World Journal of Agricultural Sciences & Engineering
Vol. 1, No. 1, January 2015, pp. 1 –10
Available online at http://scenrp.com/Journals.php

Research article

Performance Evaluation and Improvement on a Melon Seed Shelling Machine

Egbe Daniel E[*1,2], Mayah Theodore F[1]., Ebot Etta G[1]., Egbe Patrick A[2]., and Abraham John P[3].

[1] School of Engineering, Catholic University Institute of Buea, Cameroon.
[2]Process Machinery Research Laboratory, TAAKO Industries, Douala-Cameroon
[3]Department of Mechanical Engineering, University of St. Thomas, Minnesota, USA.

*Corresponding author: dna.egbe101@yahoo.com,

Abstract

Manual shelling of melon seeds in order to extract the edible cotyledon is a tedious, time consuming and boring process. A performance evaluation, followed by critical analysis on a locally constructed electrically powered melon seed shelling prototype (constructed by TAAKO Industries, Douala, Cameroon) was done. Two types of melon seeds: yellow and white types were purchased from the Douala Central Market. These seeds were phenotypically characterized (average seed area, length, width and density) prior to shelling trials. Results from the performance evaluation of the shelling unit revealed that for one shelling cycle; best efficiencies of 48% at 11.8Kgh^{-1} feed rate, 30mins wetting time, 45^0 feed angle and 22.5% at 12.23Kgh^{-1} feed rate, 30mins wetting time, 45^0 feed angle were obtained respectively for seeds type A and B. After a critical analysis of the current design, some modifications to improve on the former were proposed. Amongst others, it was determined by calculations that the unit needed a 1Hp motor instead of a 2Hp motor. A V-belt pulley system was also proposed to facilitate shelling speed variation. Finally the modifications to be adapted were evaluated at a cost of about 600$ USD.

Keywords: melon seed, shelling machine, shelling efficiency, seed damage, food processing

---

1 Introduction

Melon seeds, commonly called “egusi”, a name widely used throughout West Africa, is produced by the melon plant which belongs to the Cucumber family. Melon seeds are very rich in dietary oils (50%) and proteins (37.4%) (Ajilola et al.,1990). In West and Central African countries especially in Cameroon and Nigeria, the yellow type and white type melon seeds are manually shelled and their cotyledon is extracted and used in the preparation of soups and puddings. Other potential ways of processing the crop involve the extraction of oils from the cotyledon which could be used in pharmaceutical applications or as cooking oil. The shells could also be used as a potential poultry feed ingredient (Ogbe and George, 2012). However, the tedious and time-consuming process involved in the manual shelling of the seeds is a limiting factor to the mass production and industrialisation of this sector especially as mechanical systems to handle this operation are not common.

Most local inhabitants use alternative protein and dietary oil sources because the commercialised manually shelled seeds sold in local markets are very expensive. A cup (about 100g) for the yellow and white type shelled seeds costs 0.90-1$ and 1.10 – 1.20$ respectively. Compared to other dietary protein and oil sources such as groundnuts and soya beans with an average cost of about $ 0.30 per cup, the melon seeds are not priced competitively.

A few studies investigating the development and use of mechanical systems to address the problems associated with the traditional methods of shelling has been completed (Shittu and Ndrika, 2012). Tests conducted on these machines show that their yield rates were on average not more than 30% (Olokon *et al*., 2010). Apparently, the low efficiencies could be due to the lack of process optimization (rotational speed of machine impeller, feedrate of melon seeds during shelling, moisture content of seeds, and impact force of machine impeller) during the operation.

TAAKO Industries, a process machinery research laboratory situated in Douala, Cameroon has developed melon shelling machines with efficiencies very similar to those previously reported by other authors. Shelling in two or more cycles (two or more passes through the shelling machine) have proven to improve on the amount of shelled seeds produced, but such attempts have ultimately failed because many more seeds are broken, and those previously shelled in the first cycle become bruised. As a result, many seeds are predisposed to oxidation. Consequently, the quality of the final product is poor and could potentially influence its market value. Moreover, shelling in more than one cycle involves more time and electricity.

The purpose of the present study is to characterize the melon-seed phenotypes and to optimize shelling conditions for yellow and white melon seeds. Focus will be given to one-cycle shelling and possible modifications to that process will be given.

