Determination of Some Mechanical and Aerodynamic Properties of Castor Fruits and Seeds

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ABSTRACT: This study was carried out to determine some mechanical and aerodynamic properties of castor fruits and seeds as a function of moisture content. The knowledge of these mechanical and aerodynamic properties of fruits and seeds are important parameters in the design, harvesting, handling, storage and processing equipment and in the analysis and prediction of their dehusking and shelling behavior during handling and processing. To provide the needed data, investigation of the mechanical and aerodynamic properties of the fruits and seeds under different moisture content levels of 5%, 6% and 7% was carried out. Two varieties of castor fruits and seeds namely large and Small were collected and some of the mechanical and aerodynamic properties, such as compressive strength, bio-yield force, rupture force, deformation at rupture, energy, modulus of deformation , toughness and drag force, terminal velocity and acceleration were determined. The results obtained for the mechanical properties of castor fruits and seeds showed that on 6% and 7% moisture content, the forces and energy required for dehusking and shelling are higher than on 5% moisture content on both large and small castor fruits and seeds. The results obtained for the aerodynamic properties of large and small castor fruits and seeds at three moisture content showed that the larger the fruits and seeds the higher the aerodynamic properties. The Analysis of Variance (ANOVA) using randomized block design method at 5% probability level was used to analyze the effect of moisture content, and size on mechanical and aerodynamic properties of castor fruits and seeds. It is also to determine the effect on dehusking and shelling of castor fruits and seeds.

Keywords: Determination, Mechanical, Aerodynamic, Properties, Castor Fruits, Castor Seeds.

1 INTRODUCTION

Castor (*Ricinus communis),* a semi-tropical perennial, belongs to the Euphorbiaceae or spurge family containing a vast number of plants native to the tropics. It is essentially a long day plant, but can also adapt with some loss of yield to a fairly wide range of a day. Castor plants can be basically divided into two types, tall (giant) and short (dwarf). The period from emergence to maturity varies with variety and it greatly influenced by the environment [11].

Castors prefer deep sandy loam soil with a PH of 6, but it can be cultivated on a wide variety of soils with PH range of 5 – 8. Castor grows both in the wild and cultivated. The cultivated varieties are annuals, growing to a height of between 1–7m [3]. There is currently no existing variety although between the late 50s and late 70s, R63, Kaba local, Kogi varieties and some improved varieties from overseas were grown in Northern Nigeria for export to Britain but this was stagnated. Its cultivation in the wild should be discouraged because of the extremely poisonous seed or beans. This is particularly true where small children might be attracted to the large beautifully mottled seed which are produced in prodigious numbers [1]. In handling, storage and design of processing machineries of agricultural material, knowledge of the basic properties of these materials are required. The physical properties, mechanical properties, aerodynamic properties among others are important in designing of the machine and equipment for various agricultural operations. These properties will be an aid for choosing right materials or component during construction and to enhance proper storage after processing [10]. As a result of the ever-increasing world population to be fed and for raw material development, there is the need for the increase in production, handling, processing, preservation and marketing of plants and animals to meet up with food demand of the

ISSN 2229-5518

teaming population. For machines, processes and handling operation to be designed for maximum efficiency and highest quality of the end products of castor seed, their physical, mechanical aerodynamic properties are required [7].
The objective of the study is to determine the mechanical and aerodynamic properties of castor fruits and seeds.

1.2 Economic Importance of Castor Seed

A poultice of castor leaves is useful as an external application to boils and swellings. Coated with some bland oil such as coconut oil and heated, the hot leaves can be applied over guinea-worm sores to extract the worms. A poultice of castor seed is also applied with beneficial result to gouty and rheumatic swellings. A decoction of the roots of castor plant with carbonate of potash is useful in the treatment of lumbago, rheumatism and sciatica. A paste of kernel without the embryo, boiled in milk, is also given as a medicine for the treatment of lumbago, rheumatism and sciatica [10].

