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Research Article

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Effect of Soaking Time and Temperature on Some Physical and Mechanical Properties of Cowpea (*Vigna unguiculata*)

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Abstract The physical and mechanical properties of cowpea are useful for the design of its processing equipment and machines. These properties were determined for three cowpea varieties in Nigeria (*Iron* beans, *Oloyun* beans, and *Potiskum* beans). The effect of soaking time (10, 15 and 20 min) and soaking water temperature (30, 50 and 70^{o}C) on these properties were also investigated. The average weight, major diameter, intermediate diameter, minor diameter, arithmetic mean diameter (AMD), geometric mean diameter (GMD), and volume of a grain of cowpea were 0.35 g, 9.04 mm, 5.73 mm, 4.20 mm, 6.32 mm, 6.01 mm, and 15.94 mm^3 respectively for *Iron* beans. The values were 0.31 g, 9.06 mm, 5.46 mm, 3.33 mm, 5.95 mm, 5.48 mm, and 13.23 mm^3 respectively for *Oloyun* beans. And for *Potiskum* beans variety, the values were 0.30 g, 8.83 mm, 5.32 mm 3.77 mm, 5.97 mm, 5.61 mm and 13.87 mm^3 respectively. The average moisture content of the three varieties ranged from 9.53% db (for *Iron* beans) to 10.70% db (for *Potiskum* beans). Experimental results also showed that the moisture content of the three beans varieties increased as the soaking time and soaking water temperature increased. *Potiskum* beans absorbed more water as both the soaking time and soaking water temperature increased, followed by *Iron* beans. All the size indices also increased as the soaking time and soaking water temperature increased. The mechanical properties measured, generally decreased with increased soaking time and increased soaking water temperature. The results of the investigation showed that increasing soaking time and soaking water temperature could reduce processing time and energy of cowpea.

Keywords cowpea, physical properties, mechanical properties, soaking time, soaking temperature

1. Introduction

Cowpea is also known as the black eyed beans or southern peas. It is an important source of protein in both rural and urban Nigeria. It is also a fact that Nigeria is the largest producer and consumer of cowpea in all West Africa [1]. More than 8 million hectares of cowpea are grown in the West and Central Africa and they serve as a good source of protein, energy and other nutrients. Nigeria is the largest producer with 4 million hectares, followed by Niger with 3 million hectares. Other producers includes: Mali, Senegal, Burkina Faso, etc [1]. The cowpea grain contains about 25% protein and 64% carbohydrate. It is considered a dual- purpose crop that provides grains for human consumption and fodder for livestock [1]. Cowpea seed has a coat called testa or hull. This hull contains tannin and trypsin inhibitor which are anti-nutritional factors [2]. The testa, however, is rich in mineral elements [3] cited in [2]. Cowpea can be processed into various finished and semi-finished products. The advantages of cowpea processing include improving digestibility, reducing or eliminating anti-nutritional factors, improving consumer appeal and acceptability, extending shelf-life, income generation, etc. The flour is less prone to insect pest attack and can be stored for relatively longer period of time. Cowpea flour is usually rehydrated and utilized in formulations as desired. Cooked cowpea seeds can be consumed in form of cooked whole cowpea or cooked de-hulled cowpea. Whole cowpea (with intact testa) takes longer period of time to cook than de-hulled cowpea. Cooked whole cowpea is eaten whole or de-hulled, either alone or in combination with other food products like bread, *garri*, boiled yam with vegetable soup. Cowpea flour is used to prepare *akara* (bean cake), *dawanke* (cowpea dumplings), and moi-moi (steamed cowpea paste). Cowpea seeds are utilized whole or processed into flour and further into paste.

Cowpea seed is a nutritious component in the human diet as well as a nutritious livestock feed. Cowpea is used at all stages of growth as a vegetable crop. It is cultivated mainly for its seeds which can be processed into flour which is used to make cake, *akara* balls, etc., into paste to make *moi-moi* (pudding), or even cooked and eaten alone. It gives the working mothers the opportunity to prepare this favourite meal with the comfort it provides. The high protein content of cowpea makes it an excellent fodder crop. Various parts of cowpea are used medically. Cowpea is a good fertilizer because of its ability to fix nitrogen from the air. Cowpea grain contains about 25% protein and 64% carbohydrate and the product can be marketed through market women, food canteens, hotels and super markets. Cowpea is of considerable importance in Nigeria and in many African countries as a nutritious leguminous crop providing an alternative source to animal protein [4]. The consumption of bean is however curtailed because of the long cooking time needed to achieve the desired palatability and digestibility [5-6]. Cowpea is used as a feed ingredient in diet for poultry and pigs [7]. It is also used as a digestible ingredient in diets for aquatic organisms such as penaeusmonodon [8] and tilapia [9]. Cowpea seed is a nutritious component in the human diet, as well as a nutritious livestock feed. The protein in cowpea seed is rich in the amino acids, lysine and tryptophan, compared to cereal grains. However, it is deficient in methionine and cystine when compared to animal proteins. Therefore, cowpea seed is valued as a nutritional supplement to cereals and an extender of animal proteins. Cowpea can be used at all stages of growth as a vegetable crop. The tender green leaves are an important food source in Africa and are prepared as a pot herb, like spinach. Immature snapped pods are used in the same way as snap beans, often being mixed with other foods. Green cowpea seeds are boiled as a fresh vegetable, or may be canned or frozen. Dry mature seeds are also suitable for boiling and canning. In many areas of the world, the cowpea is the only available high quality legume hay for livestock feed. Digestibility and yield of certain cultivars have been shown to be comparable to alfalfa. Cowpea may be used green or as dry fodder. It also is used as a green manure crop, a nitrogen fixing crop, or for erosion control. Similar to other grain legumes, cowpea contains trypsin inhibitors which limit protein utilization. Both physical and mechanical properties are important factors in solving problems associated with the design of specific machines or analysis of the behaviour of the product during agricultural processes such as planting, harvesting, and handling, threshing, sorting, and drying. Solution to these problems involves having the knowledge of the physical and the mechanical properties of products [10]. The aim of this study is to investigate the influence of soaking time and soaking water temperature on some physical and mechanical properties of cowpea seeds relevant for de-hulling and milling.

