Determination of Some Mechanical Properties of Almond Seed Related to Design of Food Processing Machines

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ABSTRACT: In this study, some selected mechanical properties of red and white varieties of Almond seeds grown in Nigeria were determined using Testometric M500 – 100AT machine. The fracture force, compressive strength, deformation at yield for red varieties were 2679.40 ± 580.29 N, 408.70 ± 41.90 N/mm^2 and 7.03 ± 0.65 mm respectively. The values obtained for the white varieties were 2843.90 ± 330.22 N, 396.20 ± 49.40 N/mm^2, and 7.27 ± 0.46 mm. The determined engineering properties are vital for the design of postharvest handling and processing systems for Almond seeds as statistical test showed that there are significant differences (at 5% level) between the engineering properties of the two seeds studied.

KEYWORDS: fracture force, compressive strength, deformation, almond seeds

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I. Introduction

Information on mechanical properties of agricultural products as a function of moisture content is needed in the design and adjustment of machines used during harvest, separation, cleaning, handling and storage. It is also used in processing these agricultural materials into food. The properties useful for design must be determined at laboratory conditions (Gürsoy and Güzel, 2010). Mechanical properties such as stress, strain, hardness and compressive strength are vital to engineers handling agricultural products. The physical and mechanical properties of nuts, kernels, seeds and fruits such as soya, sunflower, pigeon pea, apricot kernels have been studies (Deshpande, 1993; Gupta, 1997; Baryeh, 2003; Fathollahzadeh, 2008). The output of agricultural and processing machines depends on these properties (Mohsenin, 1986).

In agricultural products, mechanical damages are majorly due to external forces under static and dynamic conditions. However, internal forces that cause mechanical damage include the factors such as variation in temperature & moisture content and when this mechanical damage occurs; the product becomes more susceptible to infection and diseases (Chukwu and Sunmonu, 2010). Stroshine (1998) reported that the particle size distributions of agricultural products influence their handling, storage and utilization characteristics. Also, when agricultural materials such as oilseeds, almond, and hazelnut are ground in mills, the distribution of particle sizes must be known in order to achieve desirable properties without unnecessary expenditure of energy.

Almond *(Amygdales Communist L.)* is perennial plant that is grown in the cold and xeric environments of Iran. The kernels of almond form an important source of energy with 6 Kcal/g, protein. It contains about 26% carbohydrates, and can be processed into flour used for cakes and cookies (biscuits) low-carbohydrate diets. Almond nuts are rich source of vitamin E 26 mg per 100g, high quality protein and have essential amino acids. Almond is rich in dietary fibre, B vitamins, essential minerals and monounsaturated fat.

The mechanical properties are required in order to avoid deformation on the kernels when almond nuts are subjected to impact to crack and release the kernels. These properties would be useful for quality determination and characterization of nuts from the seed especially when the nuts are to be processed into other useful products like oil. Also the data generated will be useful in the design of almond nut machines.

This study therefore is aimed at determination of selected mechanical properties of almond seeds (**(***Amygdales Communist L.***)** related to the design of food processing machines.

II. Materials and Methods

A. Determination of Fracture Force and Strain at Yield

A universal testing machine (Testometric M500-100AT) was used to obtain the fracture force of the kernel. The slots were screwed to compress the kernel placed between them. The counter reading was taken immediately the first cracking sound was heard. The strain at yield was also recorded during the test on the Universal Testing Machine shown in Plate 1. The deformation at yield was also recorded during the test on the Universal Testing Machine. Compressive strength was calculated by dividing the fracture force with the area in contact with the kernel.

B. Co-efficient of Static Friction

The coefficient of static friction was determined on wood with the kernel parallel to the direction of flow. A topless and bottomless box was used to determine the coefficient of static friction. The surface was raised gradually until the field cube just starts to slide down. The angle at this point was recorded

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and the coefficient of static friction was calculated using the expression in eqn (1).

$$\mu = \tan\theta \qquad (1)$$

where μ is static coefficient of friction and θ is the angle from the horizontal plane.

Plate 1: A universal testing machine.

