Innovative Systems Design and Engineering
ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online)
Vol.6, No.12, 2015

Design and Development of Integrated Melon Processing Machine

Onwuka, Osinachi Stanley* Nwankwojike, Bethrand Nduka
Department of Mechanical Engineering, Micheal Okpara University of Agriculture, Umudike
P. M. B. 7267, Umuahia

Abstract
An integrated machine comprising electric motors, hopper, shelling, separating and pressing/grinding units for processing melon seed to either melon kernel, melon flour or melon oil was developed. This machine which was fabricated using locally sourced standard materials eliminated the drudgery in the loading and discharging of intermediate materials among stand-alone machines for melon shelling, melon shell and kernel separation, melon grinding and melon oil extraction. Performance Analysis of this machine indicated that it performed best at 9.7% melon seed moisture content, press temperature of 100^{o}C, blow-dryer heat rating of 1500W and shelling, conveyor, blower speeds of 950 rpm, 24 rpm and 1200 rpm respectively. Its melon kernel, flour and oil extraction capacities are 94.4kg/hr, 10.42kg/hr and 4.67kg/hr respectively while 93%. 89.3% and 91.5% constitute the respective melon seed shelling, kernel/shell separation and oil extraction efficiencies of the integrated machine. Adoption of this innovation is recommended because it reduced seed breakage during shelling, improved hygiene (as human contact with the product during processing is reduced) and also energy saving.

Key Words: Integrated machine, melon seed, melon kernel, melon flour, melon oil, processing

1.0 INTRODUCTION

Melon ‘‘Egusi’’ (Citrullus lanatus ssp coloeynthoides), is an annual herbaceous climber of the cucurbitaceous family best grown on a sandy free draining soil. This crop bears its fruits in pods which contain many individual seeds. Processing of harvested melon pod to three major edible products- melon kernel, melon flour and melon oil involves two distinct stages. These are the field and factory/house operations. Melon seeds are extracted from its pod after harvest in farm/field. The field process involve depodding of the fruit to expose its internal content for effective fermentation, separation of the seeds from the fermented pulp by washing/sieving and drying of the seeds. Dehusking (shelling) of outer shell of the melon seed from its cotyledon/kernel, separation of its shell and kernel, grinding of the kernel or pressing of the kernel for oil constitute the factory operations (NRC, 2006; Ukonze and Okeke, 2015). Melon kernel is an excellent source of protein with higher levels of amino acids than soybean meal. It is also used as an ingredient for making soup/stew, melon bread/cake, etc when processed into flour while its oil is medicinal constituting a raw material for production of pomade, soap, margarine etc. The two by-products of the factory stage of melon processing- the shell and residual chaff are also of economic value. The chaff is a source of protein for livestock feed and also for producing a local melon snack known as “robo” while the shell, an excellent poultry litter is also used for reclaiming crude oil polluted soil (Abioye et al, 2009; Adekunle et al, 2009).

Successes recorded in the design and development of mechanized systems for factory melon processing operations such as melon shellers, burr mills, blenders and melon seed oil expeller of various sizes are acknowledged (Shittu and Ndirika, 2012; Adekunle et al, 2009; Kassim et al, 2001; Oyediran et al, 2014; Samaila and Chukwu, 2014). However, high melon seed/kernel breakage constitute the major consistent limitation of melon seed shellers while the yearn for an integrated system that will offer the opportunity of processing melon seed to any of the three end users products- kernel, flour and oil as desired is not yet met. Although, Kassim et al. (2011), developed an integrated melon shelling and cleaning machine, its cleaning efficiency is poor. Development of an integrated machine for processing melon is highly required to meet people’s desire of just in time production of melon kernel, flour or oil. This is because freshly shelled melon tastes better than those that have been dehusked for a period of time. Melon kernel easily absorbs moisture and consequently ferments at a high rate than the undehusked seed (Tuhin, 2015). According to Oriaku et al (2013), damaged melon kernels are easily susceptible to deterioration which affects the taste consequently. High melon seed/kernel breakage associated with the existing melon shellers is partly due to lack of means of flexibly regulating the shelling speed with respect to the various melon species (bara, serewe, sofin etc), thus, the preference of locally shelled melon kernel to the ones shelled by mechanical method.

In addition, apart from the high set up cost of using individual stand-alone shelling, separation, milling and oil extraction machines for melon processing, discharging and reloading of processing materials amongst these machines as observed in the existing melon seed processing technologies is tedious and unhygienic. In order to reduce the set up cost, drudgery, losses due to melon kernel breakage as well as improve hygiene in melon seed processing, an integrated machine with output options for melon kernel, melon flour and melon oil was developed to encourage just in time production in the sector.

2.0 MATERIALS AND METHODS

2.1 Manufacturing Procedure/Description of Integrated Melon Processing Machine

The integrated melon processing machine (Fig.1) comprises of three major units- shelling/dehusking, separating, and pressing units.