2. Materials and Methods

2.1 Materials

The materials that were used in the course of this study include: Cowpea seeds, universal Hounsfield tensometer, an oven, a Vernier caliper, a stop clock, a weighing balance, a thermometer, a sieve, plastic bucket, and a boiling ring.

2.1.1 Cowpea seeds

The varieties of the cowpea seeds used include:

Iron beans (Sample A)
Oloyun beans (Sample B)
Potiskum beans (Sample C)

2.1.2 Universal Hounsfield Tensometer

The photograph of the universal hounsfield tensometer (UHT) used in this work is shown in Figure 1. It is also known as the universal tester. It was used to find compressive strength, rupture, bio-yield force, deformation at rupture, hardness, etc. of the beans. The components of the UHT includes: load frame, load cell, cross head, means of measuring extension or deformation, output device, conditioning and the test fixtures.

Figure 1: Universal hounsfield tensometer (UHT)

2.1.3 Oven

The photograph of the oven used in this work is shown in Figure 2. The oven was used to determine the moisture content in the cowpea seeds immediately it was procured from the market and immediately after soaking.

2.1.4 A digital Vernier caliper

The photograph of the Vernier caliper used to measure the major (length), minor (thickness) and intermediate (width) diameter of the cowpea seeds (with the digital Vernier caliper having an accuracy of 0.01mm) is shown in Figure 3.

2.1.5 A stop clock

The stop clock used in this study is shown in Figure 4. It was actually used for measuring the soaking time of the cowpea seeds.

2.1.6 A digital weighing balance

The picture of the digital weighing balance that was used for this work is shown in Figure 5. It was used to measure the weight of the beans before soaking and after soaking.

Figure 2: An oven

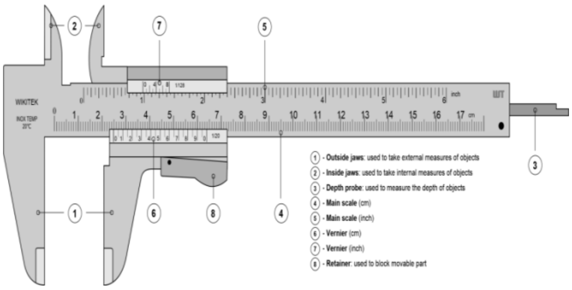

Figure 3: A digital Vernier caliper

Figure 4: A diagram of a stop clock

Figure 5: A picture of a digital weighing balance

2.1.7 A thermometer

The thermometer used for this work is shown in Figure 6. This was used to measure the initial soaking water temperature.

Figure 6: A Thermometer

2.1.8 A sieve

Another material that was used in this study is the sieve. It was used to sieve out water from the wet beans. A photograph of the sieve used is shown in Figure 7.

Figure 7: A sieve

2.1.9 Plastic Buckets

Some plastic buckets (Figure 8), for soaking, some amount of water to be put into another container (Figure 9) used in heating the water using a boiling ring (Figure 10) to the initial water temperature needed.

Figure 8: Soaked bean seeds at different time and temperature

Figure 9: Boiled water in a plastic container

Figure 10: Boiling ring

2.2 Methods

2.2.1 Sample preparation

The cowpea seeds were procured from a local market in Enugu state, South Eastern Nigeria. The samples included three varieties namely: *Iron* beans (Sample A), *Oloyun* beans (Sample B) and *Potiskum* (Sample C). The seeds were cleaned manually; all foreign materials such as dust, stones, chaff, immature and broken seeds as well as bad seeds were removed by winnowing and picking. The sample selection was randomized all through the tests. The samples were numbered to avoid repeating measurements with the same seed. The moisture contents of the seeds as they were bought from the market were determined by drying the samples in an air circulating oven set at 105 °C for 24 hours [13].

The moisture content was determined by using equation (2.1)

Moisture content, $M_{DB} = \frac{M_W - M_D}{M_D} \times 100$ (2.1)

Where: M_{DB}= Moisture content in dry basis of the seeds.

M_W = Initial weight of the seeds.

M_D = Weight of the seeds after drying.

The moisture content of the samples was calculated for both wet basis and dry basis as a percentage dry basis [5]. Every test was repeated three times in other to determine the mean values for the mechanical properties described below for each moisture content level.

2.2.2 Soaking time

The soaking time of the beans were measured with the use of a stop clock.

The soaking times used were: 10, 15, and 20 min for the three varieties.

2.2.3 Soaking temperature

The soaking temperature of the beans was measured with the thermometer. The soaking temperatures were: 30, 50, and 70°C.

2.3 Determination of physical properties

The physical properties that were considered in the course of this study included: size (major, intermediate and minor diameter, arithmetic mean diameter, geometric mean diameter), sphericity, weight, angle of repose, static co-efficient of friction, true density, and surface area.

2.3.1 Seed size

To determine the average size of the seed, a sample of 10 seeds from the different varieties were randomly selected. The three principal dimensions namely: the major diameter (length), the minor diameter (thickness) and the intermediate diameter (width) were measured with the use of a digital Vernier caliper. The geometric mean diameter (D_m) of the seeds was calculated using the following relationship in equation (2.2) 12].

$D_m = (LWT)^{1/3}$ (2.2)

And the arithmetic mean diameter, D_a was calculated using equation (2.3).

$D_a = (L+W+T)/3$ (2.3)

Where: L= Length (major diameter) in cm

T= Thickness (minor diameter) in cm

W= Width (intermediate diameter) in cm

To calculate the sphericity, [14] has the following equation (2.4).

$\emptyset = (LWD)^{1/3}/L$ (2.4)

The size measurements were done for the seeds before soaking and after soaking.

2.3.2 Angle of repose

This was determined by the use of a tilting surface, with a smaller diameter 45 mm, bigger diameter 200 mm and height 350 mm, having a discharge gate at the bottom. After filling the tube with seeds, the gate was quickly removed. The height of the seeds that piled above the floor and the radius of the heap (r) were measured and used to determine the angle of repose.

$$\emptyset = \tan^{-1} h/r \qquad (2.5)$$

Where h = height of the surface
r = radius of the heap
∅ = Angle of repose.