To the best knowledge of the authors, there is a single mechanical device available to accomplishing the shelling. This device, observed by the authors was imported from Ivory Coast and is currently being used to shell egusi. The device is very rudimentary, its method of operation was not clear, and its technology was proprietary. On the other hand, the vast majority of current shelling is accomplished through manual labor. The goal of this project is to create a shelling machine which is robust and reliable and can be commercialized.

Although not directly related to this study, interested readers are directed to literature which discusses melon-processing machines (Adekunle et al., 2009; Oloko et al., 2002; Oloko et al., 2006; Oluwole and Adedeji, 2012; and Oriaku et al., 2013).

Also, some literature which discusses the properties of various seeds includes (Aviara et al., 1999; Davis 2010; Makanjoula, 1972; Manuwa and Afuye, 2004; Nwossu, 1988; and Razari, et al., 2007).

2 MATERIALS AND METHODS

Yellow (Type A) and White (Type B) melon seeds will be used in this study. The seeds were purchased from the Douala central market. The seeds were sorted by hand to eliminate debris and immature seeds and washed thereafter to eliminate foreign matter (dust) from the seed surface which could possibly affect the colour of the shelled seeds and accelerate spoilage. The seeds were then sun dried for three hours. Figure 1 consists of photographs of the two seed types.

Figure 1: Melon Seed Types used in this study: a) Yellow seeds (Type A); b) White seeds (Type B)

To initiate the shelling, seeds are first loaded into a hopper. A rotating disk at the base of the hopper projects the seeds onto the surface of the rotating shelling drum, which will be described later. The drum removes the shells. The drum also imparts a motion to the seeds which directs them to an outlet.

In order to complete the major shelling tasks, a number of components are incorporated into the machine. The major components of the shelling machine are the hopper, the shelling chamber, the outlet chute and the cleaning chamber. The hopper is made up of four welded metal sheets slanting towards an opening to form a trapezium. Melon seeds are fed through the larger upper opening while the smaller lower opening connects the hopper to the shelling chamber.

An annotated photograph of the machine assembly is provided in Figure 2; the figure shows two views of the machine.