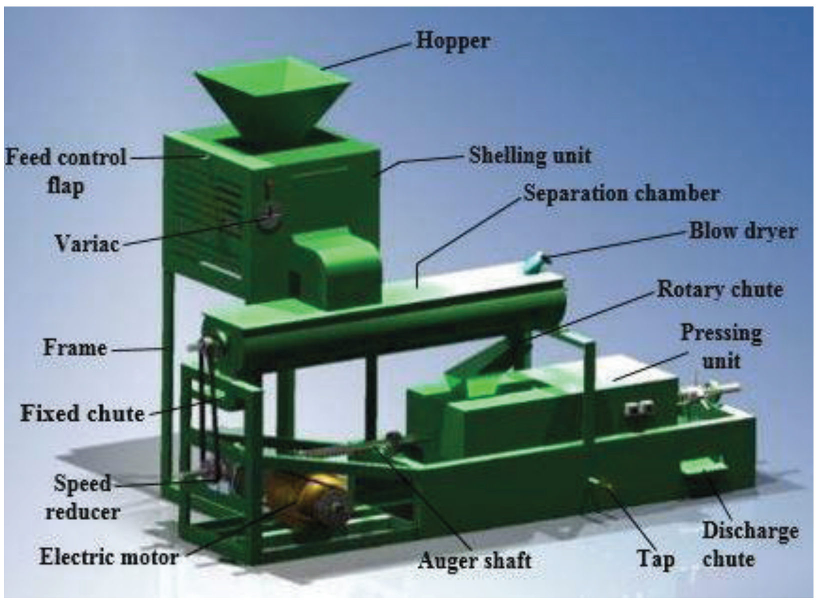

Fig. 1: Integrated melon processing machine

All the components of this machine are mounted on a frame which was fabricated from a 5.08mm (2 inches) angle iron. The hopper through which moist melon seeds are fed into the machine is an inverted pyramidal-frustum structure fabricated from a 2mm mild steel sheet metal with upper and lower cavities of 300mm x 300mm and 100mm x 80mm respectively. Below the lower cavity of the hopper is a feed control flap which ensures intermittent supply of the melon seeds into the shelling unit. The shelling unit comprises of an externally-vaned rotating drum, internally-vaned cylindrical shaped casing, variable transformer and 1.5 HP electric motor. The rotating drum is a mild steel multi-vane blower wheel with diameter and height of 170mm and 230mm respectively upon which additional slanted vanes have been patterned longitudinally across its curved surface. The cylindrical casing with internal vanes have rectangular cavities of dimensions 50mm x 90mm and 100mm x 140mm which serves as the respective inlet for the melon seeds and discharge for the kernel/shell mix. Anticlockwise movement of the inner drum in the casing with the melon in-between creates the shelling action. The 5 KVA variable transformer (variac) ensures this speed is varied for efficient shelling. Thereafter, the shell/cotyledon mix falls by gravity into the separation chamber. The separation chamber is made up of a U-shaped trough, paddle conveyor, blow dryer and discharge chutes. The 250mm diameter separating trough was fabricated from a 2mm thick, 800mm long mild steel sheet. Two rectangular cavities of dimensions 80mm x 50mm and 50mm x 40mm with fixed and rotary discharge chutes respectively were created at both ends of the trough for the discharge of the shell and kernel. When melon oil or flour are the desired products, the rotary chute is aligned with the top cavity of the hopper of the press barrel otherwise it is displaced 90^o away from the barrel where the melon kernel can now be safely collected in a bag. The paddle conveyor on the other hand is an assembly of the paddle membrane fabricated from a 17mm diameter, 800mm long mild steel pipe, paddles and the paddle shaft which is a 16mm diameter, 1000mm long mild steel shaft. The paddles (40mm x 30mm x 2mm metal sheet fastened to a 40mm x 30mm x 3mm leather pad) were placed across the longitudinal axis of the paddle membrane. Separation is achieved when hot air from the blow dryer blow against the direction of motion of the kernel/shell mixture as the paddle conveyor rotates.

The dual purpose press which serves as a mill and oil extractor comprises of hopper, auger conveyor, locknut-spring mechanism, cone, barrel, temperature controller and a heater. The barrel was fabricated from a standard 85mm diameter hollow stainless steel pipe of length and thickness 400mm and 3mm respectively. This pipe was cut axially into two halves and a cavity of 20mm x 25mm was removed from the curved surface of each halve. This cavity was covered with 1.27mm (1/2 inch) stainless steel square rods with a space of about 1mm serving as an outlet for the oil. One end of this barrel is closed while the other is left open for articulation of the press cone (stainless steel conical frustum of height 70mm). The cone regulates the discharge of the melon flour or residual cake (by-product of the oil extraction process) by means of the spring-locknut mechanism placed behind it. The auger conveyor is made up of the auger membrane, helix and the auger shaft. The auger membrane is a 28mm diameter, 400mm long stainless steel pipe while is helix is formed by scroll-welding four 5mm metal rods in spiral form on the pipe to form a flight and pitch of 45mm and 16.5mm respectively. The auger shaft is made from an 18mm diameter and 1300mm long stainless steel shaft in which 350mm (from the right end) have been threaded for the locknut-spring mechanism. A 1000W hot plate is fixed under the press barrel to reduce the moisture content of the kernel with the temperature controller and thermocouple keeping the temperature within the desired value. When the desired end product is melon flour, the machine should be operated with the hot plate switched 'OFF'. The collector is a 550mm x 380mm x 100mm rectangular tray, made from a 2mm thick stainless steel sheet metal. It has been partitioned into two sections for the oil and melon cake/melon flour. It is directly underneath the press where it is welded in position to the structural frame. A tap is attached to the base of the collector for regulating the flow of oil from the collector.

2.2 Design Analysis of Integrated Melon Processing Machine

2.2.1 Design considerations

The integrated melon processing machine was designed and developed based on the following considerations:

i. The shelling speed was regulated by a variable transformer so as to allow different species of melon seed to be processed efficiently.
ii. A blow-dryer whose terminal velocity is less than that of melon seeds and shell was selected and used.

2.2.2 Analysis of the Weight Capacities of the Various Units

The volume capacity of the shelling unit, depends on the volume of the hopper; that of the separation chamber depends on the volume of the U-trough as well as the volume occupied by the paddle shaft/paddles integrated assembly while that of the press depends on the volume of the press barrel, auger membrane, helix and cone. The weight capacities were thus derived from the weight-density-volume relationship (Equation 1).

$$W = \rho v g \tag{1}$$

Where ρ = density, v = volume and g = acceleration due to gravity (9.8m/s^2).

