Comparative Performance Analysis of Melon (*Colocynthis Citrullus L.)* De-Husking and Separation Machines by Principles of Impact and Attrition

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***Abstract*– Melons are grown in Nigeria not for their pulp which is bitter, but for their seeds which are particularly rich in protein and fat, in addition to essential vitamins and minerals. The seeds are shelled to obtain the cotyledons and two methods (impact and attrition) were identified for carrying out this process. A machine was designed for each method and an optimal speed of 1000rpm selected after testing. Dehusking at an impeller speed between 1400–1800 rpm at moisture content of 16.47% ±2 resulted to high percentage breakage ranging from 40 - 80%. However, using an optimal speed of 1000rpm, percentage breakage was reduced to 12% for impact principle and 1% for attrition. Percentage undehusked for both methods was 10%, while percentage separation of dehusked shell from the white seed was 60% for impact and 70% for attrition. The attrition method clearly has the advantage of reducing post harvest loses due to deterioration caused by breakage. Both machines are applicable to agro processing industry.**

***Keywords*– Melon (Egusi), Dehusking, Attrition, Impact and Separation**

I. INTRODUCTION

The Melon (Egusi) *Colocynthis citrullus L.*, a member of the Cucurbitaceae family is an important crop in Nigeria and most other African countries. It is native to Africa where it has been in cultivation for many centuries [1]. It has been referred to in some texts as *Citrullus vulgaris* [2] and *Citrullus lanatus* [3]. The melon seeds are small, flat and oval (Fig. 1) containing a white cotyledon in a thin walled shell with a thick ring around the edges [4]. They are grown in Nigeria not for their pulp which is bitter, but for their seeds which are particularly rich in protein and fat, in addition to essential vitamins and minerals. The seed kernel (Egusi) has been used as the basis for a number of soups where it results in thickening, emulsifying, fat binding and flavoring. The oil is also used and is highly valued [5].

The egusi soup is the most popular among the dishes. The seed is an excellent source of dietary oil (53.1%), high in protein (33.8%), and contains higher levels of most amino acids than soyabean meal [6]. In south-eastern Nigeria, melon (Egusi) is usually grown mixed with other crops like yam, cassava, maize, etc. in the typical mixed cropping system practiced by farmers in West Africa [7]. In such crop combination, the egusi melon is regarded as a minor crop receiving lesser attention of the farmer. In some cases, it serves as a cover crop to smoother weeds in the farm [8].

Due to its variety and global spread, various researches have been carried out on melon and its seeds. In Nigeria, the bending properties of melon seeds, when compressed between two parallel plates under static loading was studied by Makanjuola [9]. He discovered that depending on the orientation of the seeds under load, they either broke longitudinally and transversely. The percentage of broken seeds were found to be higher in unwetted seeds (14.24 - 24.93%) than for wetted seeds (8.64 – 17.05%) as reported by Odigboh [10]. This was considered too high, as mechanical damage to shelled melon seed predisposes them to deterioration especially rancidification. Akobundu [11] studied the chemical, functional and nutritional qualities of Egusi seed protein products while Denton [12] worked on the development of breeding populations of the major seed types of melon. The fatty acid composition of melon seed oil lipids and phospholipids was studied by Akoh and Nwosu [13]; while the microbial population associated with the retting of melon pods during seed recovery was studied by Offonry and Achi, [14].

Speed and impeller diameter were reported to influence number of broken shelled melon seeds [15]. The researchers, after carrying out experiments, found out that a high speed and small diameter impeller produced five times as much broken shelled seeds as a low speed and large diameter impeller. Akpan [16] investigated forces required to crack melon seed shell between two parallel plates and reported that, 9.9 x 10^{-3} N, 11.6 x 10^{-3}N and 11.3 x 10^{-3}N was required to achieve cracking according to breadth wise, lengthwise with tip up and lengthwise with tip down orientations respectively for seeds at 8.3% moisture content (w.b). The values were also reported to increase with increase in moisture content. Similar experiment was conducted by Obot [17] with reported values of 12.54 x 10^{-3}N, 18.92 x 10^{-3}N and 19.58 x 10^{-3}N for breadth wise, lengthwise with tip up and lengthwise with tip down orientations respectively. These works may have prompted the study of the impact force of melon seeds during shelling [18]. It was reported that the factors affecting the impact force were impeller speed, seed cross section area at impact and mass ratio, while mean forces for breaking melon seeds were 13.14 x 10^{-3}N, 19.62 x 10^{-3}N and 19.55 x 10^{-3}N for the same orientations mentioned above.