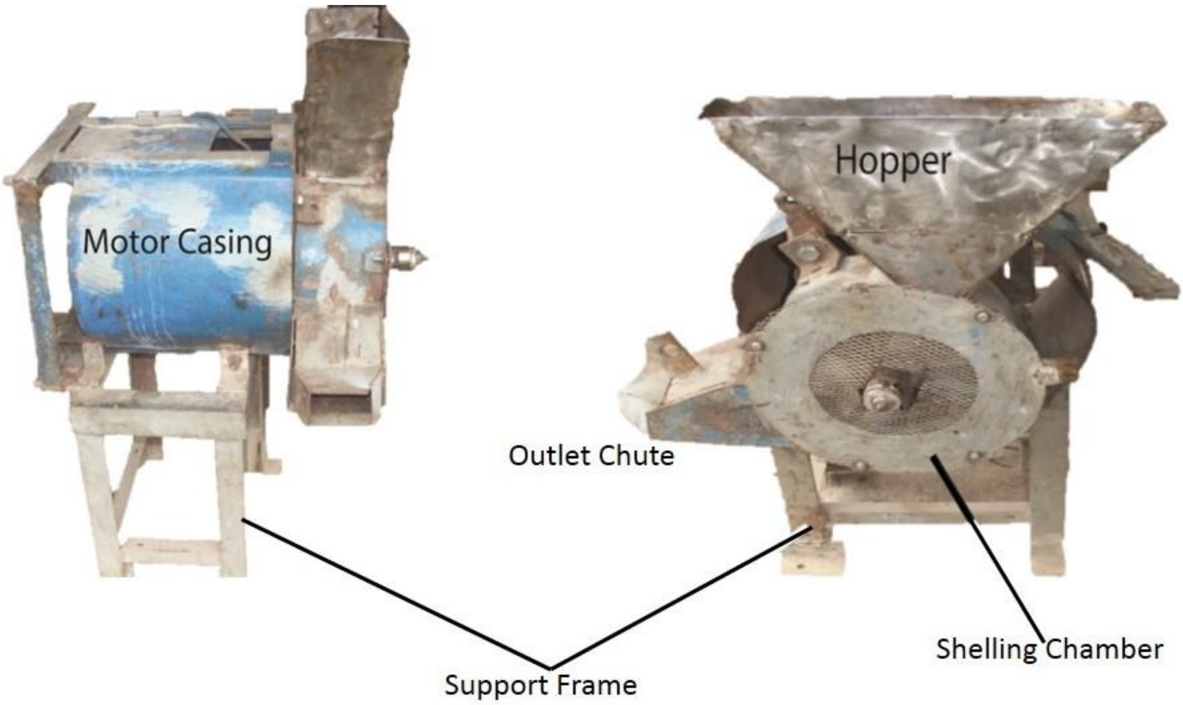

Figure 2: Photographs of the shelling machine with annotations of major components.

The shelling chamber contains a rotating circular impeller powered by a 2 hp electric motor. Both the shelling chamber and the rotating circular impeller are lined with circular metal rods. A diagram of side and front views of the circular disks and attached circular rods are shown in Figure 3. As indicated in the figure, there are ten rods distributed uniformly around the circle, each with a diameter of 3 mm and a length of 250 mm.

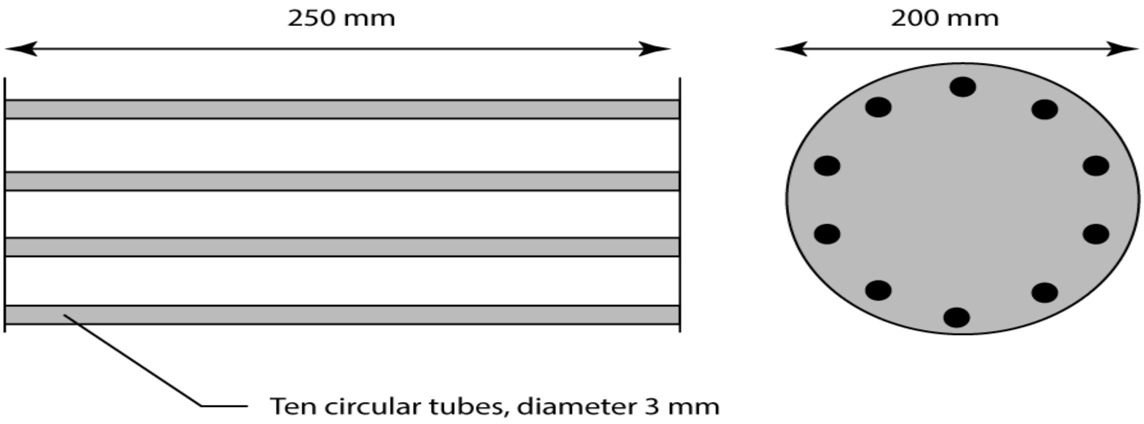

Figure 3: Configuration of the thrashing tubes and their distribution around a circular end plate.

Upon introduction of melon seeds into the machine, the rods of the rotating impeller project the melon seeds on the rods of the stationary shelling drum for further impact. Between the point of feed and the exit of the melon seeds, several impacts occur leading to cracks on the husk with subsequent removal of shells as the seeds rub between the rods of the impeller and the shelling drum. As the seeds leave the exit chute into the cleaning chamber, the air collected from the environment by rotating impeller blades winnow the seeds in the cleaning chamber. While the shells (lighter part) are blown off the shelled seeds fall because of their greater weight and are collected from the bottom of the cleaning chamber.

The length, width and thickness of the seeds were measured using a calliper. The measurements were repeated for about 20 randomly selected seeds and the average values recorded. The mass of 200 seeds was obtained using an analytical balance and the average was taken as the mass of one seed. The process was repeated five times and the average was recorded. The surface (A) area was calculated from the approximation illustrated in Figure 4. This was repeated several times and the average value recorded. In addition, variation in the dimensional and density parameters were measured and statistics will be presented later.