C. Determination of Moisture Content

Red almond of 0.47 kg and white of 0.466 kg were accurately weighed on an electric weighing balance. The samples were dried at $100^{o}C$ – $132^{o}C$ for 24 hours in an electric oven after which the samples were taken out from the oven and weighed again. The loss in weight was recorded as the moisture content determined using eqn (2).

$$\%\text{ moisture content} = \frac{M1-M2}{MI} \times 100\%\, wb \qquad (2)$$

where *M1*= initial weight of the sample, and *M2* = final weight of the sample.

III. RESULTS AND DISCUSSION

The mechanical properties of the two varieties of Almond seed (Red and White Almond) are presented in Table 1. The moisture content of 36.5% and 45.9% were obtained for red and white almond respectively. The two moisture content levels were observed to be the range at which almond seed can be extracted with least percentage of cracking. Further decrease in the moisture content will make the kernel to be brittle, while a higher moisture level will make the kernel to stick to the shell, therefore, resulting to crushing if cracked. The average force required to fracture red almond seed for minor axis, intermediate axis and major axis were 2679.40 ± 580.29 N, 2533.3 ± 301.03 N and 2268.70 ± 740.11 N respectively, while their compressive strength are: 408.70 ± 41.90 N/mm^2, 219.6 ± 65.30 N/mm^2 and 224.80 ± 104.00 N/mm^2 for minor axis, intermediate axis and major axis respectively.

In designing food processing machines, the knowledge of these properties has been emphasized by Adebayo (2004) when he carried out carried a compression test on Dura varieties of the palm nut in order to determine the force required for cracking the palm nut. The deformation at yield, strain at yield, and strain at break are 7.03mm, 33.24% and 33.77% for red almonds. The average force to fracture white almond for minor axis, intermediate axis and major axis are 2843.90 ± 330.33 N, 1379.20 ± 823.15 N and 2003.00 ± 1198.26 N respectively. The compressive strengths for minor, major and intermediate axis are 396.20 ± 49.40 N/mm^2, 216.30 ± 23.92 N/mm^2 and 262.4 ± 174.80 N/mm^2 respectively for the white almond. The result revealed lower fracture force for red almond seed in minor axis and a higher fracture force for red almond seed in intermediate and major axis. These parameters are important in designing of machines for processing biomaterials, particularly in the design of a cracking machine for extraction of nut from the kernel. These parameters also give the energy requirement and consideration governing equipment selection in size reduction operation. (Orhevba *et al.*, 2013).

The results in Table 1 were represented using graphical illustrations as shown in Figure 1 to 5. The results of deformation at yield (mm), strain at yield (%), deformation at break (mm), strain at break (%) and compressive strength of red and white almond seed for minor and intermediate axis were shown in Figure 1, 2 and 3. The result shows relatively the same mean values of these properties for both varieties. A higher value of deformation yield (mm), strain at yield (%),

Deformation at break (mm), strain at break (%) were noticed in red almond seed compared to white almond seed when tested using major diameter axis as shown in Figure 4. Figure 5 shows that while fracture force was lower for red almond seed in minor axis, this property was higher for red almond seed in intermediate and major axis. The importance of this this property in determining the required force for fracture of Mamaei cultivar of almond in the loading rate of 5 mm/s and moisture content of 6.3% w.b. is about 673 N is as described by Khazaei (2008). Fracture force is also very important in determining the compression and shear coefficients if the probe diameters are known Bourne (1975).

In order to draw a valid statistical inference on the differences between the mechanical properties of a randomly selected red and white almond seed, an independent t test was employed. Table 2 shows the result of the independent test. The following inference was drawn from Table 2;

1. Mechanical properties such as the deflection at peak (mm), fracture force (N), and strain at yield (%) of a randomly selected red almond seed is significantly higher than those of white almond seed.
2. The higher values of all other mechanical properties irrespective of the varieties and axial test earlier observed were not significantly different.

Significant mechanical properties imply that the two varieties of seed do not behave the same when subject to mechanical test such as cracking, etc. Therefore, it can be concluded that the significant mechanical properties of red and white almond seed differs from one another. Hence designing agricultural processing equipment/machines for almond seed could take into account this observed phenomenon.

Table 1: Results of the determined mechanical properties of almond seed.

