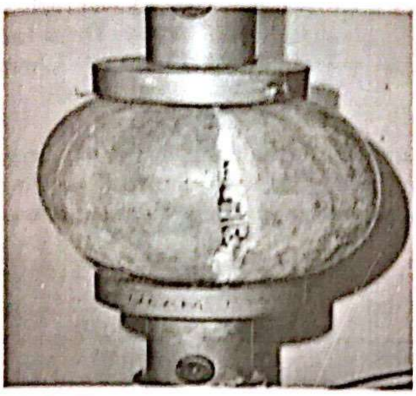

Fig.2a Compression test on melon fruit using UMT

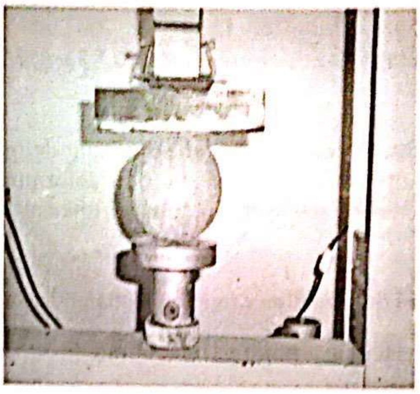

Fig.2b Shear force test set up on melon fruit using UMT

Modulus of deformability: The modulus of deformability of most biomaterials depends on the point at which it is calculated (Moshenin, 1990). This means that for the same material, there could be different values of modulus of deformability depending on the point at which it is calculated. The following expression could be used for flat and spherical indenter.

$$Si = 0.365[F/A^2 (1/R + 1/R_1 + 4/d_1)^2]^{1/3} \quad \ldots\ldots 1$$

Where: Si = Stress index; di = diameter of the indenter; F = force; A = area R = radius.

3. RESULTS AND DISCUSSION

3.1 Compression of Melon Fruit

Fig. 3 shows the forces at point of linear limit (POLL), bioyield point (BYP), and rupture point (RP) as the fruit diameter increased. It suggests that during the compression test, the rupture and the bioyield point of the melon fruit forces are same. And the magnitude of force at POLL, BYP, and RP increases with increase in the melon fruit diameter.

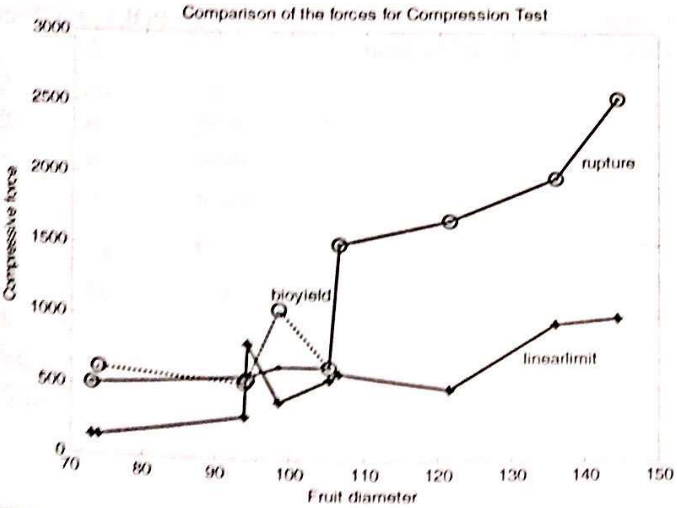

Figure 3. Compressive forces at POLL, BYP, and RP versus melon fruit diameter

The average diameter of the melon fruit which was used in the compression test was 104.7 ± 23.7mm. And the corresponding average forces at point of linear limit (POLL), bioyield point (BYP), and rupture point (RP) were 538 ± 308.21N, 1157.886 ±721.20N, and 1162.81 ± 716.62N respectively. These had corresponding average fruit deformation of 12.33 ± 7.2 mm, 25.153 ± 7.74mm and 25.0153 ± 7.7mm respectively.

Table 1 presents the forces and the corresponding deformation of melon fruits under compression force. In this Table, the maximum force required in deforming melon fruit was 2531N and the corresponding deformation was 35mm, while the minimum force was 506N and the corresponding deformation was 16mm.

Table 1: Forces and deformation of melon fruits under compression test

S/N	Sample	Height (mm)	Point of linear limit		Bioyield point		Rupture point	
			Forces (N)	Deformation mm	Forces (N)	Deformation mm	Forces (N)	Deformation mm
1	A_1	73.9	140	4	618.1	15.5		
2	A_2	73.1	140	4	505.9	15.5	505	15.5
3	B_1	98.5	400	7	1052.0	18.2		
4	B_2	105.2	560	19.8	641.6	23.2	641.6	23.2
5	C_1	93.8	290	11	526.6	22.2	576.5	22.2
6	C_2	94.3	800	22	558.5	21.9		
7	D_1	121.5	500	6.5	1674.5	32.4	1674.5	32.3
8	D_2	106.5	600	13	1501.0	34.7	1501.0	34.7
9	E_1	144.4	1000	13	2531.1	34.5	2531.1	34.5
10	E_2	135.9	950	23	1969.6	32.3	1969.8	32.3
Mean		104.7	538	12.3	1157.9	25.0	1162.8	25.0
S.D		23.7	308.2	7.20	721.2	7.7	716.6	7.7

3.2 Forces and deformation of melon fruits under shear force

Fig. 4 shows the forces at POLL, BYP, and RP as the fruit diameter increased. Forces at POLL were observed to be less than forces at BYP and RP as shown in Fig. 4. It was also observed that there was a fall in the magnitude of forces at POLL, BYP and RP for melon fruit diameter greater than 95mm. This was attributed to the inherent properties of the biological material. Perhaps the wall thickness of the fruits was thinner at diameters greater than 95mm and it required lesser shear force to initiate POLL, BYP and RP. Another possible reason could be the degree of ripeness of the fruit.