Dried melon seeds were investigated for nutritional quality and the oil seed characteristics by Mirjana and Ksenija [19]. In 2007, Ogbonna and Obi [20] studied the effect of time of planting and poultry manure application on growth and yield of egusi melon in a derived savannah agro-ecology. Okokon [21] determined the young's modulus of elasticity of melon seeds by applying the theory of thin plates under compression while the kinetics of water absorption by (egusi) melon seeds was studied using the gravimetric method during soaking for a temperature range of 30-70°C to determine its moisture diffusivity by Addo and Bart-Plange [22] .

A coring machine was designed [23] and used to remove the seed-bearing pulp of the fruit core to accelerate decomposition of the mesocarp and endocarp. A melon washing machine has been developed [24] to reduce the drudgery involved in the traditional method of washing melon after fermentation and depodding. Oloko and Agbetoye [25] developed and evaluated a melon depodding machine with average depodding efficiency observed to range from 65.6% at speed 200 rpm to optimum level of 82.1% at speed 300 rpm before reducing gradually to 31.8% at speed 400 rpm. The overall efficiency of the depodding machine was reported to be 68.8%, at an optimal speed of 300 rpm.

The above mentioned works all involve methods of extracting seeds from pulp but melon seeds are shelled to obtain the cotyledons and it is usually done by mechanical impact method. This involves moving the seeds between vanes on a rotating impeller and impacting them on a fixed cylindrical ring [26]. This method is popular amongst communities where melon is grown especially when done in commercial quantities. However, very little information abounds in literature on methods of dehusking melon and obtaining the cotyledons. This work was aimed at designing, constructing, testing and comparing the results of melon dehusking machines which employ the principles of impact and attrition. It is expected that the results will help improve melon seed dehusking and separation operations.

II. MATERIALS AND METHODS

A) Mechanised method of dehusking

A review of literature shows that machines already developed in Nigeria mostly adopted the principle of impact. In this method, the wetted melon is directed to hit the chequered surface of a stationary anvil, thereby breaking the shell of the melon. Both the broken shells and the white melon seed exit through an outlet channel. The impeller is hollow and the melons move through the vanes provided in the impeller. The melons reach the centre of the impeller by force of gravity through the receiving hopper. Due to rotation of the impeller, the melons leave the impeller tangentially.

Centrifugal force plays a major role in this method of dehusking. Shelling of melon takes place throughout the circumference of the anvil (Fig. 2). Its advantages include; high productivity in dehusking and separation with reduction in dehusking and separation time. Labour is also reduced but the major setback of this method is the high percentage of breakage (12% and above).

B) Attrition (friction) method

In this method, the treated melons are directed to the periphery of the rotating impeller. The rotating impeller rubs the melons against the chequered surface of the stationary anvil and equally against the melons themselves thereby breaking the shell. The rotating impeller equally moves the melons and the broken shells along its direction of motion until the exit channel is reached. The rotating impeller and the anvil may or may not have the same centre of rotation. Its advantages are similar to that of impact but in this method percentage breakage is very low (about 1%).

C) Mechanics of melon dehusking and separation machines

The mechanics of operation of these machines is purely based on the dynamics and statics of the machine components. The machine components are pulleys, belt, shaft, bearings, and structural stand. Friction also played a very important role in the mechanics of the machines.

Circular motion of some of these components, gravitational motion of melon to be dehusked from the hopper to dehusking point, abrasion motion of the melon on the wall of the casing and air motion are applied to achieve material flow, dehusking regulatory feed of materials, discharge of dehusked melon from the exit point on the machine and separation of dehusked shell from the white seed. The engineering properties needed for the design were obtained from literature and some are shown in Table 1 and Table 2.