The cake of castor contains poisonous substance and should not be fed to livestock. It is a useful fertilizer to crops [6]. Castor oil is one of the world most versatile natural products. Its water resistant qualities make it ideal for coating fabrics and for protective coverings, insulations, food containers and gums [9].
Castor oil is regarded as one of the best laxative and purgative preparation available. It is of particular benefit for children and pregnant women due to its mild action in easing constipation, colic and diarrhea due to slow digestion. When applied externally, castor oil eases contagious complaints such as ringworms, itch and leprosy, while it is used as carrier oil for solutions of pure alkaloids, e.g. atropine or cocaine, from belladonna, that these drugs can be used in eye surgery. Castor oil is used for a range of industrial purposes from soap making to vanishes. Castor oil is used very effectively in the treatment of rheumatic and skin disorders. The oil of castor is massaged over the breast after child birth to increases the flow of milk, as it stimulates the mammary glands. Castor leaves can also be used to foment the breasts, for the same purpose. If used regularly as hair oil, it helps the growth of the hair and cures dandruff [10].

This has been interpreted by many that castor seed is herb for birth control and if a woman swallows one castor seed, after the menstrual circle, she will not conceive during that month. When pregnancy is desired, the practice can be given up and conception follows after a year. Castor oil massaged over the body, before birth keeps the skin healthy and imparts sound sleep. Such an oil bath may be taken once a week. Applying castor oil over hand and feet before going to bed keeps them soft and similarly over the eyes brows and eye lashes keeps them well groomed. The negative aspects of castor oils are: repeated use of castor oils as a laxative should be avoided as it causes secondary constipation that is recurrence of the condition after cure. Persons suffering from kidney infection should not take castor oil as a purgative. It should also not be used when there is abdominal pain or intestine infections such as appendicitis, enteritis, or inflammation of the small intestine and peritonitis. Large doses of castor oil during the early months of pregnancy may cause abortion [12].

2 MATERIALS AND METHODS

The five samples of small and large castor fruits and seeds for this study were obtained from Nsukka in Enugu State, Nigeria. The sample materials were sorted, cleaned and screened manually to remove sand, dust, stones and the bad ones. They were dehydrated in an oven at a temperature of 130^0 C to obtain different moisture content level of 5, 6 and 7% (db) at which the test was conducted. A total number of 15fruits and seeds for both small and large were used for each experiment. These samples were taken to the Mechanical Engineering workshop to determine the mechanical properties and Agricultural Engineering Power and Machinery Laboratory to determine the aerodynamic properties in Enugu State University of Science and Technology, Enugu, Nigeria.

2.1 Mechanical Properties of Castor Seed and Fruits

ISSN 2229-5518

A material testing machine was used for determination of mechanical properties of castor seeds and fruits.
A sample of five fruits and seeds were randomly selected for each test. The sample was located between two parallel plates. The amount of force and deformation at rupture point for the castor fruits and seed were determined.

2.2 Determination of Compressive Test.

Compression tests were performed on the castor fruits and seeds using the digital venier caliper of precision 0.01mm and Monsato Tensometer testing machine. The testing condition for the Monsato Tensometer machine was at 0.01N. The mechanical properties of castor fruits and seeds were determined in terms of rupture force, bio-yield force, young's modulus, modulus at deformability and energy at rupture, etc (Fig.1) for the five sample of castor fruits and seeds.

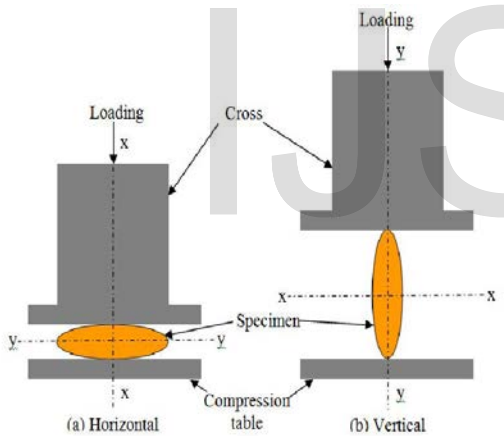

Figure1: Block Diagram of orientations of Castor Fruit or Seed under compressive loading