2.4 Mechanical properties

The Universal Hounsfield Tensometer (UHT), manufactured by Testometric Co. Ltd in UK was used for the determination of the mechanical properties. The tests carried out using this equipment included: rupture force, bio-yield force, compressive strength and deformation at rupture, and energy of the seed. These tests were done at different moisture levels, soaking time and soaking temperature. These tests were carried out at the Civil Engineering Laboratory, University of Nigeria, Nsukka at an average room temperature of 30 °C. The faces of the compression plates of the UHT were properly cleaned to remove dust and any other foreign material. The machine was switched on. Each seed was placed in-between the compression plates. As the test proceeded, the graph of force deformation was plotted. As soon as the specimen cracked, the tests were stopped. The rupture force, deformation, bio-yield force were read on the graph.

3. Results and Discussion

3.1 Basic Geometric Characteristics of Cowpea Seed

The basic geometric characteristics of the seeds that were measured were weight (Wt), Major diameter, Intermediate diameter, Minor diameter and Volume. Arithmetic mean diameter and Geometric mean diameter were calculated. The basic geometric characteristics of the seeds before soaking are presented in Table 1a.

Table 1a: Basic geometric characteristics of cowpea seed samples.

Cowpea variety	Wt (g)	Maj. diam (mm)	Interm. diam (mm)	Min diam (mm)	Arith mean diam (mm)	Geom mean diam (mm)	Vol (mm^3)
Iron beans	0.35	9.04	5.73	4.20	6.32	6.01	15.94
Oloyun beans	0.31	9.06	5.46	3.33	5.95	5.48	13.23
Potiskum beans	0.30	8.83	5.32	3.77	5.97	5.61	13.87

Generally, from Table 1a, it can be observed that *Iron* beans have the highest size (AMD of 6.32 mm) and volume of 15.94 mm^3 followed by *Potiskum* beans (AMD of 5.97 mm) and volume of 13.87$mm^3$and then *Oloyun* beans (AMD 5.95 mm; volume of 13.23 mm^3. It also show that *Iron* beans weighed highest (0.35 g) followed by *Oloyun* beans (0.31g) and then *Potiskum* (0.30 g). *Oloyun* beans had the highest major diameter (9.06 mm) followed by *Iron* beans (9.04 mm) and then by *Potiskum* beans (8.83 mm). *Iron* beans has the highest intermediate diameter (5.73 mm) followed by *Oloyun* beans (5.46 mm).

The complex physical characteristics of the cowpea seeds are shown in Table 1b.

Table 1b: Complex physical characteristics of the seed samples

Variety	True density (g/mm^3)	Sphericity (%)	Surface Area (mm^2)
Iron beans	0.02	0.66	95.62
Oloyun beans	0.02	0-60	79.37
Potiskum beans	0.02	0.64	74.06

Table 1b shows that the three varieties have the same true density of (0.02 g/mm^3. *Iron* beans has the highest sphericity (0.66%) followed by Potiskum beans (0.64%) and then Oloyun beans (0.60%). *Iron* beans has the highest surface area (95.62 mm^2) followed by *Oloyun* beans (79.37 mm^2), and then followed by *Potiskum* beans (74.06 mm^2).

Table 2a: Moisture content of seed samples before soaking

Variety	Moisture Content (% db)	Moisture Content (%wb)
Iron beans	9.53	8.70
Oloyun beans	10.58	9.57
Potiskum beans	10.70	9.67

The moisture contents of the beans before soaking are shown in Table 2a.The moisture content of the three varieties before soaking ranged from 8.70 to 9.67% wb. The moisture contents of the beans after soaking are shown in Table 2b.

Table 2b: Moisture content of the seed samples after soaking

Variety	Moisture Content (%wb)
***Iron* beans**	
At 30 °C	
10 min	24.50
15 min	30.49
20 min	33.25
At 50 °C	
10 min	33.57
15 min	34.01
20 min	36.94
At 70 °C	
10 min	33.76
15 min	35.01
20 min	36.00
Oloyun beans	
At 30 °C	
10 min	24.87
15 min	26.43
20 min	28.19
At 50 °C	
10 min	30.86
15 min	32.00
20 min	37.53
At 70 °C	
10 min	31.52
15 min	34.00
20 min	37.62
Potiskum beans	
At 30 °C	
10 min	26.13
15 min	32.00
20 min	34.90

At 50 °C	
10 min	35.00
15 min	36.11
20 min	39.00
At 70 °C	
10 min	34.00
15 min	37.00
20 min	40.10

Table 2b shows that as the soaking time and soaking water temperature increased, the moisture content also increased for all the varieties. At soaking water temperature of 30°C (ambient) and soaking time of 20 min, *Potiskum* beans attained the highest moisture content of 34.9%wb, followed by Iron beans (33.3%wb) and the *Oloyun* beans (28.2%wb). At soaking water temperature of 50°C and at soaking time of 20 min, *Potiskum* beans still attained the highest moisture content of 39.0% wb followed by *Oloyun* beans (37.5% wb) and then *Iron* beans (36.9% wb). The same positions were maintained at soaking water temperature of 70°C and soaking time of 20 min.

The basic physical properties of the seed varieties after soaking are shown in Table 3. At soaking water temperature of 30°C, the weight of the *Iron* beans increased with soaking time most probably due to more water absorption. *Potiskum* and *Oloyun* beans behaved alike even at soaking water temperatures of 50°C and 70°C. The seed size (AMD) of the three varieties followed the same trend except for *Oloyun* beans which showed a decrease at soaking water temperature of 50°C as the soaking time increased. This was likely due to loss of some seed components like the hull at that temperature.