D) Circular motion and centrifugal force (F_G)

The circular motion from the prime mover (electric motor) shaft is transmitted to the output shaft or impeller of the machine via pulleys, belt and bearings. For any object of mass M moving in a circular motion, its acceleration is directed towards the centre of the body and its linear velocity is tangential to the radius of the object.

The displacement which starts from the point A (see fig. above), then to B and continues is in terms of θ. The angular velocity is designated ω. The acceleration (a) of the rotating body is given as:

$$a = \omega^2 r. \quad (1)$$

Where r = radius of the object.

The acceleration is called centripetal acceleration. The radially inwards, or centripetal force required to produce this acceleration is given as:

$$F_C = m.a = m\omega^2 r = \frac{mv^2}{r} \text{ [27]} \quad (2)$$

If the body rotates at the end of an arm, this force is provided by the tension on the arm. The reaction to this force acts at the centre of the rotation and is called the centrifugal force. It represents the inertia of the body, resisting the change in the direction of motion. A common concept of centrifugal force in engineering problems is to regard it as a radially outward force which must be applied to a body to convert the dynamical condition to the equivalent static condition. This is known as d'Alembert's principle. This concept is particularly useful in problems on engine governors and balancing rotating masses.

Rotational Torque (T):

The value of torque developed by a rotating body is taken as the product of the force producing the rotation multiplied by the radius of rotation [27].

$$T = F_C \times r \quad (3)$$

Work done by a torque:

If a constant torque T moves through an angle θ, work done = T*θ

If the torque varies linearly from zero to maximum value T, work done = ½Tθ.

In a general case where T = f (θ)

$$\text{Work done} \int f(\theta)d\theta \quad (4)$$

The power (P) developed by a torque T (N.M) moving at ω rad/sec is

$$P = T\omega = 2\pi NT \text{ (watts)} \quad (5)$$

Where N is the speed in rev/min and

$$\omega = \frac{2\pi N}{60} \quad (6)$$

Velocity of air generated by the air blades (V_g):

$$V_g = \omega_i \times r_i \quad (7)$$

where ω_i = angular velocity of air impeller
r_i = radius of air impeller

$$\omega_i = \frac{2\pi N}{60} \quad (8)$$

Where N = rpm

$$V_g = \frac{2\pi N r_i}{60} \text{ m/sec} \quad [27] \quad (9)$$

Friction analysis in the attrition principle:

The rotating impeller rubs the melons against the chequered anvil formed by the static dehusking casing. The impeller simultaneously rubs and moves the melons up along the walls of the casing until the exit spout positioned almost at half the diameter of the casing is reached. The motion is analogical to friction motion on an inclined plane.

This is illustrated in Fig. 5 and Fig. 6.

The Fig. 5 shows a body experiencing static friction. From experiment it has been found that:

$$\frac{F}{R} = \mu \,;\, F = \mu R \quad [28] \quad (10)$$

Where W = mg = weight of the body

R = normal reaction which is equal and opposite to the value of W

μ = coefficient of friction between the weight and the support

When support is inclined, the analysis below holds for moving up or going down the inclination. We have

$$\mu = \frac{F}{R} = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta \quad [28] \quad (12)$$

Determination of optimal speed of dehusking:

A dehusking machine by method of impact force for the melon seeds was designed and fabricated applying the principles and equations stated above. The speed of this machine was varied in order to determine the optimal speed. The obtained speed was then used in the design and fabrication of a dehusking machine by method of attrition. Tests where then carried out for both machines and their performance was evaluated.

II. RESULTS AND DISSCUSION

Table 3 shows the effects of varying speeds on dehusking of melons seeds. It can be noticed that there was an increase in percentage of seeds dehusked as speed increased from 600rpm to 1000 rpm and a decrease in percentage undehusked and broken. Subsequent increase in speed resulted in more breakage and lesser percentage of undehusked. This is further illustrated in the graphs (Fig. 7, Fig. 8 and Fig. 9).