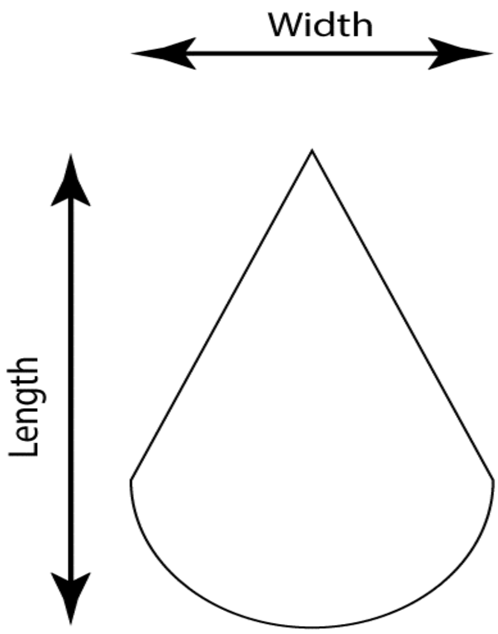

Figure 4: General shape and length measurements for a seed.

Since the seeds are nearly equal to a super position of a half circle and a triangle, the calculation of the surface area was straightforward.

The density of the melon seeds was calculated from

$$\rho = \frac{m}{V} \quad (1)$$

where ρ is the density, (kgm^{-3}); m is the seed mass, (kg), and V is the volume (m^3) which was measured by the water displacement method.

As stated earlier, 200 seeds were randomly selected and weighed on an analytical balance and the mass was noted. The 200 seeds were then tied in a very thin polythene paper of noted mass and immersed wholly in a measuring cylinder and the volume of water displayed was recorded. The average density of the 200 seeds was then calculated by dividing the mass of the collection by the displaced volume of the collection.

Seeds used for performance evaluation were counted in multiples of one hundred. About 20ml of water was used to moisten the seeds for every 100 seeds collected. The seeds were then allowed to air dry up to 30 minutes (wetting time) prior to shelling trials. Shelling was performed at different feed rates at a constant impeller rotational speed of 1430rpm. The shelling machine was cleaned before and between shelling trials.

Shelling Efficiency

The effectiveness of the machine in terms of number of seeds shelled was based on the shelling efficiency metric (Shittu and Nriku, 2012) which is expressed as

$$\eta = \frac{W_{su}+W_{sb}}{W_t} x100\% \quad (2)$$

Here, η is the shelling efficiency, W_{su} is the number of unbroken seeds that were shelled, W_{sb} is the number of broken seeds that were shelled (broken), and W_t is the total number of seeds.

Likelihood of Damaging Shells

A similar measure is made of the number of damaged seeds (Shittu and Ndrika, 2012) which is

$$\eta_b = \frac{W_{ub}+W_{sb}}{W_t} x100\% \quad (3)$$

Where η_b is the percentage of seeds which are broken, W_{ub} is the number of broken unshelled seeds, W_{sb} is the number of broken seeds that were shelled (broken), and W_t is the total number of seeds.

Critical Spreading Time

A third performance metric is the critical spreading time. This time is related to a water-soaking process which is needed in order to sufficiently soften the shells. Water is applied in sufficient amounts to thoroughly moisten the shells. The seeds are then allowed time to uptake the water into the shell. This uptake duration is the Critical Spreading Time.

To obtain this measure, samples of 200 seeds each for both A and B types, weighing 22g and 36g respectively were washed with 40ml of water each and spread to air dry up to 30 minutes prior to shelling trials.

The above-mentioned performance metrics were evaluated for different feed rates of seeds into the machine. Five different samples of seeds with different masses were introduced into the machine, and the time taken to complete the shelling was noted. The feed rate was defined as the mass of seeds (in kg) leaving the machine per unit time. The effect of feed rate on machine shelling efficiency and percentage of seed damage was evaluated.

3 RESULTS AND DISCUSSIONS

3.1 Phenotypic Characterization of Melon Seeds

The measured physical dimensions of the seed types are listed in Table1. Measurements are provided for five dimensional quantities along with the standard deviation. A quick review of the table shows that the yellow seeds are smaller and less dense than their white counterparts.

Table 1: Dimensional characterization of seeds

Parameter	Type A (Yellow Seeds)	Type B (White Seeds)
Surface Area (m^2)	0.037±0.002	0.048±0.002
Density (kg/m^3)	405±15.2	446±18.32
Length (m)	0.020±0.003	0.025±0.006
Thickness (m)	0.002±0.00015	0.003±0.0008
Width (m)	0.011±0.0005	0.013±0.004

3.2 Machine Performance Evaluation

Next, performance measures are made for the machine. The three measures, which have already been mentioned in the foregoing, are the shelling efficiency, the likelihood of damaging seeds, and the critical spreading time. These results will now be discussed in order.