2.3 Absorbed Energy

Absorbed energy by the sample at rupture point was determined by calculating the area under force deformation curve from the following equation

$$E_a = \frac{f_r D_r}{2} \quad \text{........................1}$$

Where
E_a = the rupture energy in MJ,
F_r = the rupture force in N
D_r = the deformation at rupture point in mm

2.4 Bio- Yield Point

There was a decrease in force after rupture occurred in the specimen and this point was denoted as the bio-yield point.

2.5 Toughness

This is work per unit volume needed to rupture the material, since the area under force deformation curve is representative of the work that is done for failing the sample. The amount of toughness was estimated by calculating the seed volume, considering the assumption that seed is spherical in shape.
The Sphericity relates to the overall shape of a feature. Irrespective of sharpness of edges and is a measure of the degree of its conformity to a sphere

2.6 Aerodynamic Properties

Terminal velocity was measured using an air column for each test, a sample of seed and fruit was dropped into the air stream from the top of air column, and air was blown up the column to suspend the material in the air stream. The air velocity near the location of the sample suspension was measured by a digital anemometer having a least count of $0.1ms^{-1}$

3 RESULTS AND DISCUSSION

The results obtained for the mechanical properties of small castor fruits are shown in table1. The average results on determining the compression strength, bio-yield force, rupture force deformation at rupture, energy, modulus of deformation and toughness at 5 % moisture content are given as $6.15N/mm^2$, 437N, 605N, 2.45mm, 1358J, $26.26N/mm^2$ and $2.13J/mm^3$. On moisture content of 6%, the results were given as $5.77N/mm^2$, 432N, 581N, 2.45mm, 1584J, $29.40N/mm^2$ and $1.71J/mm^3$ respectively. At 7% moisture content, the average results are $6.34N/mm^2$, 432N, 619N, 2.48mm, 1506J, $24.41N/mm^2$ and $1.72J/mm^3$ respectively. The results showed that at 6% and 7% moisture content, the forces and energy required for dehusking are higher than at 5% moisture content.

Table 2 shows the results obtained for the mechanical properties of large castor fruits. The average results on determining the compression strength, bio-yield force, rupture force deformation at rupture, energy, modulus of deformation and toughness at 5 % moisture content are given as 5.78N/mm^2, 461N, 566N, 2.48mm, 1428J, 26.53N/mm^2 and 1.86J/mm^3 and at 6% moisture content are 5.88N/mm^2, 487N, 588N, 2.38mm, 1424J, 27.16N/mm^2 and 1.69J/mm^3 respectively. The average results at 7% moisture content are 6.38N/mm^2, 530N, 631N, 2.45mm, 1616J, 27.14N/mm^2 and 2.05J/mm^3 respectively. The results showed that at 6% and 7% moisture content, the forces and energy required for dehusking are higher than at 5% moisture content.

The mechanical properties of small castor seeds results at three different moisture contents are given in table 3. The average results obtained on the compression strength, bio-yield force, rupture force, deformation at rupture, energy, modulus of deformation and toughness at 5 % moisture content are given as 2.93N/mm^2, 603N, 765N, 2.95mm, 2723J, 17.26N/mm^2 and 3.37J/mm^3 respectively. Also the average results using 6% moisture content are 2.97N/mm^2, 608N, 754N, 4.78mm, 3197J, 16.65N/mm^2 and 4.82J/mm^3, while the average results at 7% moisture content are 3.12N/mm^2, 658N, 785N, 5.44mm, 3632J, 17.66N/mm^2 and 5.20J/mm^3 respectively. The results showed that the higher the moisture content, the higher the forces and energy required for shelling small castor seeds.