The graph (Fig. 10) shows the optimal speed chosen because of its high percentage of dehusked melon seeds. All three graphs fit into second order regression models with corresponding high R^2 values. These are presented below:

$P_1 = -4.17\,\mathbf{S}^2 + 26.54\,\mathbf{S} + 22.85$ $\quad(\mathbf{R^2 = 0.940})$

$P_2 = 2.5\,\mathbf{S}^2 - 26.21\,\mathbf{S} + 73.85$ $\quad(\mathbf{R^2 = 0.938})$

$P_3 = 1.67\,\mathbf{S}^2 - 0.333\,\mathbf{S} + 3.285$ $\quad(\mathbf{R^2 = 0.988})$

(P_1, P_2 and P_3 are percentage dehusked, undehusked and broken respectively; S is speed in Rpm)

The rotational speed of the impeller in both principles of impact and attrition affects greatly the efficiency of the dehusking and separation of dehusked shell from the cotyledon. From table 3 for the determination of optimal speed of dehusking, high speeds ranging from 1400 – 1800 rpm result in tremendous breakage of the melon seeds up to 50%. Lower speeds below 1000 rpm resulted in high level of undehusking up to 55%. Test result carried out with 5kg of wetted melon on the impact machine at optimum speed of impeller at 1000 rpm still resulted in melon breakage up to 12%, 10% undehusked and 60% separation efficiency. However, the attrition machine with the same optimal speed of 1000 rpm, gave 86% dehusking, 1% breakage, 10% undehusked, and 70% efficiency were achieved.

IV. CONCLUSION

From the analysis of the two methods of melon dehusking it can be concluded that:

- Attrition method has the highest dehusking efficiency, lowest breakage value and highest separation efficiency.
- The optimal speed (1000 rpm) of dehusking is easily attainable and works best for both machines.
- The use of the attrition machine under specified conditions can help reduce post harvest losses that occur in broken melons seeds which are susceptible to fast deterioration due to rancidification and mould formation during storage.

REFERENCES

[1] Cobley, S. H. "An Introduction to the Botany of Tropical Crops" Longmans, Green & Co. pp. 293 –301; 1957.

[2] Okoli, B. E. "Wild and Cultivated cucurbits in Nigeria" Econ. Bot. 38(3): 350 –357. edn.) McGraw –Hill Book Company Inc. NY. 633pp; 1984.

[3] Ogunremi, E. A. "Effect of nitrogen on melon (Citrullus lanatus)" at Ibadan, Nigeria. Expl. Agric. 14: 357 – 365. 1978.

[4] Adeniran, M. O. and G. F. Wilson. "Seed type classification of egusi melon in Nigeria" Paper presented at the 6th African Horticultural Symposium, University of Ibadan, 9th – 25th, July, 1981.

[5] Oyenuga V.A and Fetuga B.L. "Some aspects of biochemical and nutritive value of thewater melon seeds (Citrullus colocynthis)" J Sci Food Agric 26: 843–854: 1975.

[6] Nwokolo, E. and J.S. Sim, "Nutritional assessment of defatted pumpkin (Telferia occidentalis Hook)" by chick assay. J.Sci. Fd. Agric. 38: 237-246. 1987.

[7] Barden, J.A., R.G. Halfacre and D.J. Parish, "Plant Science." McGraw-Hill NewYork pp: 551: 1989.

[8] Akobundu, L.0. "Weed Science in the Tropics: Principles and Practices." John Wiley & Sons Ltd. NY pp: 522: 1987.

[9] Makanjuola G.A. "A study of the physical properties of melon seeds". Journal of Agricultural Engineering Research pp 17(1), 128-137: 1972.

[10] Odigboh E.U.). "Impact egusi shelling machine". Transaction of the ASAE pp 22(5), 1264 -1269; 1979.

[11] Akobundu , E.N.T, Cherry T.P and Simons J.P (1982) *Chemical functional and nutritional qualities of egusi (Colocynthis citrullus L.) seed protein products*. J Food Sci 47: 829–835.

[12] Denton, O. A, Taylor, O. A., Makinde, M. C, and Adeniji, S.B., (1989). *Development of breeding populations of the major seed types of "Egusi" melon*. NIHORT Annual Report. Ibadan, Nigeria p 188.

[13] Akoh , C.C, and C.V. Nwosu (1992): *Fatty Acid Composition of Melon Seed Oil Lipids and Phospholipids*, J. Am. Oil Chem. Soc., 69, pp. 314-317.