Table 3: Basic physical properties of the seed varieties after soaking

Variety	Wt (g)	L (mm)	Wth (mm)	Th (mm)	Arith. Mean Diam (mm)	Geom. Mean Dia (mm)	Vol. (mm^3)
***Iron* beans**							
At 30 °C							
10 min	0.39	8.82	5.38	4.36	6.01	5.79	16.42
15 min	0.38	9.76	6.42	6.00	7.39	7.21	23.25
20 min	0.64	10.38	6.20	5.96	7.51	7.27	23.36
At 50 °C							
10 min	0.52	9.06	5.66	5.32	6.68	6.49	18.67
15 min	0.50	9.68	5.62	4.98	6.76	6.47	18.45
20 min	0.52	9.28	6.30	5.26	6.95	6.75	20.28
At 70 °C							
10 min	0.58	10.00	6.20	4.00	6.73	6.28	17.36
15 min	0.62	10.26	6.78	5.34	7.46	7.19	22.87
20 min	0.66	10.48	6.76	6.04	7.76	7.54	25.22
***Oloyun* beans**							
At 30 °C							
10 min							

Variety	Wt (g)	L (mm)	Wth (mm)	Th (mm)	Arith. Mean Diam (mm)	Geom. Mean Dia (mm)	Vol. (mm^3)
15 min	0.42	9.58	5.90	4.26	6.58	6.22	17.03
20 min	0.54	9.38	5.72	4.54	6.54	6.25	17.18
	0.50	9.94	5.66	4.34	6.64	6.25	17.18
At 50 °C							
10 min							
15 min	0.36	7.96	5.10	5.60	6.22	6.10	16.77
20 min	0.54	9.92	5.06	4.40	6.46	6.04	16.08
	0.50	10.68	6.22	3.62	6.84	6.22	17.06
At 70 °C							
10 min							
15 min	0.46	9.64	5.34	4.30	6.43	6.05	16.10
20 min	0.54	9.80	5.20	3.60	6.20	5.68	14.25
	0.40	9.20	5.22	3.98	6.13	5.76	14.60
***Potiskum* beans**							
At 30 °C							
10 min	0.44	9.40	6.06	4.60	6.69	6.40	18.07
15 min	0.42	10.26	6.48	4.64	7.12	6.76	20.10
20 min	0.54	10.26	6.64	4.80	7.23	6.89	20.92
At 50°C							
10 min	0.52	9.66	6.16	4.10	6.64	6.25	17.18
15 min	0.38	9.72	6.34	4.16	6.74	6.35	17.93
20 min	0.34	10.02	6.54	4.64	7.04	6.72	19.92
At 70 °C							
10 min	0.52	11.00	6.14	3.70	6.95	6.30	17.52
15 min	0.62	11.32	6.40	4.92	7.55	7.10	22.11
20 min	0.62	11.06	7.18	4.98	7.74	7.34	23.73

3.2 Mechanical Properties of the Cowpea Seed Samples

The mechanical properties of the seed samples were measured using the horizontal loading position. These mechanical properties are very important as they help processing engineers to have an idea of the kind of milling or processing machine design with respect to de-hulling. Table 4 gives the average values of some of the mechanical properties with respect to its soaking time and initial soaking water temperature. *Iron* beans have its lowest rupture force (131.3N) at soaking water temperature of 70°C and soaking time of 20 min. The lowest rupture force (127.0N) for *Oloyun* beans occurred at 30°C and soaking time of 20 min; while the lowest for *Potiskum* beans (117.0N) occurred at soaking water temperature of 70°C and soaking time of 20 min. The three varieties followed the same trend for bio-yield force. For compressive strength, *Iron* beans showed the lowest value of 135.7N/mm^2 at soaking water temperature of 50°C and soaking time of 20 min; *Oloyun* beans had its lowest at 191N/mm^2 at soaking water temperature of 50°C and soaking time of 20 min; while *Potiskum* beans lowest was 154.0N/mm^2 which occurred at soaking water temperature of 70°C and soaking time of 20 min. The lowest energy for the three varieties occurred at soaking water temperature of 70°C and soaking time of 20 min. This indicates that less heat energy is needed to cook beans pre-treated with hot water than beans that are not pre-treated. The graphical plots of rupture force versus soaking time for the three cowpea varieties for 30, 50 and 70°C are shown in Fig.11, 12 and 13 respectively.

Fig.11 shows that: for soaking time of 10 min and soaking water temperature of 30°C, *Potiskum* beans have the highest rupture force, bio-yield force, and deformation at rupture, compressive strength, and energy, followed by *Oloyun* beans and then *Iron* beans. And for soaking time of 15 min and soaking water temperature of 30°C, *Potiskum* beans have the highest rupture force, followed by *Oloyun* and then *Iron* beans. And then for soaking time of 20 min and soaking water temperature of 30°C, *Iron* beans have the highest rupture force followed by *Potiskum* beans and then *Oloyun* beans. Fig.12 shows that: for soaking time of 10 min and soaking water temperature of 50°C, *Iron* beans have the highest rupture force closely followed by *Potiskum* beans and then *Oloyun* beans.

Table 4: Mechanical properties of the cowpea variety with respect to the soaking time and initial soaking water temperature

Variety	Rupture force (N)	Bio-yield force (N)	Deformation at rupture (mm)	Compressive strength (N/mm^2)	Energy of seed (J)
***Iron* beans**					
30°C					
10 min	229.20	137.70	2.71	345.80	517.96
15 min	202.10	109.40	2.60	282.30	505.30
20 min	183.50	91.00	2.50	224.80	346.00
50°C					
10 min	229.30	135.60	3.25	302.33	546.70
15 min	180.60	102.30	2.42	240.00	487.30
20 min	172.00	100.00	2.80	135.70	437.10
70°C					
10 min	231.00	115.00	3.50	298.70	510.00
15 min	146.00	96.00	3.20	181.00	461.00
20 min	131.30	98.00	2.21	148.70	290.00
***Oloyun* beans**					
30°C					
10 min					
15 min	281.00	113.70	3.71	379.30	447.00
20 min	141.70	108.70	2.60	267.00	417.00
	127.00	68.70	2.51	208.70	349.70
50°C					
10 min					
15 min	190.00	112.30	2.70	252.70	519.70
20 min	189.70	107.30	2.60	219.00	487.00
	152.00	77.10	2.56	191.00	396.00
70°C					
10 min	214.00	148.70	3.00	258.00	595.00
15 min	198.00	138.00	2.40	256.00	487.00
20 min	198.90	133.70	2.30	250.00	380.00