Table 4 shows the mechanical properties results of large castor seeds at three different moisture contents. The average results obtained on the compression strength, bio-yield force, rupture force deformation at rupture, energy, modulus of deformation and toughness at 5 % moisture content are given as 2.66N/mm^2, 606N, 702N, 3.76mm, 2723J, 16.06N/mm^2 and 3.47J/mm^3 respectively. Also the average results obtained using 6% moisture content are 3.15N/mm^2, 640N, 758N, 4.29mm, 2156J, 9.61N/mm^2 and 4.23J/mm^3, while the average results at 7% moisture content are 3.08N/mm^2, 725N, 797N, 4.82mm, 2136J, 9.44N/mm^2 and 4.34J/mm^3 respectively. The results showed that the higher the moisture content, the higher the forces and energy required for shelling large castor seeds.

The aerodynamic properties of large and small castor fruits are shown in table 5. The results obtained for the acceleration, drag force and terminal velocity for the large and small castor fruits are given as 0.333m/s^2, 0.20N, 1.12m/s and 0.304m/s^2, 0.17N, 1.10m/s respectively. The results depict that the larger the castor fruits the higher the aerodynamic properties.

It was shown in table 6, the aerodynamic properties of large and small castor seeds. The results gotten for the acceleration, drag force and terminal velocity for both large and small castor seeds are given as 0.240m/s^2, 0.12N, 0.84m/s and 0.387m/s^2, 0.10N, 0.72m/s respectively. The results obtained vary because of the variation in moisture content of the sample castor seeds.

The analysis of variance (ANOVA) on the moisture content and size of castor fruits in determining its mechanical properties was shown in table 7. The results showed that size of castor fruits affect significantly the mechanical properties determination of castor fruits and also the dehusking strength of the fruits.

Table 8 shows the analysis of variance (ANOVA) on the moisture content and size of castor seeds for the mechanical properties determination. The results showed that moisture content and size of castor seeds are important parameters that affect mechanical properties determination of castor seeds and also the shelling strength of the seeds.

4 CONCLUSIONS AND RECOMMENDATION

The results obtained on the study conducted on the mechanical and aerodynamic properties of castor fruits and seeds revealed that the larger the fruits and seeds, the higher the energy and force requirement in dehusking and shelling them. Moisture content was also an important parameter in determining mechanical and aerodynamic properties of castor fruits and seeds. These properties are necessary for the design of equipment and machines for storage and processing of castor fruits and seeds. It is recommended that other properties of castor fruits and seeds such as thermal and nutritional characteristics are to be determined and changes of these properties are to be examined as a function of moisture content.

REFERENCES

[1] Armstrong, W.P (1982); "Not Beavers, stars or Sons of Jupiter" Environment South west, No. 496: pp 4-7.

[2] Atiku, A. Avlara, N. and Haque M. (2004); Performance Evaluation of a Bambara Groundnut Sheller, Agricultural Engineering International; the CIGR journal of Scientific Research and Development, Manuscript 04002, vol.6

[3] Chakravety, A (1992); Post Harvest Technology of Cereals Pulses and Oil Seeds.

[4] Gupta, R.K and Das, S.K (1997); Physical Properties of Sunflower Seed, Journal of Agricultural Engineering Research. (pg 66, 85-91).

[5] Gideon, C.A. (1995); Castor Cultivation in India, India central Oil Seed Committee Hydrevabad, India.

[6] Lew's, and Elvin-Lewis, M.P.F (1997); Medical Botany; Plants Affecting Man's Health. John Wiley and Sons New York. Pg 496-521.

[7] Marter, A.D (2004); Castor Markets Utilization and Prospects, Tropical Production Institute London. Pg 55-78.

[8] Mohsenin, N.N (1990); Physical Properties of Plant and Animal Materials. Gordon and Breach Scientific Publishers New York.

[9] Simpson, B.B. and M.C, Ogorzaly (2000); Economics Botany; Plants in our World. M.C GrawHill, New York.