Figure 5 parts (a) and (b) show both shelling efficiency and likelihood to damage seeds for the Type A and Type B seeds respectively. The values are plotted against the machine feed rate which is expressed in units of kg/hr.

From the figure, it is seen that there is first an increase from 44% to 48% and then a decrease to 41% shelling efficiency for Type A seeds as the feed rate changes from 6.85 to 11.8 and then to 18.4 kg/hr. It is therefore observed that optimal shelling of Type A seeds occurs around 11.8 kg/hr.

For the type B seed however, the shelling efficiency was significantly different. It was a maximum at the lowest feed rate (22% efficiency with a federate of 12.2 kg/hr). It monotonically decreased in efficiency as the feed rate increased, first to 20% efficiency at a feed rate of 13.8 and then a 10% efficiency at a feed rate of 27.3 kg/hr.

Likelihood of shell damage expressed a different behaviour in the two seeds. For the A type, it was lowest at the middle feed rate of 11.8 kg/hr. For the B seed, it was highest at the middle feed rate of 13.8 kg/hr and in general the damage likelihood of Type A seeds was significantly higher than that of the Type B variant.

The results of Figure 5 allow a very clear conclusion with respect to optimal operation of the machine. It was found that for both seeds, optimal performance (high efficiency and low likelihood of damage) occur for a feed rate of approximately 12 kg/hr.

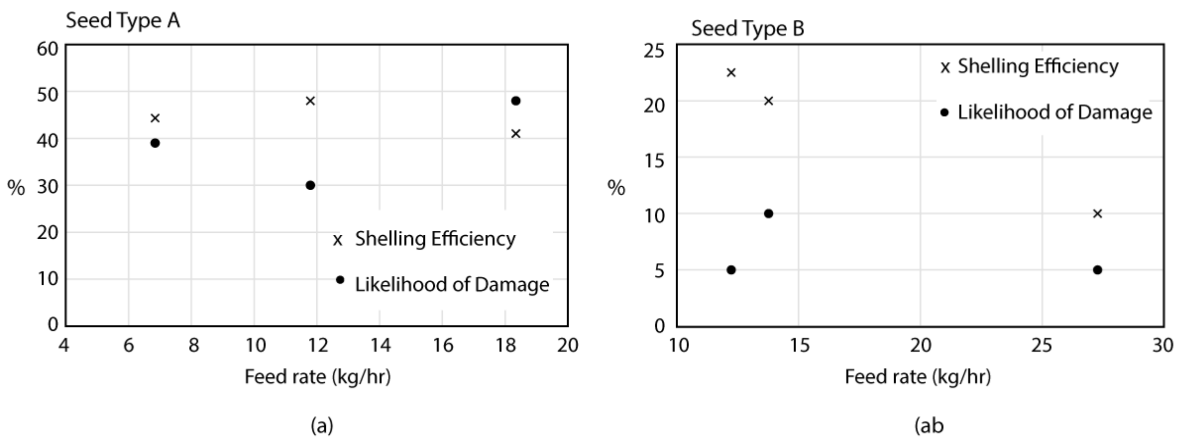

Figure 5: Graphs of Shelling Efficiency and percentage of seed damage against feed rate for Types A and B melon seeds.

Next, Figure 6 has been prepared to quantify the influence of spreading time on performance. The figure shows the shelling efficiency for both types of seeds. It is seen that there is a general (although not monotonic) trend of increasing efficiency as the spreading time increases. The short spreading time cases lead to efficiency values that are generally in the 40% range. At higher values of spreading time, efficiencies rise to 60%. There appears to be a local maximum in Type A seed performance with a spreading rate of 10 minutes; while this local maximum in performance may be a robust result, if a single spreading rate is to be used uniformly for both seed types, it is clear that a longer value should be prescribed.