Considering 94% head space for the separation chamber and 25% head space for the shelling unit and press each, the effective weight capacities of the shelling unit, w_1, separation chamber, w_5 and press, w_6 were determined as 5.89 N, 5.89 N and 6.28 N from Equation (2), (3) and (4) respectively.

$$W_1 = 2.45H\rho_m\left(L_t W_t + L_b W_b + \sqrt{L_t W_t L_b W_b}\right) \tag{2}$$

$$W_5 = 7.36\rho_m\left\{\frac{1}{2}\pi r_s^2 l_s - \left[\pi r_p^2 l_p + n(l_f b_f h_f + l_l b_l h_l)\right]\right\} \tag{3}$$

$$W_6 = 7.36\rho_k\left\{\pi r_c^2 l_c - \left[\pi r_a^2 l_a + 2\pi^2 r_h^2\sqrt{R^2 + \left(\frac{Z}{N}\right)^2} + \frac{1}{3}\pi(r_b^2 h_b - r_t^2 h_t)\right]\right\} \tag{4}$$

Where $\rho_m(600kg/m^3)$ and $\rho_k(640kg/m)^3$ are the respective bulk densities of unshelled melon and melon cotyledon at moisture content between 9.53-24.08% (R Abu et al, 2007); L_t (0.3m), L_b(0.1m), l_s(0.8m), l_p(0.8m), l_f(0.04m), l_l(0.04m), l_c(0.4m) and l_a(0.4m) constitute the respective lengths of the top aperture of the hopper, base aperture of the hopper, separation trough, paddle shaft membrane, leather pad, flat bar, casing and auger membrane; W_t (0.3m), W_b (0.08m), b_l (0.005m) and b_f (0.003m) are the respective widths of the hopper's top aperture, hopper's base aperture, flat bar and leather pads; r_s (0.125m), r_p (0.0085m),

r_a(0.014m), r_c(0.0425m), r_h(0.005m), R(0.045m), r_b(0.0425m), and r_t(0.02m) are the radius of the separation trough, paddle shaft membrane, auger membrane, barrel, rod used in forming the helix, helix, base of the cone frustum and top of the cone frustum respectively; h_f(0.03m), H(0.15m), h_l(0.03m), Z(0.09m), h_b(0.08m) and h_t = 0.01m are the respective heights of the leather pad, hopper, flat bar, helix, complete cone and cone frustum while the number of paddles, n and revolutions of helix formed, N are 24 and 5 respectively.

2.2.3 Design and Selection of Transmission Systems

This machine is powered by two electric motors via four pulleys- one drives shelling unit while other drives the separating and pressing unit. Since the slower the press is run, the higher the extraction rate for oil, 24rpm was selected as the design speed of the auger while the electric motor operates at its rated speed of 1440rpm. Due to its availability, cost and performance, 125mm diameter mild steel pulleys were selected for all the drives of this machine. A double output shaft speed reducer of gear ratio 1:60 was also used so as to achieve the required press torque with a portable design. Two pulleys are attached to each of the shafts of the speed reducer, while a pulley each is mounted on the prime mover and paddle conveyor shaft consequently forming the electric motor/speed reducer and speed reducer/paddle conveyor drives. The speed ratios of the electric motor/speed reducer and speed reducer/paddle conveyor drives were computed as 1:1 each using Equation (5).

$$VR = \frac{N_1}{N_2} = \frac{D_2}{D_1} \tag{5}$$

Where N_1 and N_2 constitute the driving and driven pulleys' speed while D_1 and D_2 are the pulleys' respective diameters. The design center distances C, between the adjacent pulleys of the electric motor/speed reducer and speed reducer/paddle conveyor drives were determined as 250mm each using the relation in Equation (6) by Khurmi and Gupta (2005).

$$C = \frac{D_1+D_2}{2}+D_1 \tag{6}$$

The design length of the belts' drives were computed as 892.5mm each using Equation (7), hence, type 'A' V-belts of standard pitch lengths of 925mm each were selected for drives since each drive transmits less than 3.75kw power (IS: 2494-1974; Khurmi and Gupta 2005). Consequently, the exact center distances between the adjacent pulleys in each of these drives were determined as 266.25mm.

$$L = 2C + 1.57\,(D_2 + D_1) + \frac{(D_2-D_1)^2}{4C} \tag{7}$$

The angle of lap (Θ) of each of the drives was computed as 180° (3.14rad), using Equation (8) while the belts' speed for the electric motor/speed reducer and speed reducer/paddle conveyor drives were determined as 9.42m/s and 0.16m/s respectively using Equation (9)

$$\Theta = 180 - [2\sin^{-1}(\frac{D_2-D_1}{2C})] \tag{8}$$

$$V = \pi\frac{N_2 D_2}{60} \tag{9}$$

Tensions on the tight side, T_i/slack side, T_j of the belts for electric motor/speed reducer and speed reducer/paddle drives were determined as 160.52N/8.85N and 170.10N/9.37N respectively from equation (10), (11), (12) and (13)

$$T_i = T_{max} - T_c \tag{10}$$

$$T_{max} = \sigma a \tag{11}$$

$$T_c = mv^2 \tag{12}$$

$$2.3 log\frac{T_i}{T_j} = \mu\theta\ cosec\ \beta \tag{13}$$

Where T_{max} and T_c are the respective maximum and centrifugal tension of the belts while the groove angle, β, coefficient of friction between the pulleys and the belts, μ, maximum safe stress, σ, mass per unit length, m and the cross sectional area, a, of the belts were obtained from IS: 2494-1974 standard Khurmi and Gupta (2005) as 0.3, 19°, 2.1N/mm^2, 0.108kg/m and 81mm^2 respectively.

Autodesk Inventor was used for the force analysis (Fig. 2 to 4) of all the transmission shafts of this machine. T_1 and T_2 constitute the respective tight and slack side tensions of the speed reducer/paddle conveyor drive belt. The result of this analysis indicated 6.26mm, 17.4377mm, and 15.811mm as the minimum diameters required of shelling drum, auger and paddle conveyor shafts respectively thus, standard 6.5mm, 18 mm, 16mm and diameter shafts were consequently selected for the respective shaft.