[14] Offonry, S.U and Achi O.K., (1998) *Microbial population associated with the retting of melon pods (Colocynthis citrullus L.) during seed recovery.* Plant Food Num Nutr 52: 37–47.

[15] Egbuta U and C.G Uyah., (2003) *"Design, Fabrication of a mechanical method of shelling and separating melon seed by centrifugal impact device and pneumatic centrifugal impact device"*. B.Sc. thesis, University of Ife, Ile-Ife,

[16] Akpan N.A.,(2004). *"Determination of the force required to crack melon seed shell by static loading at different moisture content"* B.Eng. thesis, University of Uyo, Uyo Nigeria.

[17] Obot V.W., (2005). *"Determination of the Force to break melon seed in static loading".* B.Eng. thesis of University of Uyo, Uyo Nigeria, 2005.

[18] Okokon F. B., E. Ekpenyong, C. Nwaukwa, N. Akpan and F.I. Abam. (2010). " *Impact force of melon during shelling".* Agric Eng Int. CIGR Journal, 12(1): 182-188.

[19] Mirjana Milovanović and Ksenija Pićurić-Jovanović, (2005). *Characteristics and composition of melon seed oil*. Journal of Agricultural Sciences Vol. 50, No 1, Pages 41-47.

[20] Addo A., and A. Bart-Plange, (2009). *Kinetics of water sorption by egusi melon (Cucumeropsis Edulis) seeds.* ARPN Journal of Agricultural and Biological Science Vol. 4, No. 6.

[21] Akubuo C.O and U. Odigbo (1999). "Egusi fruit coring machine" Journal of Agricultural Engineering Research, pp: 74, 121-126.

[22] Emeka Iwenofu, (1997). *"Design of melon dehusking and separation machine".* Unpublished MEng. Thesis. Dept of Mechanical Engineering, Enugu State University of Technology: (ESUT) Enugu, Nigeria.

[23] John Hannan and R.C Stephen, (1984). *"Mechanics of machines".* Edward Arnold, New York.

[24] Nelkon M and Parker P, (1984). *Advanced level physics.* Heinemann Educational Books. Fifth ed. London.

[25] Ogbonna P. E. and I. U. Obi. (2007). *Effect of time of planting and poultry manure application on growth and yield of egusi melon (colocynthis citrullus l.) in a derived savannah agro-ecology*. Journal of Agriculture, Food, Environment and Extension Vol. 6, No. 2, pp. 33-39.

[26] Okokon, F. B. (2008). *Determination of the young's modulus of elasticity of melon seeds by applying the theory of thin plates under compression.* Journal of Agricultural Engineering and Technology (JAET), Vol. 16, No. 1.

[27] Oloko, S. A; Agun, B. J. and Jimoh, A. A. (2002). *Design and Fabrication of Melon Washing Machine.* World Journal of Biotechnology, 3 (2): 481 – 486.

[28] Oloko S. and L. Agbetoye, (2006). *"Development and Performance Evaluation of a Melon Depodding Machine".* Agricultural Engineering International: the CIGR Ejournal. PM 06 018. Vol. VIII.

[29] Oriaku E. C, C.N. Agulanna, G. Chiwetalu and G.C. Ekwereike. (2010). *Official Work Document*, Projects Development Institute (PRODA). Enugu, Nigeria.

Table 1: Frictional Properties of Melon Seed

Material	Angle of repose (^{0})	Coeff. Static friction on galv. Mild steel	Coeff. Of static friction on wood
A_1- unshelled melon seed at 6.84% m.c (wb)	35.67	0.42	0.60
A_2- mixture of shells and cotyledons from A_1	40.5	0.66	0.70
A_3- shelled melons seed from A_1	43.3	0.66	0.71
B_1- unshelled melons seeds welled at 8.45% m.c (wb)	36.0	0.54	0.66
B_2- mixture of shells and cotyledons from B_1	45.81	0.81	0.93
B_3- shell melons seeds from B_1	44.00	0.65	0.72

(Source: Emeka, 1997)

Table 3: Effect of speed on dehusking of Melon seeds (Egusi)

Rpm	% dehusked	% un-dehusked	% broken
1800	10	10	80
1600	25	8	67
1400	50	10	40
1200	60	10	30
1000	70	15	15
800	65	25	10
600	40	55	5