[10] Balami A. A., Adgidzi D, Kenneth C. A. And Lamuwa G. (2012); Development and Performance Evaluation of a Dehusking and Shelling Machine for Castor Fruits and Seeds, International Organisation of Scientific Research (IOSR) Journal of Engineering, Vol 2, Issue 10, Pp 44 – 48.

[11] Weiss, E.A(2003); Oil Seed Crops, Tropical Agricultural Science, Longman London.

[12] Windholz, M.S. Budavari, R.F, Blumetti and E.S Otterbein (2000);The Merck Index, An Rahway Encyclopedia of Chemicals, Drugs, and Biological, Merck and Co Inc, New Jersey.

ISSN 2229-5518

Table 1: Some Mechanical Properties of Small Castor Fruits

Moisture Content (%)	Compression Strength (N/mm^2)	Bio-Yield Force (N)	Rupture Force (N)	Deformation at Rupture (mm)	Energy (J)	Modulus of Deformation (N/mm^2)	Toughness (N/mm^3)
5	6.80	550	650	2.75	1787	27.28	2.30
	6.02	500	575	2.50	1437	26.54	2.31
	4.98	379	575	2.52	1068	24.36	1.89
	6.54	409	625	2.00	1250	27.41	1.99
	6.43	349	601	2.49	1250	25.72	2.10
Average	6.15	437	605	2.45	1358	26.26	2.12
6	6.32	412	598	2.53	1720	28.01	2.00
	5.23	475	569	2.50	1620	29.03	1.52
	5.94	400	572	2.62	1550	28.22	1.30
	5.89	500	581	2.00	1250	32.32	1.90
	5.49	374	587	2.62	1780	29.40	1.84
Average	5.77	432	581	2.45	1584	29.40	1.71
7	5.94	471	628	2.75	1670	28.40	1.57
	6.49	389	634	2.70	1500	25.94	1.67
	6.35	398	575	2.25	1460	28.74	1.98
	6.40	440	625	2.38	1420	27.90	1.49
	6.54	463	634	2.30	1480	36.07	1.90
Average	6.34	432	619	2.48	1506	29.41	1.72

Table 2: Some Mechanical Properties of Large Castor Fruits

Moisture Content (%)	Compression Strength (N/mm^2)	Bio-Yield Force (N)	Rupture Force (N)	Deformation at Rupture (mm)	Energy (J)	Modulus of Deformation (N/mm^2)	Toughness (N/mm^3)
5	6.08	552	651	2.77	1790	27.30	2.25
	6.11	502	576	2.52	1439	26.56	1.90
	5.98	376	478	2.27	1068	26.40	1.84
	5.62	476	628	2.05	1252	24.94	1.80
	5.12	401	498	2.78	1593	27.43	1.49
Average	5.78	461	566	2.48	1428	26.53	1.86
6	6.14	502	504	2.28	1128	28.74	1.40
	6.80	376	621	2.74	1497	29.32	1.74
	6.02	464	611	2.32	1342	24.89	1.68
	4.97	502	604	2.24	1632	25.94	1.72
	5.49	592	598	2.34	1521	26.93	1.92
Average	5.88	487	588	2.38	1424	27.76	1.69
7	6.09	564	576	2.19	1450	26.60	2.14
	6.23	504	694	2.63	1440	24.98	2.04
	6.49	524	634	2.52	1780	25.60	1.94
	6.52	504	628	2.46	1940	28.40	2.00
	6.55	552	625	2.45	1470	30.11	2.15
Average	6.38	530	631	2.45	1616	27.14	2.05