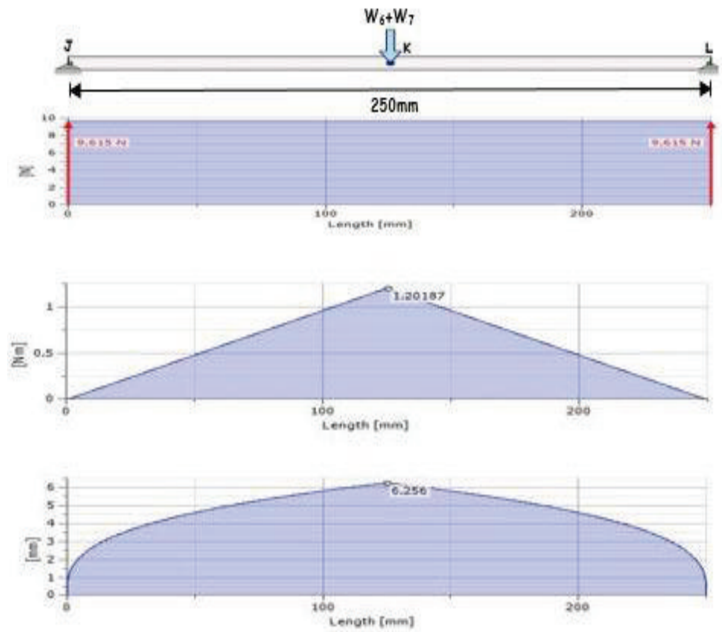

Fig. 2: Force analysis of shelling drum shaft

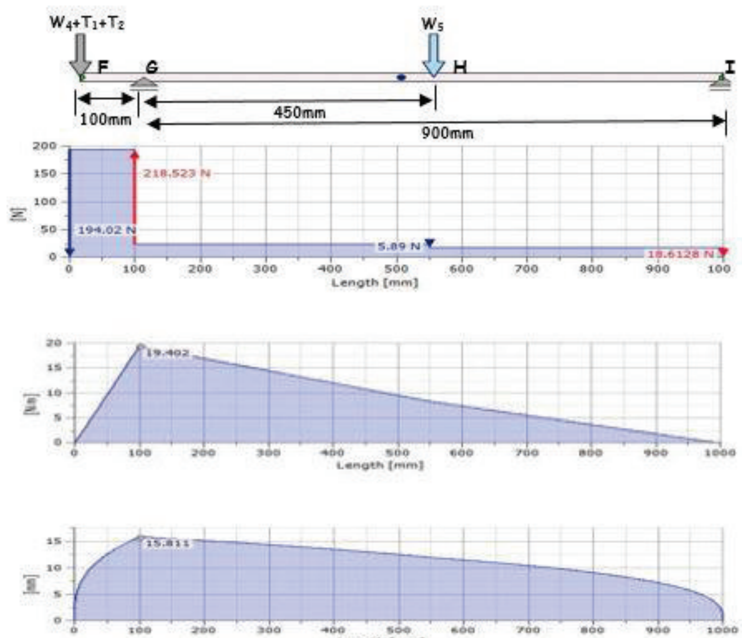

Fig. 3: Force analysis of auger shaft

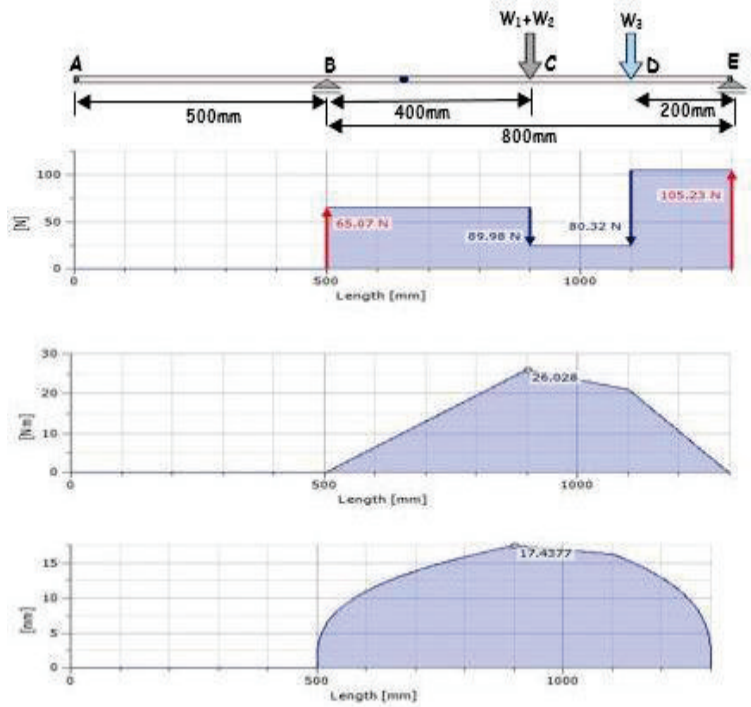

Fig. 4: Force analysis of paddle conveyor shaft

2.2.4 Press Design and Blow-dryer selection

The decreasing depth and pitch screw threading system was adopted in the design of the auger. The difference between successive screw depths d_p was determined as -1.25mm from the following relation;

$$U_n = a_f + (N-1)d_p \quad (14)$$

Where the screw depth at the feed, a_f and discharge ends, U_n are 43mm and 38mm respectively. This implies that the screw depth would be decreased consistently by 1.25 mm from the feed end to the discharge end of the press barrel. The pressure developed by the screw thread, p_r as well as the maximum allowable pressure of the press barrel, p_b were determined as 0.0025N/mm^2 and 7.01N/mm^2 respectively using following relationship:

$$P_r = \frac{T(d_m \cos\alpha \tan\theta_T + 2\mu)}{2\pi n d_m U_n \cos\alpha(1-\mu\tan\theta_T \cos\alpha)} \quad (15)$$

$$P_b = \frac{0.54t\delta_o}{d_i} \quad (16)$$

Where the helix angle, $\alpha = \tan^{-1}(\tan\theta_n \cos\theta_T)$ (17)