(Source : Oriaku et al., 2010)

Table 4: Melon seed dehusking by impact force

Rpm	% de husked & whole	% de husked but broken	% half de husked	% un De husked	% separation of dehusked shell from white seed
1000	70	12	8	10	60

(Source: Oriaku et al., 2010)

Table 5: Melon seed dehusked by attrition force

Rpm	% de husked & whole	% de husked but broken	% half de husked	% un dehusked	% separation of dehusked shell from white seed
1000	86	1	2	10	70

(Source: Oriaku et al., 2010)

Table 2: Physical Properties of Melon seeds

Material	Major Diameter (a) (mm)	Intermediate Diameter (b) mm	Minor Diameter (c) mm	Geometric Mean Diameter $(a*b*c)^1/3$mm	Projected Area $(mm)^2$ Flat down	Unit Volume (mm^3)	Unit weight W mg	Unit Density G/cm^3
A_1 – unshelled Egusi seed at 6.84% m.c (wb)	14.7 (1.09)	8.48 (0.62)	2.29 (0.32)	6.28 (0.18)	99.40 (9.40)	237.0 (26.4)	150 (30)	0.01 (0.08)
A_2 – shelled seeds or cotyledons from A_1	12.23 (0.52)	7.34 (0.39)	1.88 (0.12)	5..49 (0.14)	58.55 (7.33)	113.2 (11.4)	115 (13)	1.05 (0.05)
B_1- unshelled seeds (wetted) 8.45% m.c (wb)	14.23 (1.08)	8.51 (0.64)	2.49 (0.35)	6.66 (0.14)	99.53 (9.90)	251.7 (23.8)	158 (32)	0.62 (0.05)
B_2- shelled seed from B_1	12.27 (0.49)	7.40 (0.41)	1.89 (0.14)	5.01 (0.13)	59.13 (6.95)	114.5 (11.6)	115 (15)	1.03 (0.06)

(Source: Emeka, 1997)

