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Construction of dehulling machine for improved coffee processing

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ABSTRACT

A machine was fabricated for dehulling wet-processed coffee using local materials. It was evaluated at different drum and fan speeds using parchment coffee at 10.7 w.b. moisture content. The results obtained indicated that the dehulling efficiency, bean damage and cleaning efficiency increased as the drum and fan speeds increased between 800 – 1400rpm and 1400 – 1900rpm respectively. However, there was no significant difference in dehulling efficiency and bean damage at these speeds (0.05 sig.), but the cleaning efficiency increased significantly at higher fan speeds. The highest average dehulling efficiency, cleaning efficiency and bean damage were respectively 97.59, 93.30 and 6.17%. High dehulling and cleaning efficiencies and low bean damage obtained indicate that the machine is very appropriate to handle coffee processing. Considering the reasonable performance achieved at wide range of the machine operating conditions, this work has a good prospect for commercial coffee production.

Key words: Parchment coffee, dehulling efficiency, cleaning efficiency, bean damage, Nigeria

Coffee was first discovered in Eastern Africa, in current day Ethiopia. Coffee was used as a beverage by the Arabs as long ago as 600 A. D. and they introduced it to the Mediterranean countries about 1500 A. D. It found its way from there into Western Europe about 1630 A. D. Coffee has been for decades the most commercialized food product (Interafrican Coffee Organisation, 2006) and most widely consumed beverage in the world because of its stimulating effects (Coste, 1992). It is used for pharmaceutical purposes (Akinwale and Oduwole, 2001) and has some medicinal values (International Coffee Organization, 2001); though some of these may require further proof, some researchers believed that moderate consumption is beneficial. Coffee has a good prospect for poverty alleviation as it can create millions jobs (Oduwole and Sanusi, 2001 and Interafrican Coffee Organization, 2006). In the diets of ruminants, waste and by-products of coffee have successfully used 10 – 30% (Habtamu Lemma, 2014): the pulp can be converted into animal feed, soil conditioner or used for caffeine extraction and biogas production (Practical Action, 2011). Since the opening of the first coffee house in Mecca at the end of the fifteenth century, coffee consumption has greatly increased all around the world Farah, 2012).

The coffee bean is obtained from the fruit of the coffee plant, a small evergreen shrub belonging to the family Rubiaceae and to the genus *Coffea* (Berthaud and Charrier, 1988; Coste, 1992). The structure of coffee berry is described in the sectional view given by (Potchet, 1990 and Coste, 1992). *Coffea* is the major genus of the *Rubiaceae* family, which includes well over 500 genera and over 6,000 species. The genus *Coffea* itself is diverse and reported to comprise about 103 species (Pearl et al., 2004; Davis et al., 2006). Only *Coffea arabica* and *Coffea canephora* are currently of real economic importance. Robusta is the most widely cultivated variety of *C. canephora* in the world, so that the name of this variety is used to designate the common name of the species (Damatta *et al.*, 2007). Compared with Arabica, Robusta is easier to produce, more resistant to diseases, higher yielding, lower production cost and can be grown at lower altitudes unsuitable to Arabica, but it is traded at about half the price of Arabica because of its harsh flavour characteristics (Morten, 2004).

Coffee is the most important agricultural commodity traded on the world market (Interafrican Coffee Organization, 2006); regarded to follow closely after oil in value terms and commercial dealings, contributing greatly to the economy of many countries in Africa, Asia, South and Latin America. In Africa the crop is grown in many sub-Saharan countries and mainly by small-holder farmers. Coffee production in most major producing African countries is reported to be declining. The decrease in productivity has been attributed to a range of factors, mostly production related, such as: low yields, declining soil fertility, soil erosion, use of poor quality planting materials, pest and disease problems, low returns from coffee production, high postharvest losses and limited knowledge on organic market potential and certification (Brian Ssebunya, 2011).

Coffee plant was first introduced into Nigeria around 1920, although export figures show that the crop has been cultivated for a much longer period. However, out of all the coffee species introduced into Nigeria *C. arabica and C. canephora* are cultivated commercially (Williams, 1989). Generally, Nigeria was regarded as marginal producer of coffee producing below her potential (Federal Government of Nigeria, 1985) with Robusta accounting for about 94% of the total production while *C. arabica* and *C. liberica* account for 4% and 2% respectively (Williams, 1989 and Omolaja and Obatolu, 1996).