The torque transmitted by the auger shaft, T_a, mean thread diameter, d_m; coefficient of friction, μ ; thread lift angle, θ_n ; tapering angle, θ_T ; thickness of the barrel, t; inside diameter of the barrel, d_i and maximum yield stress of steel, δ_o are 890470Nmm, 76mm, 0.12, 12°, 6°, 3mm, 82mm and 355N/mm^2 respectively. Since the maximum allowable pressure of the press barrel is greater than that developed by the screw thread, the barrel will not burst. Furthermore, stress analysis/simulation of the press barrel was carried out using Autodesk Inventor 2014 to determine the critical stress areas and fail points. Figure 5 shows the Von Mises stress distribution diagram obtained by Finite Element Analysis (FEA).

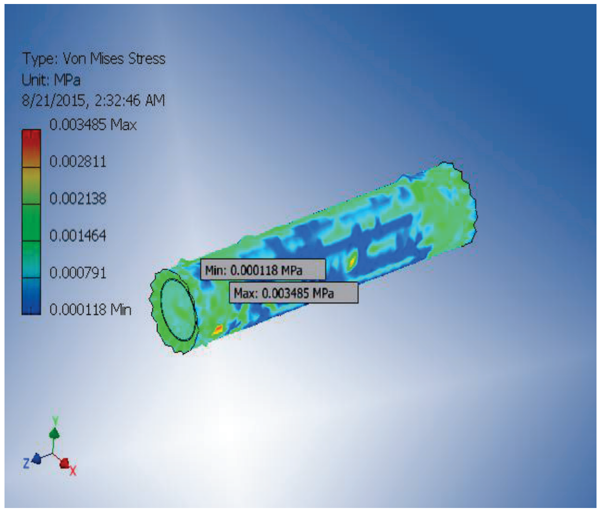

Fig. 5: Finite Element Analysis of Press Barrel

The Von Mises stress is maximum towards the ends of the barrel as indicated by the light red coloration with value approximately 0.0035Mpa. Since this value is less than the yield point value of steel, the design is safe. According to Kassim et al. (2011), for efficient chaff/kernel separation, the air velocity in the separation chamber must be less than the terminal velocity of melon seeds and shell which was determined as 6.4m/s. Thus a hand blow-dryer with double-power setting 1500-1700 W, double-speed setting 1000-1200 rpm and terminal velocity of 5.8 m/s was selected and used.

2.2.5 Selection of Electric Motor

The power, P_1 required for the operation of the shelling unit was determined as 815.74W (1.09 HP) using equations (18), (19), (20) and (21) by (Khurmi and Gupta, 2005)

$$P_1 = T\omega \tag{18}$$

$$T = I\alpha \tag{19}$$

$$\alpha = \omega^2 r \tag{20}$$

$$I = mr^2 \tag{21}$$

where the mass of the shelling drum, m; radius of the shelling drum from the axis of rotation, r and design speed of cylindrical drum, ω are 1.35kg, 85mm and 99.48 rad/s (950rpm) respectively. The power requirement of separating and pressing units were determined as 25.72W (0.03 HP) and 1429.01W (1.92 HP) respectively from Equation (22) by Khurmi and Gupta, (2005).

$$P = (T_i - T_j)\ V \tag{22}$$

Taking the load factor of electric motor, η_m as 0.75, 1.5 HP and 3HP electric motors were selected for the operation of the shelling and separating chamber/press respectively.

3.0 PERFORMANCE ANALYSIS PROCEDURE

The effect of moisture content and shelling speed on melon dehusking as well as paddle speed, blow dryer speed and heat on shell/kernel separation were first investigated. Thereafter, the oil extraction capacity, TP; extraction efficiency, η_E; and milling capacity C_M were determined. The melon seeds used were procured from Ubani market in Umuahia, Abia state, Nigeria. In the first test, the moisture content and shelling speed at five levels were used. Moisture content determination was carried out using ASAE standard S.352 (ASAE, 1982).The shelling speed was varied by regulating the variac while different moisture levels were achieved by removing a known quantity of the seeds periodically from a lot that have been soaked and dried. The initial moisture content of the seed was first used at five different inner drum speeds of 850, 950, 1000 and 1200 rpm. Thereafter, the shelling efficiency, η_s and percentage seed damage, η_b were evaluated using Equations (23) and (24) respectively.

$$\eta_s = \frac{m_{su} + m_{sb}}{m_t} \times 100 \tag{23}$$

$$\eta_b = \frac{m_{ub} + m_{sb}}{m_t} \times 100 \tag{24}$$

where m_{su}, m_{ub}, m_{sb} and m_t, are the masses of seeds shelled (unbroken), unshelled seeds but broken, seeds shelled but broken and seeds put into the machine respectively. Secondly, five different trials were carried out in which the speed of paddle conveyor was operated at 20, 24, 30, 35 and 50 rpm and the blow dryer at the two speed and heat settings of 1000-1200 rpm and 1500-1700W respectively. The paddle conveyor speed was varied by changing the diameter of the driven pulley. In each trial, a known mass of unshelled melon, m_t at the moisture content and shelling speed obtained from the first experiment was introduced into the shelling unit and the time taken to dehull and separate the kernel/shell mix, t_s was noted using a stop watch. Thereafter, the mass of melon kernel/seed received at the chaff outlet, m_c as well as the mass of chaff received at the kernel outlet, m_s were recorded as per each run and the separation efficiency, η_ϕ (%) and separation capacity, S_c (kg/h) defined as the quantity of kernels cleaned per unit time were evaluated using equations (25) and (26) respectively.