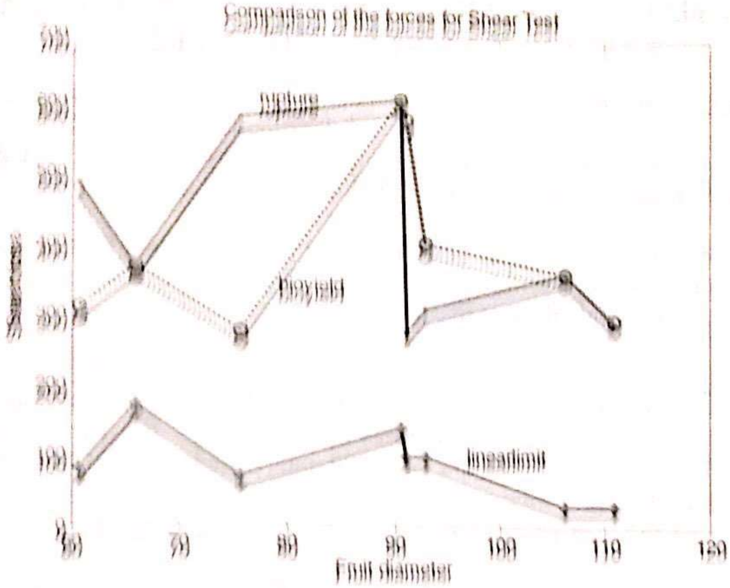

Figure 4. Shear forces at POLL, BYP, and RP versus melon fruit diameter

For an average melon fruit diameter of 86.84±18.03mm that was used under shear force test, the corresponding average forces at POLL, BYP, and RP were 90±48.98N, 400.9 ± 134.7N, and 410.9 ± 129.88N, respectively. Also, these had corresponding average fruit deformation of 3.7 ± 2.2mm, 21.83 ± 6.02mm and 21.78 ± 3.99mm, respectively. Table 2 shows the forces and the corresponding deformation of melon fruits under shear forces. The maximum shear force and the corresponding deformation were 608N and 26mm, respectively, while the minimum shear force and the corresponding deformation were 297N and 8mm, respectively. The force and deformation at linear limit, bio-yield and rupture points were determined from the graph by noting the calibration along y-axis for the force and x-axis for deformation. The force and deformation to linear limit, bio-yield and rupture points are in Table 2.

Table 2: Forces and deformation of melon fruits under shear force

S/N	Sample	Height (mm)	Point of linear limit		Bioyield point		Rupture point	
			Forces (N)	Deformation mm	Forces (N)	Deformation mm	Forces (N)	Deformation mm
1	A_1	60.8	80	4.5	310.6	23.1	484.5	23.1
2	A_2	75.7	70	4.3	277.4	26.9	579.4	26.9
3	B_1	66.0	170	7	366.5	20.5	366.5	20.5
4	B_2	90.6	140	6	608.0	26.4	608.0	26.4
5	C_1	93.0	100	3	404.5	24.0	310.6	24.0
6	C_2	91.1	100	3	579.4	20.9	277.4	20.9
7	D_1	106.2	30	1	364.0	24.7	364.0	24.3
8	D_2	111.1	30	1	297.8	8.1	297.0	8.1
Mean		86.8	90	3.7	400.9	21.8	410.9	21.8
S.D		18.0	48.98	2.2	134.7	6.0	129.7	6.0

3.3 Determination of Linear Limit, Bioyield Point and Rupture Point from Force – Deformation Curve

a. Linear limit: In engineering materials, the linear limit of a biomaterial is the greatest force (stress) which the material is capable of sustaining without any permanent deformation (strain) remaining upon complete release of the forces (stress). For ripped melon fruit the average force and the corresponding deformation at point of linear limit were 750N and 10mm, respectively.

b. Bioyield point: Bioyield point of a biomaterial is an indication of initial cell rupture in cellular structure of material. Bioyield point was noticeable on curve, the forces and the corresponding deformation at bioyield point were 1650N, and 20mm respectively.

c. Rupture point: This is the point on force deformation curve were the material ruptures. The force at this point is the minimum required to break the material. The values of force and deformation at these points were determined by noting the calibration along, these points, along y – axis for the force and x – axis for deformation. For ripped fruit, the minimum force and deformation required to rupture the fruit were 2550N and 33mm, respectively.

d. Modulus of deformation: In engineering materials, modulus of elasticity is a measure of stiffness or rigidity of the material. This is the same with biomaterial except that the values of forces and deformations differ.

4. CONCLUSION

From the compression tests, it was found that the maximum force and minimum force required to rupture melon fruits were 1950N and 562N, respectively. For sheer force, the corresponding values were 531.95N and 294N, respectively. Hence, the maximum force under compression for fruits to yield is hereby recommended for use in the design of melon fruit extractor towards the manufacture of an efficient machine.

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