Variety	Rupture force (N)	Bio-yield force (N)	Deformation at rupture (mm)	Compressive strength (N/mm^2)	Energy of seed (J)
***Potiskum* beans**					
30^{o}C					
10 min					
15 min	319.00	142.00	3.90	487.70	530.00
20 min	225.00	135.00	2.90	396.00	480.00
	162.00	110.00	2.60	275.00	340.00
50^{o}C					
10 min					
15 min	228.00	150.00	3.00	354.00	570.00
20 min	200.00	89.60	2.60	265.00	493.00
	170.80	81.50	2.50	250.30	449.00
70^{o}C					
10 min					
15 min	181.20	112.50	2.67	225.00	420.00
20 min	126.70	82.30	2.40	177.00	338.70
	117.00	75.00	2.30	154.00	280.00

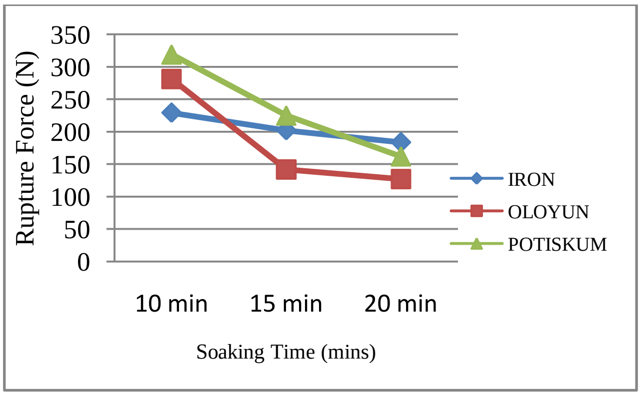

Figure 11: *Rupture force (N) of seeds at 30^{o}C*

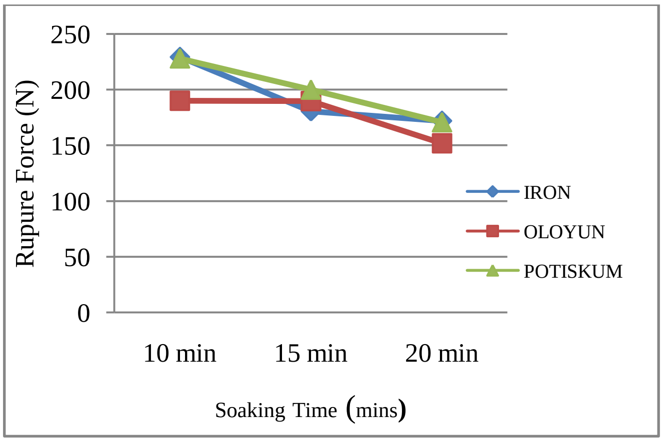

Figure 12: Rupture force (N) of seeds at 50^{o}C

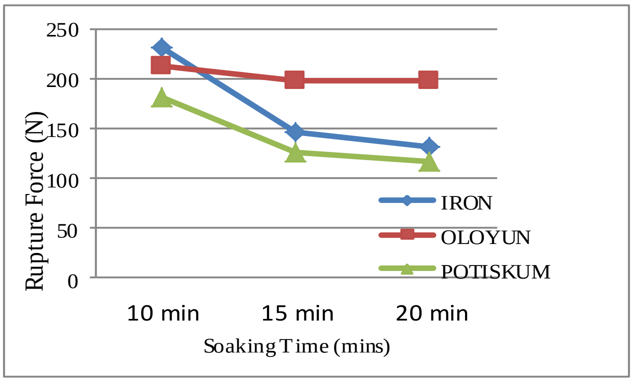

Figure 13: Rupture force (N) of seeds at 70°C

And for soaking time of 15 min and soaking water temperature of 50°C, *Potiskum* beans have highest with respect to rupture force, closely followed by *Oloyun* and then *Iron* beans. And then for soaking time of 20 min and soaking water temperature of 50°C, *Iron* beans and *Potiskum* beans lead in rupture force, closely followed by *Oloyun* beans.

Fig.13 shows that: for soaking time of 10 min and soaking water temperature of 70°C, *Iron* beans has the highest rupture force followed by *Oloyun* beans and then *Potiskum*. And for soaking time of 15 min and soaking water temperature of 70°C, *Oloyun* beans has the highest rupture force followed by *Iron* beans and then *Potiskum* beans. And then for soaking time of 20 min and soaking water temperature of 70°C, *Oloyun* beans have the highest rupture force followed by *Iron* beans and then *Potiskum.*

The graphical plots of bio-yield force versus soaking time for the three cowpea varieties for 30, 50 and 70°C are displayed in Fig.14, 15 and 16 respectively.