$$\eta_\phi = \frac{m_c}{m_c + m_s} \quad (25)$$

$$S_c = \frac{m_c}{t_s} \text{ (Kg/h)} \quad (26)$$

Finally, a completely randomized design involving five trials with the press temperature at five different levels was used. In the first trial, the press' initial temperature of 25^{o}C was first used. A stop watch was used to measure the time, t_s it takes the machine to process a known mass of moist melon seed, m_t at the moisture content, shelling drum speed, paddle speed, blow dryer speed and heat obtained above. The mass of melon oil extracted, m_o was also weighed and recorded as per each run, after which the extraction capacity, TP (kg/h) and milling capacity C_M (kg/h) of the machine were determined using equation (27) and (28) respectively. This procedure was repeated with the press temperature at 30^{o}C, 65^{o}C, 90^{o}C and 100^{o}C.

$$TP = \frac{m_o}{t_s} \quad (27)$$

$$C_M = \frac{m_t}{t_s} \quad (28)$$

Thereafter, melon oil losses to the chaff processed in each test were analyzed at Central Laboratory of College of Food Science and Technology, Michael Okpara University of Agriculture, Umudike using solvent extraction gravimetric method. The chaff from each test was wrapped separately in whatman filter paper. Each wrapped sample was then placed in a soxhlet reflux flask before mounting the flask on a weighed oil extraction flask containing 250ml of n-hexane solvent. Thereafter, the extraction flask was heated after connecting the upper end of the reflux flask to a condenser. This causes the solvent to vaporize and condense into the reflux flask to soak the wrapped sample until the flask was filled up and siphoned over, thereby carrying the refluxed oil down into a boiling flask. This cycle of vaporization, condensation, extraction and siphon were repeated for five times in each case before removing the defatted sample carefully with a pair of forceps as the solvent condensed back into the reflux flask while leaving the oil extract in the boiling flask. The boiling flask with its content was then placed in an oven at 90^o for 30 minutes, cooled in a desiccator and reweighed. The mass of oil lost to the chaff samples analyzed, m_l was computed from the difference between the mass of the flask and the oil extract, m_2 and the mass of the empty flask, m_1 (133.48g) as expressed in equation (29). The melon oil extraction efficiency η_E (%) of the integrated machine was also determined using the relationship in equation (30).

$$m_l = m_2 - m_1 \quad (29)$$

$$\eta_E = \frac{100 m_o}{m_o + m_l} \quad (30)$$

4.0 Results and Discussion

Results (Fig. 6 and 7) show that shelling efficiency increased as the moisture level and shelling drum speed increased from 5.2% to 9.7% and 850 to 950 rpm respectively but decreased with further increase in both shelling drum speed and moisture level while the percentage seed damage decreased with increase in moisture level but show marked increase with increase in the shelling drum speed.

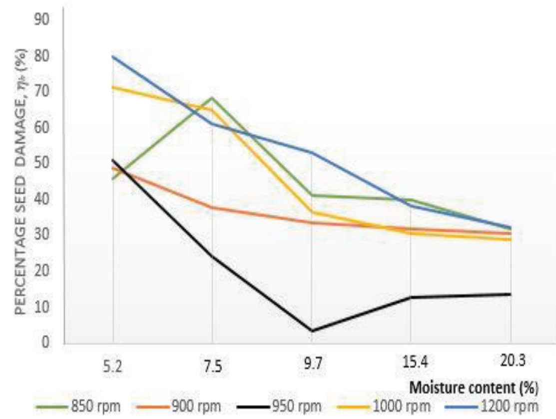

Fig. 6: Effect of melon seed moisture content on seed/kernel breakage

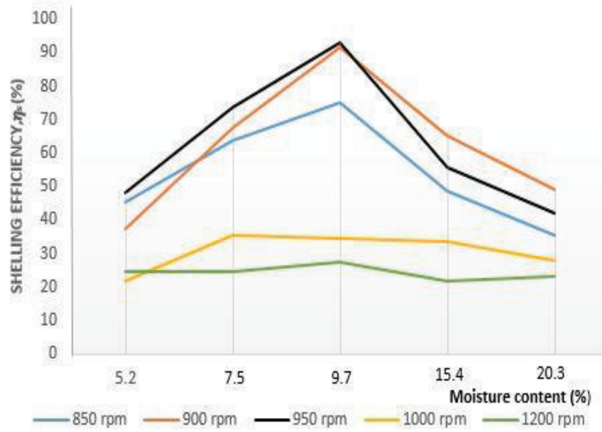

Fig. 7: Effect of melon seed moisture content on shelling efficiency

Optimal shelling efficiency and melon kernel breakage of 93.0% and 3.4% respectively were obtained at shelling speed and moisture level of 950 rpm and 9.7% respectively. These results are in consonance with the works of Kassim et al, (2011); Oluwole and Adedeji, (2012); Shittu and Ndirika, (2012).
The separation capacities and efficiencies when the blow-dryer is operated at the two speed (1000 and 1200 rpm) and heat (1500W and 1700W) settings are revealed in Figures 8-11. Increase in paddle and blow-dryer speed increased the separation capacity but decreased the separation efficiency. However, with the paddle conveyor running at 24 rpm, the optimal separation efficiency/capacity of 89.3%/94.4kg/hr was observed at blow-dryer heat and speed settings of 1500W and 1200 rpm respectively.