		Red Almond Seed						White Almond Seed					
		Def. @ Yield (mm)	Strain @ Yield (%)	Fracture force (N)	Def. @ Break (mm)	Comp-Strength (N/mm^2)	Strain @ Break (%)	Def. @ Yield (mm)	Strain @ Yield (%)	Fracture force(N)	Def. @ Break (mm)	Comp-Strength (N/mm^2)	Strain @ Break (%)
Minor Axis	Mean	7.03	33.24	2679.40	7.15	408.70	33.77	7.27	33.46	2843.90	7.36	396.20	33.85
	S.D.	0.65	3.05	580.29	0.49	41.90	2.29	0.46	2.13	330.22	0.49	49.40	2.27
	Max	7.85	37.11	3240.00	7.85	474.00	37.11	7.85	36.11	3472.00	8.14	516.60	37.44
	Min	5.73	27.08	1135.00	6.29	346.00	29.75	6.58	30.29	2419.00	6.58	343.80	30.29
	C. of V.	9.17	9.17	21.66	6.78	10.26	6.78	6.36	6.36	11.61	6.72	12.46	6.72
	L.C.L.	6.57	31.06	2264.28	6.80	-	32.13	6.94	31.94	2607.67	7.01	-	32.22
	U.C.L.	7.49	35.42	3094.52	7.49	-	35.41	7.60	34.98	3080.13	7.71	-	35.48
Intermediate Axis	Mean	10.19	33.08	2533.30	11.00	219.60	35.70	9.83	33.51	1379.20	11.32	216.30	38.58
	S.D.	2.08	6.76	301.03	1.34	65.30	4.34	1.03	3.52	823.15	1.83	23.92	6.23
	Max	12.37	40.18	3115.00	12.66	282.90	41.10	11.81	40.26	2503.00	14.32	262.12	48.82
	Min	5.43	17.62	2170.00	8.69	51.80	28.21	8.70	29.64	330.00	8.98	183.75	30.59
	C. of V.	20.43	20.43	11.88	12.16	29.76	12.16	10.51	10.51	59.68	16.16	11.06	16.16
	L.C.L.	8.70	28.24	2317.95	10.04	-	32.59	9.09	30.99	790.34	10.01	-	34.12
	U.C.L.	11.68	37.91	2748.65	11.95	-	38.80	10.57	36.03	1968.06	12.63	-	43.04
Major Axis	Mean	11.42	21.78	2268.70	12.73	224.80	24.29	9.79	15.85	2003.00	12.19	262.40	19.74
	S.D.	3.14	5.98	740.11	3.28	104.00	6.26	4.13	6.69	1198.26	5.28	174.80	8.54
	Max	13.65	26.05	3121.00	17.19	429.70	32.80	16.50	26.71	3511.00	19.93	593.20	32.27
	Min	4.75	9.07	741.00	6.58	108.80	12.56	3.77	6.10	30.00	6.73	68.00	10.90
	C. of V.	27.46	27.46	32.62	25.78	46.25	25.78	42.21	42.21	59.82	43.28	66.59	43.28
	L.C.L.	9.17	17.50	1739.24	10.38	-	19.81	6.83	11.06	1145.80	8.42	-	13.63
	U.C.L.	13.66	26.06	2798.16	15.08	-	28.77	12.74	20.63	2860.20	15.96	-	25.85