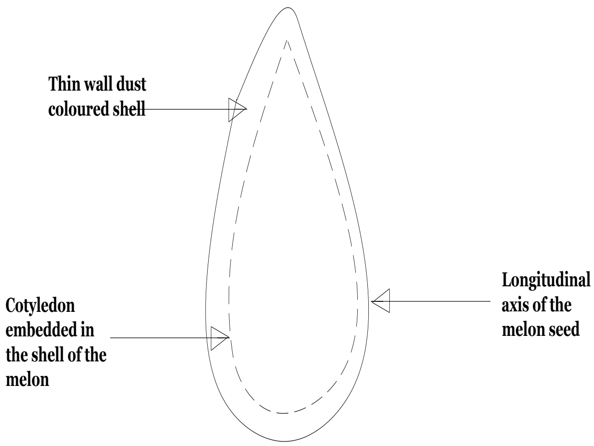

Fig. 1: Sketch of melon seed

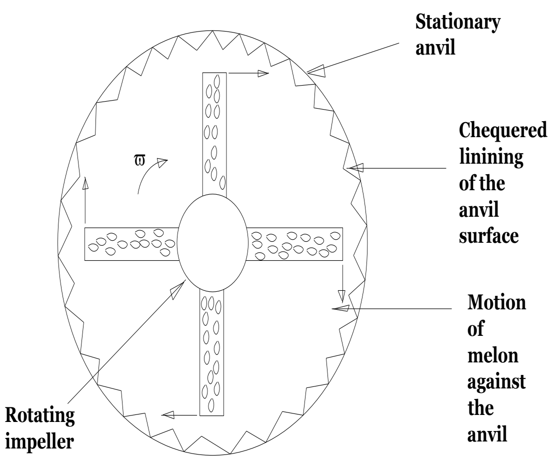

Fig. 2: Impact method

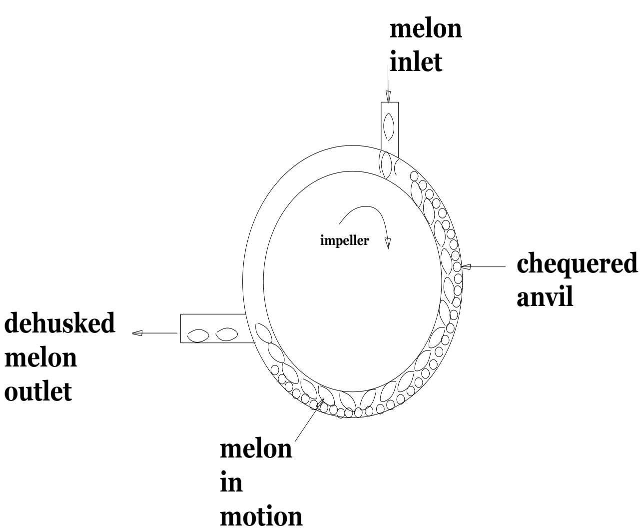

Fig. 3: Attrition Method

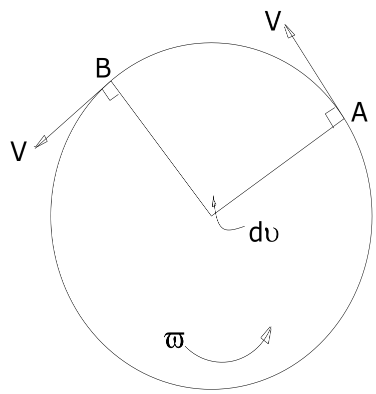

Fig. 4: Circular motion of machine

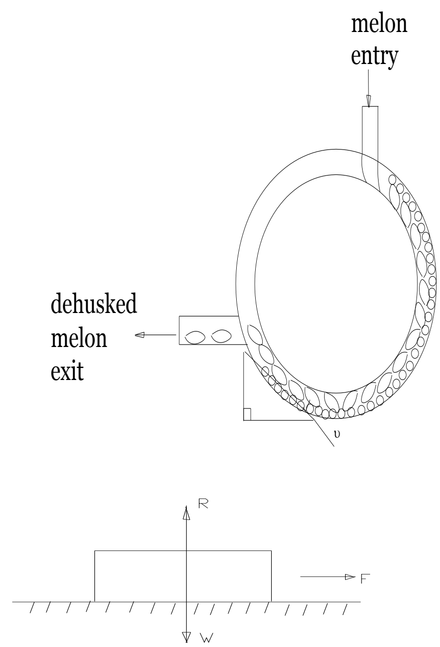

Fig. 5 Frictional motion of melon seeds in machine

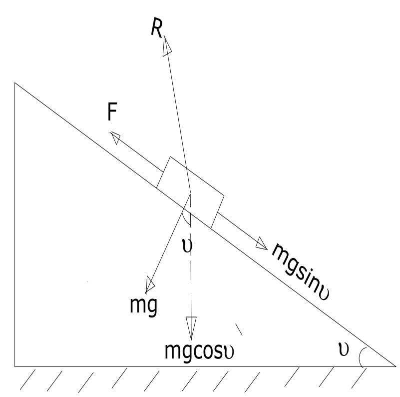

Fig. 6: Friction on an inclined plane

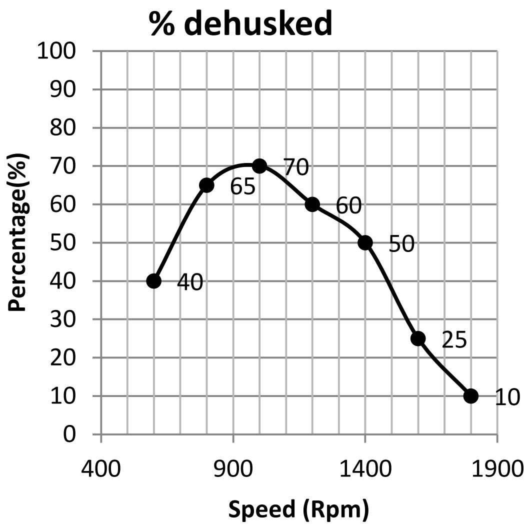

Fig. 7: Effect of speed on percentage dehusking
(Source: Oriaku et al., 2010)