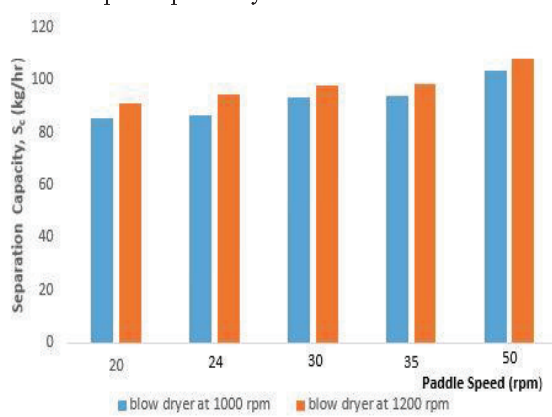

Fig. 8: Effect of paddle conveyor speed and blow-dryer speed/heat (1500W) on melon kernel/shell separation capacity.

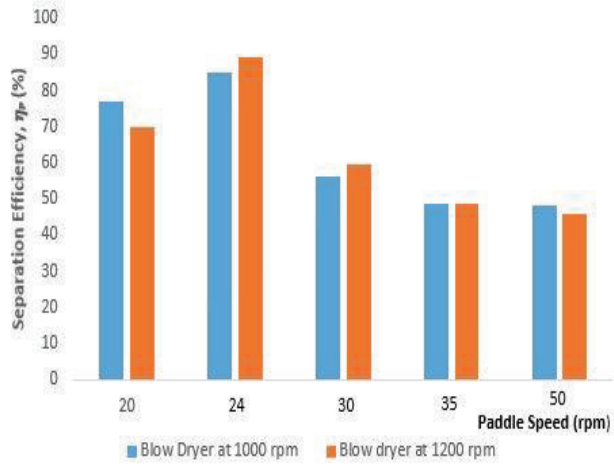

Fig. 9: Effect of paddle conveyor speed and blow-dryer speed/heat (1500W) on melon kernel/shell separation efficiency.

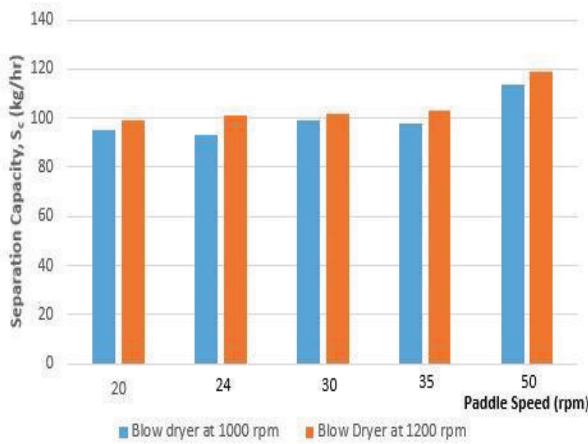

Fig. 10: Effect of paddle conveyor speed and blow-dryer speed/heat (1700W) on melon kernel/shell separation capacity.

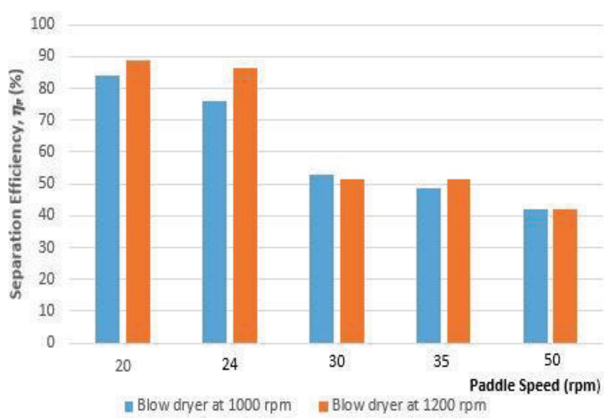

Fig. 11: Effect of paddle conveyor speed and blow-dryer speed/heat (1700W) on melon kernel/shell separation efficiency.

Table 1 shows the results of the extraction efficiency, capacity and milling capacity experiment. The oil extraction capacity and efficiency increased with increase in press temperature while 91.5%, 4.67kg/hr and 10.42kg/hr constitutes the respective average oil extraction efficiency, extraction and milling capacities.

Table1: Evaluation of oil extraction efficiency, extraction and milling capacities.

		Experimental Runs			
Evaluation Parameters	**Press Temperature (°C)**	**1**	**2**	**3**	**Average**
Mass of seed processed, m_t (kg)		1	1	1	
Process time, t_s (mins)		5.61	5.82	5.85	
Mass of chaff m_h (kg)		0.81	0.86	0.76	
Mass of oil collected, m_o (kg)	**25**	0.001	0.001	0.001	
Mass of oil lost to chaff, m_l (kg)		0.49	0.47	0.47	
Milling Capacity, C_M (kg/hr)		10.70	10.31	10.26	**10.42**
Oil Extraction Capacity, TP (kg/hr)		0.011	0.010	0.010	**0.010**
Extraction Efficiency, η_E(%)		0.2	0.21	0.21	**0.21**
Mass of seed processed, m_t (kg)		1	1	1	
Process time, t_s (mins)		6.23	5.9	6.30	
Mass of chaff, m_h (kg)		0.77	0.79	0.81	
Mass of oil collected, m_o (kg)	**30**	0.007	0.005	0.009	
Mass of oil lost to chaff, m_l (kg)		0.41	0.38	0.42	
Oil Extraction Capacity, TP (kg/hr)		0.067	0.051	0.086	**0.068**
Extraction Efficiency, η_E(%)		1.67	1.29	2.10	**1.69**
Mass of seed processed, m_t (kg)		1	1	1	
Process time, t_s (mins)	**65**	5.60	6.10	5.80	
Mass of chaff, m_h (kg)		0.62	0.58	0.55	
Mass of oil, m_o (kg)		0.35	0.37	0.29	
Mass of oil lost to chaff, m_l (kg)		0.21	0.17	0.15	
Oil Extraction Capacity, TP (kg/hr)		3.75	3.64	3.00	**3.46**
Extraction Efficiency, η_E(%)		62.5	68.5	65.9	**65.6**
Mass of seed processed, m_t (kg)		1	1	1	
Process time, t_s (mins)		5.7	5.4	6.3	
Mass of chaff, m_h (kg)	**90**	0.35	0.31	0.40	
Mass of oil collected, m_o (kg)		0.42	0.40	0.45	
Mas of oil lost to chaff, m_l (kg)		0.06	0.03	0.04	
Oil Extraction Capacity, TP (kg/hr)		4.42	4.44	4.29	**4.38**
Extraction Efficiency, η_E(%)		87.5	93.0	91.8	**90.8**
Mass of seed processed, m_t (kg)		1	1	1	
Process time, t_s (mins)		5.5	5.7	5.9	
Mass of chaff, m_h (kg)	**100**	0.36	0.29	0.32	
Mass of oil, m_o (kg)		0.45	0.43	0.45	
Mass of oil lost to chaff, m_l (kg)		0.03	0.05	0.04	
Oil Extraction Capacity, TP (kg/hr)		4.91	4.53	4.58	**4.67**
Extraction Efficiency, η_E(%)		93.0	89.6	91.8	**91.5**