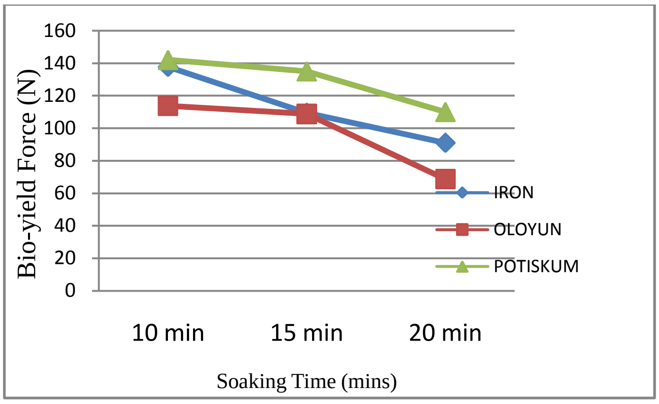

Figure 14: Bio-yield force (N) of seeds at 30 °C

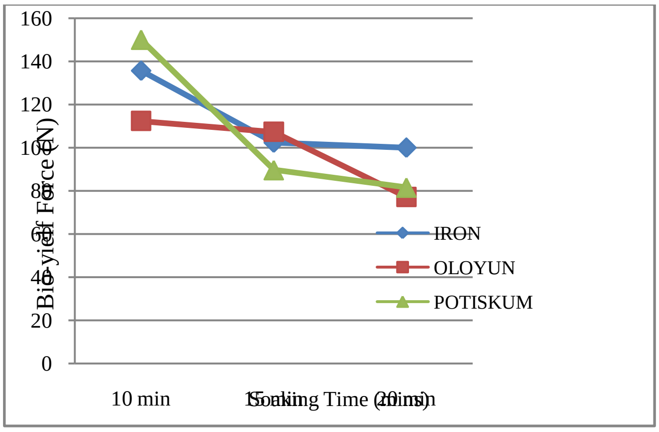

Figure 15: Bio-yield force (N) of seeds at 50°C

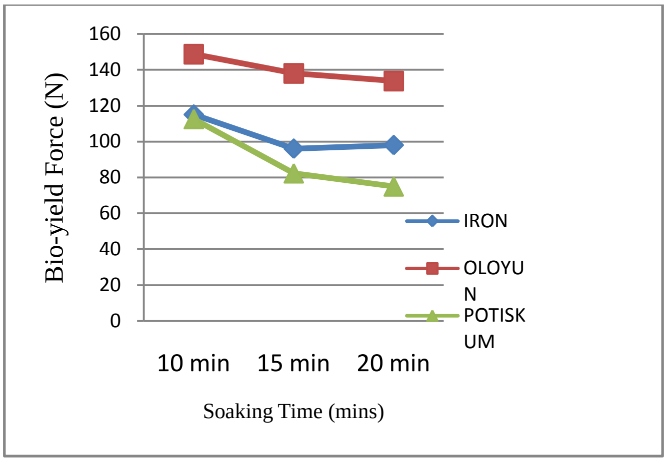

Figure 16: Bio-yield force (N) of the seeds at 70°C

Fig.14 shows that: for soaking time of 10 min and soaking water temperature of 30°C, *Potiskum* beans has the highest bio-yield force, followed by *Iron* beans and then *Oloyun* beans. And for soaking time of 15 min and soaking water temperature of 30°C, *Potiskum* beans leads followed jointly by *Iron* beans and *Oloyun* beans. And then for soaking time of 20 min and soaking water temperature of 30°C, *Potiskum* beans leads followed by *Iron* beans and then *Oloyun* beans.

Fig.15 shows that for soaking time of 10 min and soaking water temperature of 50°C, the order from highest to lowest in bio-yield force is *Potiskum*, *Iron*, and then *Oloyun* beans. And for soaking time of 15 min and soaking water temperature of 50°C the order is *Oloyun*, *Iron*, and then *Potiskum* beans. And then for soaking time of 20 min and soaking water temperature of 50°C, the order is *Iron*, P*otiskum*, and then *Oloyun* beans.

Fig.16 shows that: for soaking time of 10 min and soaking water temperature of 70°C, the order is *Oloyun* beans, *Iron* beans, and then *Potiskum* beans. And for soaking time of 15 min and soaking water temperature of 70°C, the order is *Oloyun*, *Iron* and then *Potiskum* beans. And then for soaking time of 20 min and soaking water temperature of 70°C, the order is *Oloyun, Iron*, and then *Potiskum beans*.

The graphical plots deformation at rupture versus soaking time for the three cowpea varieties for 30, 50 and 70°C are displayed in Figs.17, 18 and 19 respectively.

Fig.17 shows that for soaking time of 10 min and soaking water temperature of 30°C, the order is *Potiskum, Oloyun* and *Iron* beans. And for soaking time of 15 min and soaking water temperature of 30°C, the order is *Potiskum*, closely followed by *Iron* and *Oloyun* beans. And for soaking time of 20 min and soaking water temperature of 30°C, the order is *Potiskum*, again closely followed by *Iron* and *Oloyun* beans.

Fig.18 shows that for soaking time of 10 min and soaking water temperature of 50°C, the order is *Potiskum, Iron*, and then *Oloyun* beans. And for soaking time of 15 min and soaking water temperature of 50°C, the order is *Potiskum*, *Iron*, and *Oloyun* beans.

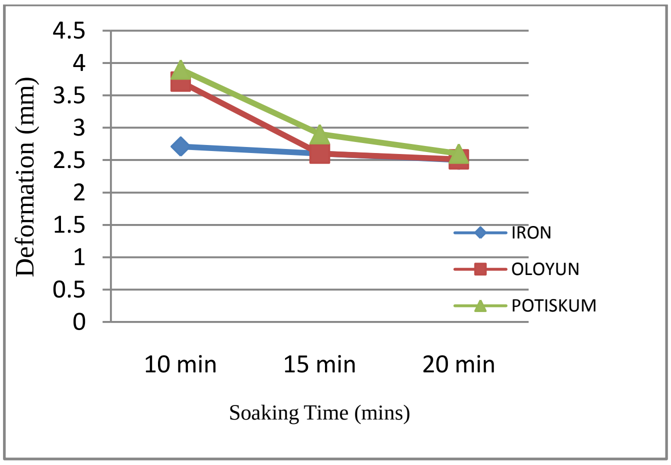

Figure 17: Deformation (mm) of seed at 30°C

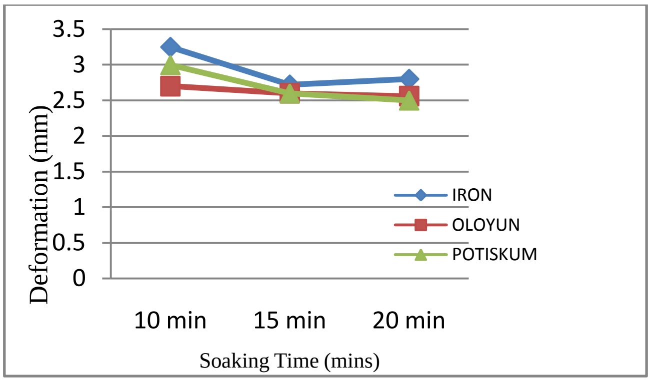

Figure 18: Deformation (mm) of seed at 50°C

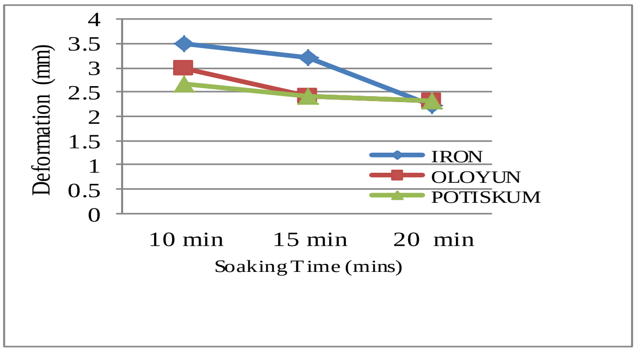

Figure 19: Deformation (mm) of seeds at 70°C

And then for soaking time of 20 min and soaking water temperature of 50°C, the order are *Potiskum, Oloyun* and then *Iron* beans.