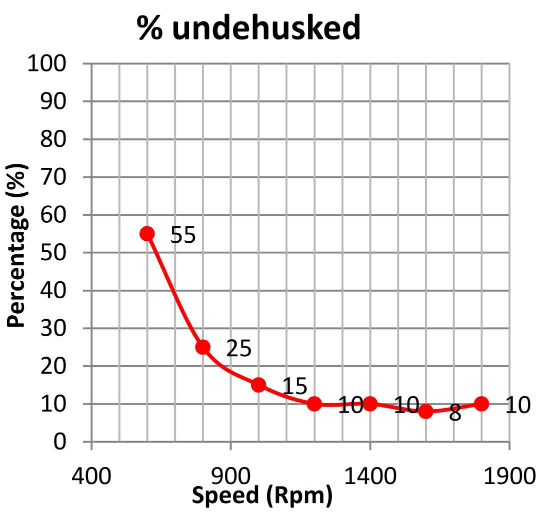

Fig. 8: Effect of speed on percentage undehusked
(Source: Oriaku et al., 2010)

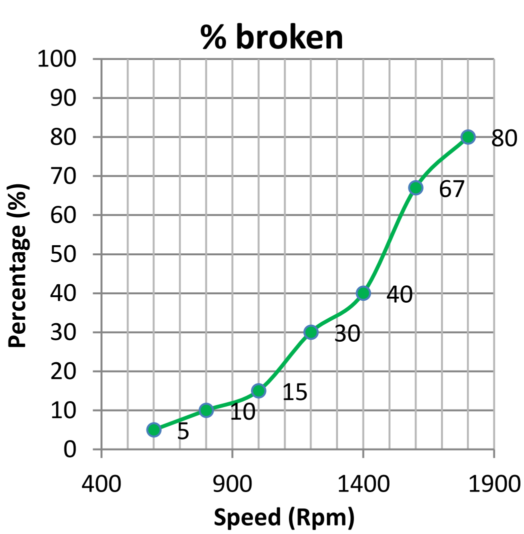

Fig. 9: Effect of speed on breakage
(Source: Oriaku et al., 2010)

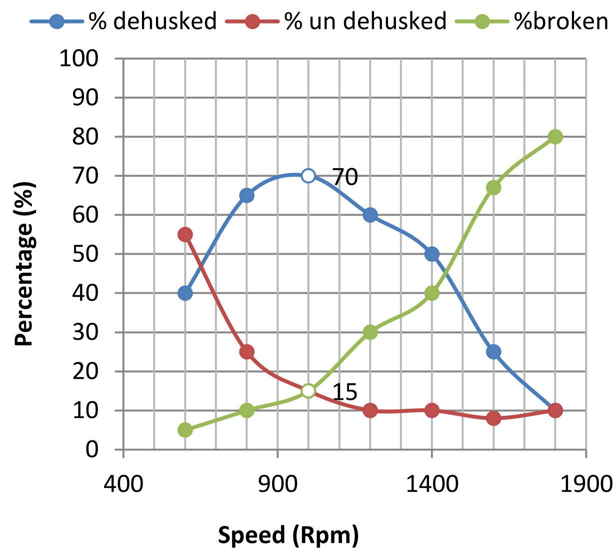

Fig. 10: Graph showing percentage dehusked, undehusked and broken
(Source: Oriaku et al., 2010)

Fig. 11: Photograph of Melon Dehusking Machine by Principle of Impact

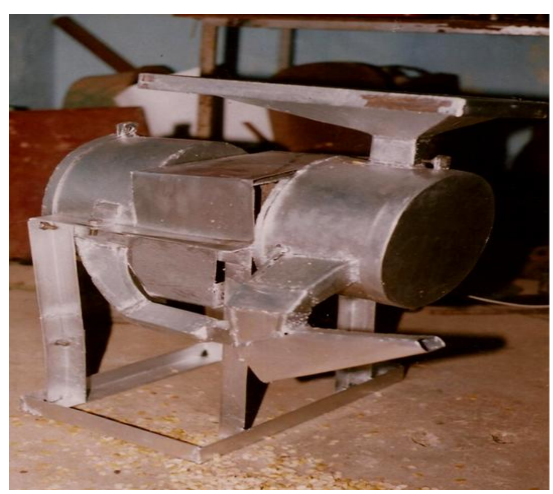

Fig. 12: Photograph of melon dehusking machine by principle of attrition