Comparatively, the motorized melon oil expeller developed by Samaila and chukwu (2014) gave an average throughput and extraction efficiency of 10.12kg/hr and 60.83% respectively whereas traditionally, an average of two hours, thirty minutes is required to expel an average of 0.84 litres of melon oil from 5kg of melon seeds and two hours is required to manually dehull 1kg of whole egusi seed (Ogbonna and Obi, 2007).

5.0 Conclusion

An integrated melon processing machine with output options for three important processed forms of melon-melon kernel, melon flour and melon oil as desired by the end user was designed and developed. This machine reduces the set up cost, drudgery, improves hygiene and eliminates the wastage associated with deterioration. Performance test analysis revealed optimal shelling, separation and extraction efficiencies of 93.0%, 89.3% and 91.5% respectively while 94.4kg/hr, 10.42kg/hr and 4.67kg/hr constitute the respective separation, milling and oil extraction capacities at shelling speed, moisture level, paddle conveyor speed, blow dryer heat/speed and press temperature of 950 rpm, 9.7%, 24 rpm, 1500W/1200 rpm and 100^{o}C respectively. Thus this innovation is recommended to both small and medium scale food processors.

References

Adekunle A. S., Ohijeagbon I.O. and 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.

ASAE Standard. (1982). S. 352. Moisture measurement – grains and seeds. St. Joseph, Michigan.

FAO (2005). Small-scale Palm Oil Processing in Africa. Food and Agricultural Organization (FAO) Agricultural Series 148. pp. 1-55.http://www.fao.org/document/Y4355E03.htm.

Justina Y.T. and Victor N.E. (2014). Physical and Chemical Evaluation of Oils from Selected Underutilized Oilseeds. Der Chemica Sinica, Vol. 5(6), pp. 9-12.

Kassim M.J., Victor U. and Isaac I. (2011). Development and Evaluation of a Melon Shelling and Cleaning Machine. Journal of Emerging Trends in Engineering and Applied Sciences, (JETEAS), Vol. 2 (3), pp.383-388.

Khurmi R.S. (2010). Strength of Materials – mechanics of solids. S. Chand publications, New Delhi.- 110055.

Khurmi, R.S. and Gupta, J.K. (2005). A Textbook of Machine Design (S.I. Units) Eurasis Publishing House (PVT) Limited, New Delhi-110055.

Nwankwojike B.N., Agunwamba J.C. and Oti O. (2014). Design and Development of Integrated Digester/Nut-Pulp Separator/Screw Press Machine. Patent No. NG/P/2014/175.

Obafemi Ajibola. (2000). Adding Value to the Farmers' Harvest. Obafemi Awolowo University, Ile – ife, University Inaugural Lecture Series.

Ogbonna P.E. and Obi I. (2007). Effect of Time of Planting and Poultry Manure Application in Growth and Yield of Egusi Melon in a Derived Savanna in Agro-ecology. Agro-science 6, 33-39.

Olusegun H. D. and Adekunle A. S. (2008). The Design, Construction and Testing of Melon Sheller. Global Journal of Engineering and Technology, Volume 1, Number 4, pp. 473-481.

Oluwole O.O. and Adedeji A.S. (2012). Effects of Moisture Content and Inner Drum Rotation Speed on the Shelling Performance of a Melon Sheller. Journal of Science and Technology, 2(2): 21-26.

Onwualu, A. P., Akubuo, C. O., & Ahaneku, I. E. (2006). Fundamentals of Engineering in Agriculture. (1st edition.). Lagos: Immaculate Publications Ltd.

Oriaku E.C., Agulanna C.N., and Nwannewuihe H.U. (2013). Comparative Performance Analysis of Melon (Colocynthis Citrullus L.) De-Husking and Separation Machines by Principles of Impact and Attrition. International Journal of Multidisciplinary Sciences and Engineering, Vol. 4, No. 7, Pp.53-59.

Quadri M.A. and Fashina A.B. (2014). Throughput and Performance Evaluation of a Designed and Fabricated Egusi Shelling Machine. International Journal of Innovative Scientific & Engineering Technologies, Vol. 2(1), pp.1-8.

Samaila R.S. and Chukwu O. (2014). Development of a Motorised Egusi Melon Seeds Oil Expeller. Journal of Agricultural Engineering and Technology (JAET), Volume 22, No. 2, pp. 13-25.

Shittu S.K. and Ndrika, V.I.O. (2012). Development and performance tests of a melon (egusi) seed shelling machine. Agric Eng Int: CIGR Journal, 14(1), pp.1-11.

Tuhin Das. (2015). http://www.Onlyfoods.net/egusi.html. Assessed 25/9/2015.