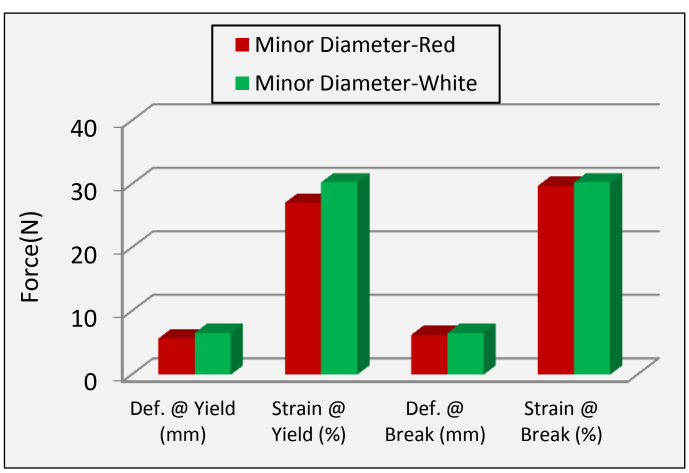

Figure 1: **Kernel compression test-minor axis.**

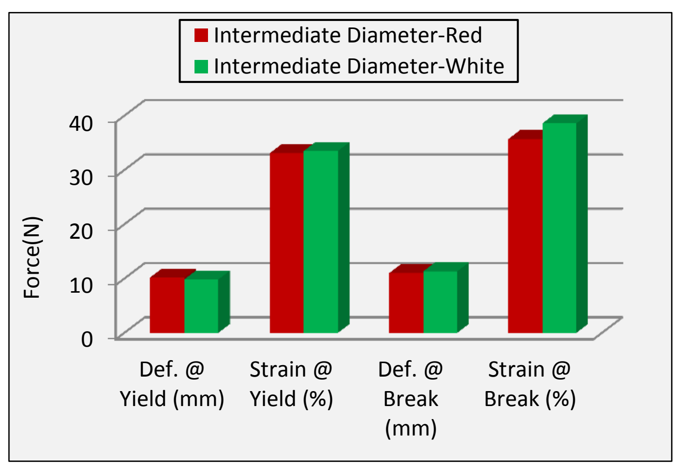

Figure 2: Kernel compression test-intermediate axis.

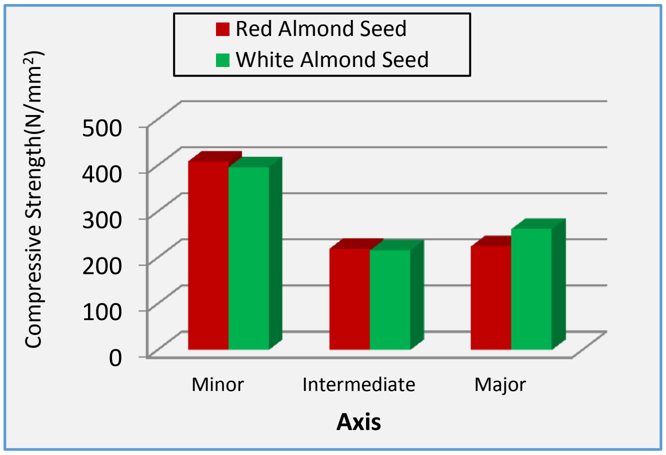

Figure 3: Comparing compressive strength at various axes.

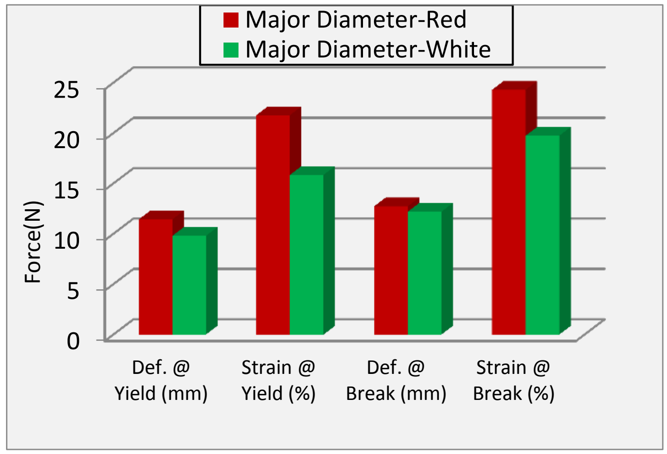

Figure 4: Kernel compression test – major axis.

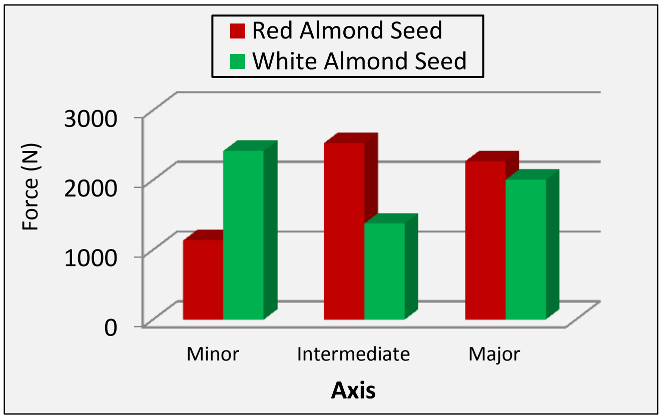

Figure 5: Comparing fracture force/force @ break.