Irrespective of the seed type, a critical spreading time of 30 minutes was found to give the best shelling efficiency. The results suggest that 30 minutes allows sufficient time for water to penetrate and soften the shell sufficiently. Consequently, there is a reduction in the impact force required to remove shells from the cotyledon of melon seeds. For shorter spreading times, it is likely that larger numbers of seeds did not have sufficient time to absorb the shell-softening water.

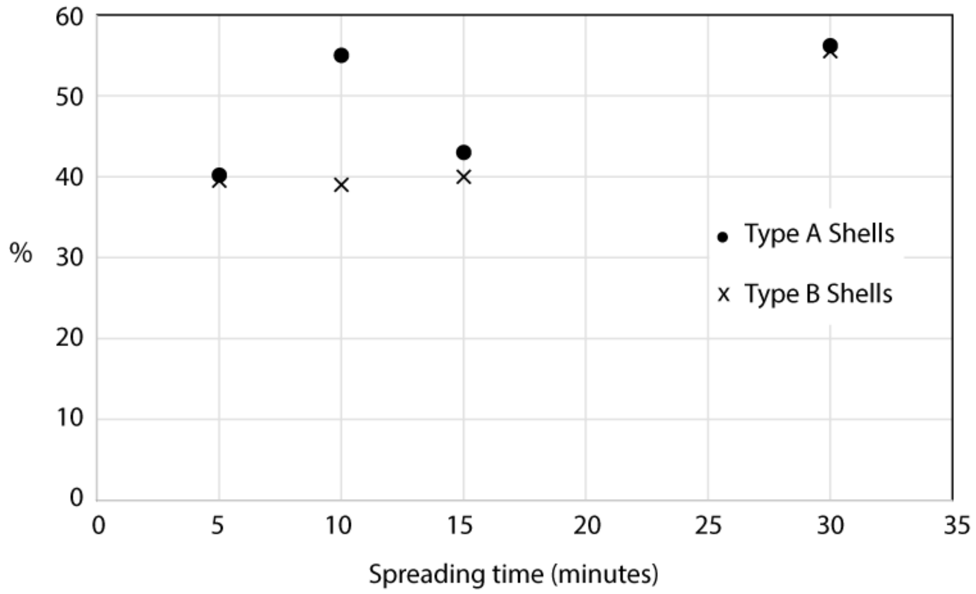

Figure 6: Influence of wetting time on the shelling efficiency for both seed types.

The results presented in Figures 6 and 7 allow some conclusions to be drawn. First, seed type A is much more likely to be broken than type B. We attribute this to the greater hardness of the type B shell. Secondly, while there was not a one-to-one relationship between spreading time and shelling efficiency, we find that generally longer spreading times result in higher shelling efficiency. In fact, for spreading times of 30 minutes, the efficiency for both seed types exceed 50%.

Other experiments showed that, subjecting a particular quantity of seeds to the best spreading time of 30mins before carrying out the feed rate test, always gave shelling performances which were more than 50%.

Another very positive observation was that when seed type B was soaked (completely immersed) in water for 30mins, and the shelling done in 3 and 4 passes, the shelling efficiencies were 75 and 91% respectively, with no seeds broken. Since these experiments were carried out at a single Critical Spreading Time, the results are not presented in graphical form.

4 ASSESSMENT OF THE SHELLING MACHINE AND SUGGESTED DESIGN IMPROVEMENTS

With the performance results presented so far, and with an analysis of the components of the machine, it is possible to make design recommendations for a next-generation prototype. Some of these suggestions are geared to provide optimal performance whereas others are suggested to lower operating costs and initial costs of the machine.

First, it was found that current operations, with undefined feed rates and wide ranges of recommending spreading times are not attuned to optimal performance. Rather, it has been shown that feed rates of 12 kg/hour results in good performance for both seed types. Also, 30 minute spreading times lead to high shelling efficiency for both seeds.

Next, it was discovered that the power produced by the motor was in excess of that necessary for the shelling operation. As a result, excess energy was used and electro-mechanical efficiency was reduced. Consequently, next generation prototypes should be designed with 1 hp motors instead of the current 2 hp.

Third, the rotation rate of 1430 rpm is unlikely to be optimal for the present design. It has been shown by other authors that for similarly designed machines, rotational rates of were optimal in the range 950-1200 rpm.