Fig.19 shows that for soaking time of 10 min and soaking water temperature of 70°C, the order is *Iron*, *Oloyun*, and then *Potiskum* beans. And for soaking time of 15 min and soaking water temperature of 70°C, the order is *Oloyun* beans, jointly followed by *Iron* and *Potiskum* beans. And then for soaking time of 20 min and soaking water temperature of 70°C, the order is *Oloyun* beans, again jointly followed by *Iron* and *Potiskum* beans. The graphical plots of compressive strength versus soaking time for the three cowpea varieties for 30, 50 and 70°C are displayed in Figs.20, 21 and 22 respectively.

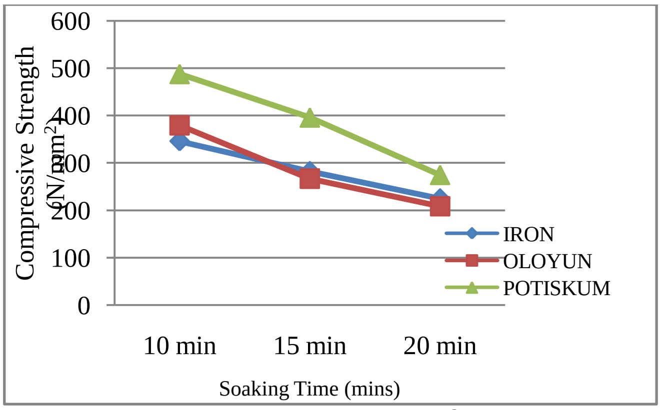

Figure 20: Compressive Strength (N/mm²) of seeds at 30°C

Fig. 20 shows that: for soaking time of 10 mins and soaking water temperature of 30°C, *Potiskum* beans have the highest compressive strength followed by *Oloyun* and then *Iron* beans. And for soaking time of 15 min and soaking water temperature of 30°C, the order is *Potiskum*, *Iron* and *Oloyun* beans. And then for soaking time of 20 min and soaking water temperature of 30°C, the order is *Potiskum*, *Iron* and *Oloyun* beans.

Fig. 21 shows that: for soaking time of 10 min and soaking water temperature of 50°C, the order is *Potiskum*, *Iron* and *Oloyun* beans. And for soaking time of 15 min and soaking water temperature of 50°C, the order is *Potiskum, Iron* beans and *Oloyun* beans. And then for soaking time of 20 min and soaking water temperature of

50^{o}C, the order is *Potiskum*, *Oloyun* and *Iron* beans. Fig. 22 shows that: for soaking time of 10 min and soaking water temperature of 70^{o}C, *Iron* beans has the highest compressive strength, followed by *Oloyun* beans and then *Potiskum* beans. And for soaking time of 15 min and soaking water temperature of 70^{o}C, the order is *Oloyun* beans, *Iron* and then *Potiskum* beans.