IV. Conclusion

This research focused on the determination of some mechanical properties of Almond seed (*Amygdales Communist L.)* related to the design of food processing machines. The mechanical properties determined for both red and white almond seeds were fracture force; strain at yield, and deformation at yield, compressive strength and coefficient of static friction. It can be concluded that the determined engineering properties are vital for the design of postharvest handling and processing systems for almond seeds as statistical test showed that there are significant differences between the engineering properties of the two seeds studied. It is also economical to load white almond kernel in major axis to reduce energy demand when necessary to fracture or compress the almond kernel and to load red almond kernel in intermediate axis to reduce energy demand when necessary to fracture or compress the kernel.

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Table 2: Comparing the Mechanical Properties of Red and White Almond Seed (Independent T test).

Mechanical properties		T	Df	Sig.	MD	S.E	95% CI Lower	95% CI Upper
Minor Axis	Fracture force (N)	-0.155	18	0.8790	-18.900	122.057	-275.333	237.533
	Def. @ Peak (mm)	-0.959	18	0.3500	-0.241	0.251	-0.768	0.287
	Strain @ Peak (%)	-0.187	18	0.8540	-0.220	1.175	-2.688	2.249
	Force @ Yield (N)	-0.155	18	0.8790	-18.900	122.057	-275.333	237.533
	Comp_Strength	0.609	18	0.5500	12.468	20.485	-30.569	55.504
	Def. @ Yield (mm)	-0.959	18	0.3500	-0.241	0.251	-0.768	0.287
	Strain @ Yield (%)	-0.187	18	0.8540	-0.220	1.175	-2.688	2.249
	Force @ Break (N)	-0.779	18	0.4460	-164.500	211.136	-608.081	279.081
	Def. @ Break (mm)	-0.971	18	0.3440	-0.213	0.219	-0.673	0.247
	Strain @ Break (%)	-0.076	18	0.9410	-0.077	1.021	-2.221	2.067
Intermediate Axis	Fracture force (N)	3.394	18	0.003*	435.500	128.327	165.894	705.106
	Def. @ Peak (mm)	1.959	18	0.066#	1.050	0.536	-0.076	2.176
	Strain @ Peak (%)	1.027	18	0.3180	1.821	1.773	-1.904	5.545
	Force @ Yield (N)	0.988	18	0.3360	225.100	227.824	-253.541	703.741
	Comp_Strength	0.148	18	0.8840	3.255	22.003	-42.972	49.482
	Def. @ Yield (mm)	0.485	18	0.6340	0.356	0.735	-1.187	1.900
	Strain @ Yield (%)	-0.179	18	0.8600	-0.432	2.409	-5.493	4.630
	Force @ Break (N)	4.164	18	0.001*	1154.100	277.163	571.803	1736.397
	Def. @ Break (mm)	-0.451	1	0.6570	-0.323	0.716	-1.828	1.182
	Strain @ Break (%)	-1.198	18	0.2460	-2.878	2.402	-7.924	2.168
Major Axis	Fracture force (N)	0.14	18	0.8900	31.900	228.332	-447.807	511.607
	Def. @ Peak (mm)	0.403	18	0.6920	0.843	2.093	-3.554	5.239
	Strain @ Peak (%)	1.353	18	0.1930	4.839	3.577	-2.677	12.354
	Force @ Yield (N)	0.895	18	0.3830	217.100	242.654	-292.697	726.897
	Comp_Strength	-0.586	18	0.5650	-37.652	64.300	-172.743	97.438
	Def. @ Yield (mm)	0.993	18	0.3340	1.629	1.640	-1.816	5.074
	Strain @ Yield (%)	2.093	18	0.051#	5.939	2.838	-0.023	11.901
	Force @ Break (N)	0.597	18	0.5580	265.700	445.375	-669.997	1201.397
	Def. @ Break (mm)	0.275	18	0.7860	0.540	1.964	-3.587	4.667
	Strain @ Break (%)	1.361	18	0.1900	4.556	3.349	-2.479	11.592

*significant at 5% level, #significant at 10% level

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