It was also found that the presently designed machine is subject to vibration during its operation. To reduce vibration and the likelihood of machine failure, it is recommended that a wider base footprint be used with polymeric dampening pads. Also a dampening on the motor casing should be considered.

A summary of the current design protocol and the proposed optimal settings is given in Table 2. With these modifications, the efficiency of the operation, the quality of the project, and the sustainability of the device will be improved.

Table2: Critical analysis of the old model

Parameter	**Current Design**	**Proposal**	**Basis of Proposal**
Spreading time	5 – 30 mins	30 mins	Best shelling performance were obtained at 30 mins.
Feed Rate	Not defined	12kg/hr	Gave best shelling performance.
Machine power requirement.	2 hp	1 hp	A 2 hp motor is too powerful, energy is wasted.
Shelling speed	1430 rpm	950 - 1200rpm	Best shelling performances have been recorded with this speed range (Olusegun and Adekunle, 2003)
Machine Vibrations	Present at high amplitude.	A wider base area of the support frame and attachment of visco-elastic rubber material to motor seating.	A wide base provides stability and rubber material absorbs vibrations.

A computer rendition of the optimal machine is shown in Figure 7. That figure contains overall dimensions of the sections of the machine. It also has annotations identifying the major components. Two items of note are added to this design which were not present in the original model. First, a belt and pulley system is seen to the right hand side of the left image. This belt and pulley system allows for variable rotational speed. Second, a feed control flap is incorporated into the base of the hopper to allow more control to the rate at which the seeds enter the shelling chamber. Plans are underway to begin the manufacture and testing of the below-referenced second prototype. However, the affirmative results with the first generation device warrant its use in current shelling processing.

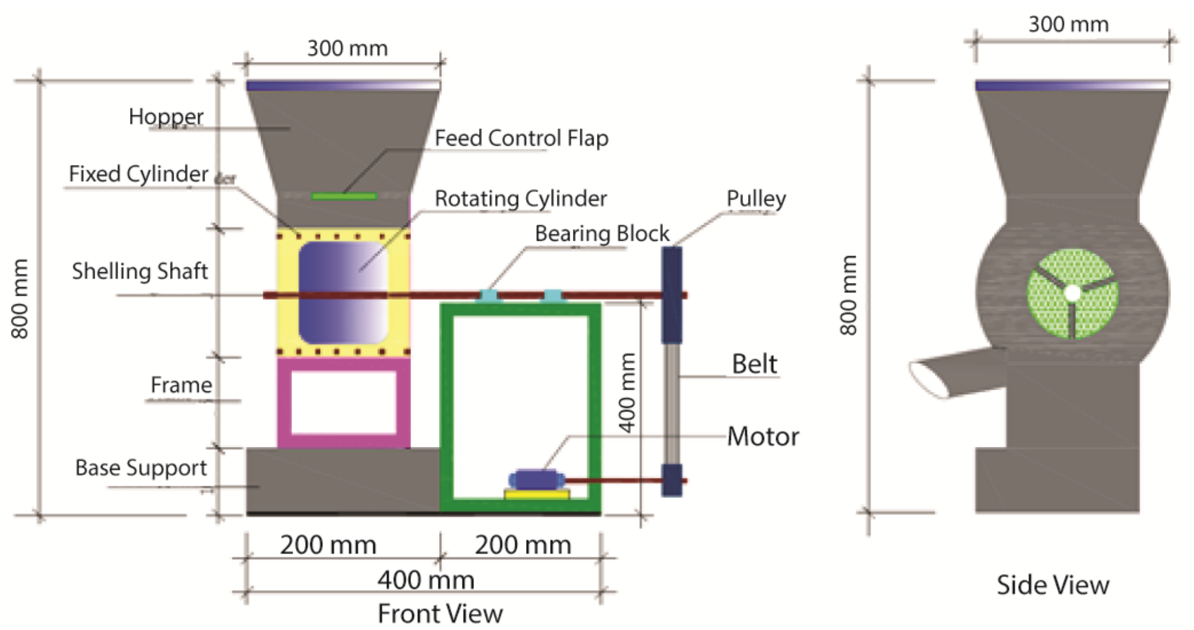

Figure 7: Annotated and dimensioned images of machine

5 CONCLUSION

Performance evaluation and proposals for the creation and optimization of a melon-seed shelling machine were completed and the results show that the initial performance was encouraging and an improvement over the current predominant method of manual shell removal.