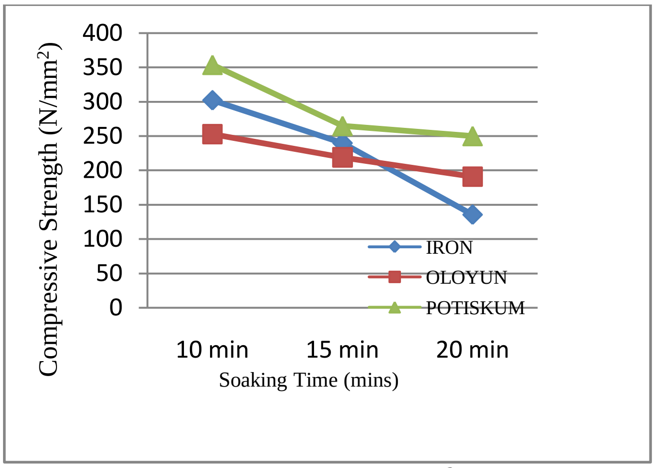

Figure 21: Compressive strength (N/mm^2) of seeds at 50^{o}C

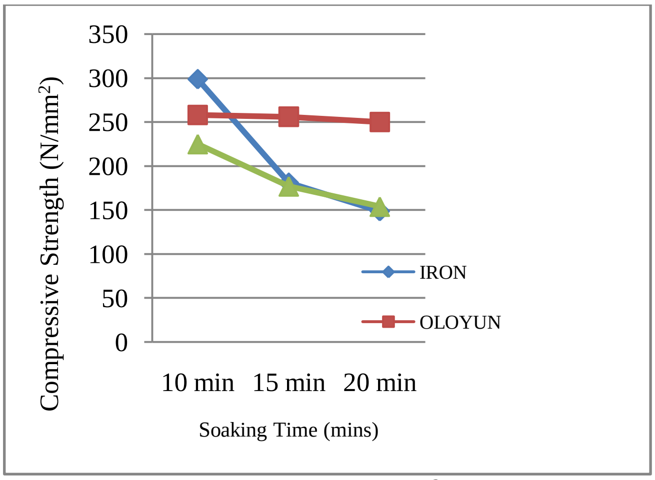

Figure 22: Compressive strength (N/mm^2) of the seed at 70^{o}C

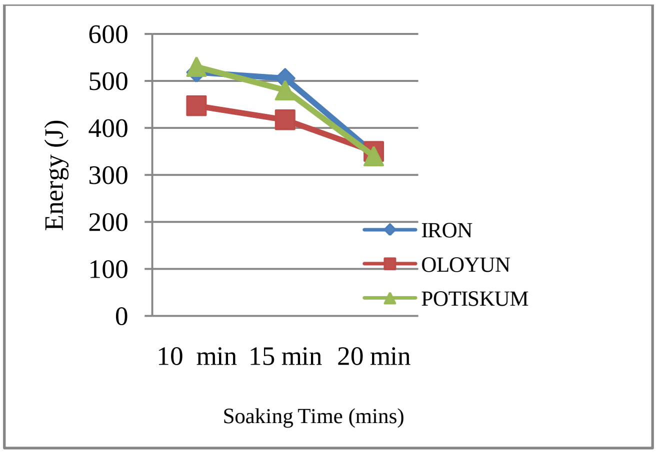

Figure 23: Energy (J) of seeds at 30^{o}C

And then for soaking time of 20 min and soaking water temperature of 70^{o}C, the order is *Oloyun* beans, followed by *Iron* beans, and then by *Potiskum* beans.

The graphical plots of energy versus soaking time for the three cowpea varieties for 30, 50 and 70^{o}C are displayed in Figs.23, 24 and 25 respectively.

Fig. 23 shows that: for soaking time of 10 min and soaking water temperature of 30°C, *Potiskum* and *Iron* bean have the highest energy followed by *Oloyun* beans. And for soaking time of 15 min and soaking water temperature of 30°C, the order is *Iron* beans, *Potiskum* beans, and then *Oloyun* beans. And then for soaking time of 20 min and 30°C, the three varieties have the same energy

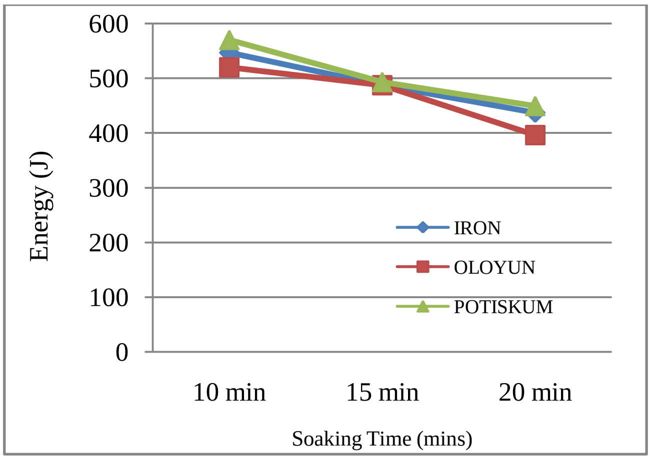

Figure 24: Energy (J) of seeds at 50 °C

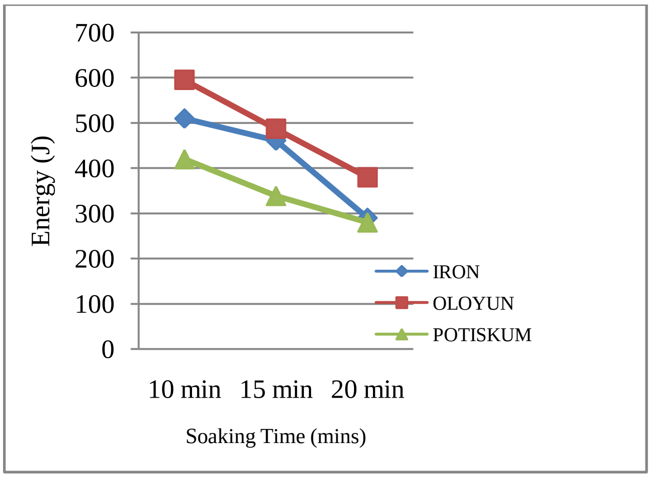

Figure 25: *Energy (J) of the seed at 70°C*

Fig. 24 shows that: for soaking time of 10 min and soaking water temperature of 50°C, *Potiskum* beans has the highest energy followed by *Iron* beans, and then *Oloyun* beans. And for soaking time of 15 min and soaking water temperature of 50°C, the three varieties have the same energy. And then for soaking time of 20 min and soaking water temperature of 50°C, the order is *Potiskum* beans, closely followed by *Iron* beans, and then *Oloyun* beans.

Fig. 25 shows that: for soaking time of 10 min and soaking water temperature of 70°C, *Oloyun* beans has the highest energy followed by *Iron* beans and then *Potiskum* beans. And for soaking time of 15 min and soaking water temperature of 70°C, the order is *Oloyun* beans, *Iron* beans, and then *Potiskum* beans. And then for soaking time of 20 min and soaking water temperature of 70 °C, the order is *Oloyun*, *Iron* and then *Potiskum* beans.

4. Conclusions and Recommendations

4.1 Conclusions

Soaking time affects positively the moisture content, weight, and the size of the cowpea seeds. Soaking time affects negatively the mechanical properties (rupture force, bio-yield force, deformation at rupture, compressive strength and energy) of the cowpea seeds. Soaking water temperature correlates positively with the moisture content, density, size (AMD), volume, sphericity, and the surface area of the cowpea seeds. Soaking water temperature affects negatively the rupture force, bio-yield force, compressive strength and energy of the cowpea seeds. Reduction of thermal energy for cooking beans could be achieved by pre-soaking in cold water (30^{o}C), or hot water (50 or 70^{o}C) for 10-15 min. *Iron* beans responds differently from *Potiskum* beans and *Oloyun* beans when soaked for a given time in either cold or hot water. Therefore, they should be soaked differently for better management of thermal cooking energy. Soaked in cold water (30 - 50^{o}C) *Potiskum* beans is adjudged stronger than Iron beans and *Oloyun* beans. Soaked in hot water (70^{o}C), *Oloyun* beans become stronger than *Potiskum* beans and *Iron* beans.

4.2 Recommendation

It is recommended that further studies be done to determine the shear strength of the hull or testa of cowpea and the effects of soaking time and soaking water temperature on it. Such data is important for the design of dehulling machine so as to reduce the present drudgery inherent in the processing of cowpea.

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