Table 3: Some Mechanical Properties of Small Castor Seeds

Moisture	Compression	Bio-	Rupture	Deformation	Energy	Modulus of	Toughness

ISSN 2229-5518

Content (%)	Strength (N/mm²)	Yield Force (N)	Force (N)	at Rupture (mm)	(J)	Deformation (N/mm²)	(N/mm³)
5	2.91	600	725	3.00	2175	17.26	2.70
	2.81	575	700	2.50	1400	20.03	1.73
	2.61	525	650	3.00	1950	16.40	2.40
	3.51	588	875	2.25	4590	17.97	5.70
	2.81	725	875	4.00	5500	15.60	4.30
Average	2.93	603	765	2.95	2723	17.26	3.37
6	3.01	575	700	5.50	3800	15.68	4.80
	2.91	625	750	5.00	3900	16.43	4.60
	2.92	475	780	2.50	2840	17.01	4.90
	3.01	632	760	5.40	2604	16.90	4.80
	3.01	734	781	5.50	2840	17.03	5.00
Average	2.97	608	754	4.78	3197	16.61	4.82
7	3.20	625	791	5.40	3840	17.04	5.20
	3.30	576	783	4.60	3940	17.92	5.30
	2.99	678	791	5.90	3404	17.84	5.10
	3.04	705	774	6.60	3504	17.64	5.00
	3.08	708	786	5.70	3472	17.83	5.40
Average	3.12	658	785	5.44	3632	17.66	5.20

Table 4: Some Mechanical Properties of Large Castor Seeds

Moisture Content (%)	Compression Strength (N/mm²)	Bio-Yield Force (N)	Rupture Force (N)	Deformation at Rupture (mm)	Energy (J)	Modulus of Deformation (N/mm²)	Toughness (N/mm³)
5	2.91	602	726	3.30	2178	17.27	2.75
	2.81	578	701	2.70	1404	20.01	1.75
	2.26	529	703	3.40	1954	15.48	2.65
	2.61	592	695	5.28	4567	11.91	5.80
	2.70	726	685	4.12	3514	15.62	4.40
Average	2.66	606	702	3.76	2723	16.06	3.47
6	3.51	652	878	5.52	3111	9.09	4.90
	3.50	632	702	5.02	3214	10.70	4.80
	2.81	625	712	2.03	1478	10.10	2.00
	2.91	598	698	3.47	1477	9.07	4.64
	3.01	694	800	2.43	1498	9.10	4.80
Average	3.15	640	758	4.29	2156	9.61	4.23
7	3.01	711	819	2.93	1988	8.94	4.90
	3.02	709	824	3.94	1697	9.45	3.90
	3.11	729	719	3.84	1984	8.98	4.80
	3.12	742	819	6.34	1970	9.07	4.30
	3.14	736	804	6.07	3040	10.76	3.80
Average	3.08	725	797	4.82	2136	9.44	4.34

Table 5: Aerodynamic Properties of Small and Large Castor Fruits

Aerodynamic Properties	Small Castor Fruits	Large Castor Fruits
Acceleration (m/s²)	0.304	0.333
Drag Force (N)	0.17	0.20
Terminal Velocity (m/s)	1.10	1.12

ISSN 2229-5518

Table 6: Aerodynamic Properties of Small and Large Castor Seeds

Aerodynamic Properties	Small Castor Seeds	Large Castor Seeds
Acceleration (m/s^2)	0.387	0.240
Drag Force (N)	0.10	0.12
Terminal Velocity (m/s)	0.72	0.84

Table 7: Analysis of Variance (ANOVA) on the Effect of Moisture Content and Size on Mechanical Properties Determination of Castor Fruits.

Source of Variation	Sum of Squares	Degree of Freedom	Mean Squares	Computed F
A(Size)	29.07	3	9.690	6.098*
B(Moisture Content)	0.396	2	0.198	0.125
AB	14.69	2	7.345	4.622
Error	6.354	4	1.589	
Total	50.51	11		

Table 8: Analysis of Variance (ANOVA) on the Effect of Moisture Content and Size on Mechanical Properties Determination of Castor Seeds.

Source of Variation	Sum of Squares	Degree of Freedom	Mean Squares	Computed F
A(Size)	3.46	3	1.153	0.134*
B(Moisture Content)	2.36	2	1.180	0.137*
AB	2.53	2	1.265	0.147
Error	34.34	4	8.585	
Total	42.69	11		

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