Tests were carried out of two seed types (yellow and white).Among the independent parameters are the feed rate of the melon seeds into the shelling machine. Additionally, the pre-shelling soak time was varied. It was found that both the feed rate and the soaking time had an effect on the outcome. For both seed types, a feed rate of 12 kg/hr was optimal with the highest shelling efficiency and lowest percentage of broken seeds. With respect to water soaking (termed the Critical Spreading Time), it was discovered that there is a general trend of improving performance with increase in this parameter. Based on the range of Critical Spreading Times investigated in this study, a 30 minute duration is recommended.

It was also found that when type B seeds were completely soaked in water for 30 minutes and were then passed through the shelling machine multiple times (3-4 passes), the shelling efficiencies were 75 and 91% respectively, with no seeds broken.

A number of recommendations are made which are designed to optimize the shelling performance and to decrease power consumption or machine vibration. Future experiments are planned on this newly proposed device.

REFERENCES

[1] Adekunle, A.S., Ohijeagbon, I.O., Olusegun, H.D. 2009. Development and Performance Evaluation of Manually and Motorized Operated Melon Shelling Machine using impact technique. Journal of Engineering Science and Technology Review, 2:12-17.

[2] Ajilola ,O.O, Eniyemo, S.E, Fasina, O.O, Adeeko., K.A. 1990. Mechanical extraction of oil from melon seeds. Journal of Agricultural Engineering Research, 45, 1.

[3] Aviara, N.A., Gwandzung, M.I, Hague M.A.N. 1999. Physical properties of Guna seeds. Journal of Agricultural Engineering Research,73: 105-111.

[4] Davies, R.M. 2010. Engineering properties of three varieties of melon seeds as potentials for development of melon processing machines. Advanced Journal of Food Science and Technology, 2: 63-66.

[5] Makanjoula G.A. 1972. Study on some of the physical properties of melon seed. Journal of Agricultural Engineering Research, 17:128 – 137.

[6] Manuwa, S.I. Afuye, G.G. 2004. Moisture dependent physical properties of soya bean (Var-TGx 1871-5E). Nigeria Journal of Industrial Studies, 3:45-54.

[7] Nwosu, R.C. 1988. Engineering Properties of Egusi fruit and the design of Egusi seed extraction equipment. B.Eng. Project Report, Department of Agricultural Engineering, University of Nigeria, Nsukka.

[8] Ogbe, A.O. and George, G.A.L. 2012. Nutritional and anti-nutrient composition of melon husks: potential as feed ingredient in poultry diet. Research Journal of Chemical Sciences, 2:35-39.

[9] Okokon, F.B., Ekpenyong, E., Nwaukwa, C., Akpan, N. Abam, F.I. 2010. Impact force of melon during shelling. Agricultural Engineering International: CIGR Journal, 12:182-188.

[10] Oloko S.A., Agun, B.J., Jimoh, A.A. 2002. Design and fabrication of melon washing machine. World Journal of Biotechnology, 3: 481 – 486.

[11] Oloko S.A. and Agbetoye. 2006. Development and performance evaluation of a melon depodding machine. Agricultural Engineering International: CIGR journal. Manuscript PM 06 018. Vol. VIII.

[12] Oluwole, O.O., Adedeji, A.S. 2012. Effect of moisture content and inner drum rotation speed on the shelling performance of a melon sheller. Journal of Science and Technology, 2: 21-26.

[13] Oriaku, E.C, Agulanna, C.N., Chiwetalu, G. Ekwereike, G.C. 2013. Comparative performance analysis of melon (colocynthis citrullus l.) de-husking and separation machines by principle of impact and attrition. International Journal of Multidisciplinary Sciences and Engineering, 4.

[14] Razari, M.A., Emadzadeh, B., Rafe, A., Mohammed, A.A. 2007. The physical properties of pistachio nut and its kernel as a function of moisture content and variety, part 1 Geometric properties. J. Food Eng., 81: 209-217.

[15] Shittu, S.K., Ndrika, V.I.O. 2012. Development and performance tests of a melon (Egusi) seed shelling machine. Department of agricultural Engineering, Faculty of Engineering, Bayero University Kano, Nigeria.