Postharvest processes are very important in coffee production having significant effects on quality (Barel and Jacquet, 1994) and price determination: coffee is ruined and quality lost often at the processing stage (Pochet, 1990). Coffee is either processed by the wet or dry methods, which vary in complexity and expected quality of the coffee. He also added that the dry method is technologically simpler than the wet method. The method chosen to prepare green coffee depends on the species grown, the conditions and resources in each production region. Dry cherry and parchment coffee are normally produced by the growers while dehulling to produce green coffee is centralized near points of export in most producing countries where production has been commercialized. Unfortunately, coffee is manually processed in many producing countries in Africa (Interafrican Coffee Organization, 2006), including Nigeria, which usually results in poor quality beans. Coffee processing is also popularly done by dry method in Nigeria probably due to lack of appropriate machinery, but wet processing method is a quality factor and most coffee drinkers preferred washed (wet-processed) coffee (Potchet, 1990). Development and construction of a dehulling machine will reduce drudgery, reduce postharvest losses and encourage production of improved quality of coffee.

Dehulling is the post-harvest operation performed to remove hulls and skins from parchment coffee (Fig.1) or dry cherry. The dehulling operation should be done as close as possible to export in order to maintain the product’s original characteristics. Coste (1992) described various equipment for dehulling coffee including ‘Bonifiries’ which is a pestle driven by a hydraulic wheel, a rotary mill consisting of a circular trough and 2 millstones, hand-operated horizontal millstones and centrifugal disk based on force of impact. Some of the defects of these mechanisms according to the author include breakage and heating of the beans. Breakage will affect size which is important for uniform roasting just as excessive heating prior to roasting would affect chemical composition which may be detrimental to aroma and taste development. The simplest traditional method of hulling coffee is by pestle and mortar which can only handle small consignment (Practical Action, 2011) with attendant drudgery and poor quality beans.

Rubber strip beaters in axial flow arrangement are efficient for threshing tender crops like legumes (Adewumi, 2005). He added that the choice of threshing mechanism affect the power requirement, threshing efficiency, grain damage and the optimum conditions for machine operations. Olukunle (2002) listed average energy absorbed before cracking, static and dynamic modulus of elasticity and aerodynamic lift among important engineering properties of crops for mechanical handling. The process of detaching grains or seeds from the straw or pods of harvested crops involves the interaction of machine and crop which can be achieved by a combination of two or more of centrifugal, crushing and shear forces (Raji and Akaaimo, 2005) or compression, shearing and impact forces (Oloko, 2004). A threshing machine usually consists of a rotating drum in a cylinder or concave with a pneumatic separating unit using blower or aspirator. Adewumi (2005) grouped parameters affecting crop threshing generally into crop size, shape, density, strength and moisture content, drum speed, feed rate, cylinder-concave clearance, fan capacity, and crop and mog/grain feed rates. Decrease in moisture content causes increase in threshing efficiency (Simonyan and Oni, 2001). Increasing drum speed significantly increases crop damage with the susceptibility to damage varying greatly among different crops (Raji and Akaaimo, 2005) while increasing moisture content increases grain damage, but at very low moisture content grain damage increases. Increasing materials other than grains (MOG) feed rate of the crop increases grain loss exponentially and increases in MOG/grain ratio increase separation loss exponentially. The power requirement was reported to be directly proportional to the drum speed, moisture content and grain damage (El-Nono and Mohammed, 2000). Materials seperated through the concave and sieves are composed of grains, chaffs and other small components of materials other than grains (Miu, 2003). He added that straw and loose kernels accelerate round the concave at different rates due to difference in coefficients of restitution of straw and grains. This situation initiates separation of grains in the threshing unit. Simonyan and Yiljep (2008) reported that initial distribution of grains in the cleaning unit depends on degree of pre-segregation achieved during threshing, on grain pan and by stepping to the cleaning sieve while Miu (2003) divided overal movement of grains within the chaff layer as segregation movement to the top of the sieve, transport movement along the sieve and passing through sieve openings. Pneumatic cleaning is the process of using air to lift light, chaffy and dusty materials out of the grain while heavier materials move downward. Hollatz and Quick (2003) postulated that at low feed rates, aerodynamic seperation of grains from straw and chaff took place over the sieve and at higher feed rates material particles were no longer supported aerodynamically, forming a mat on sieve and increasing grain losses. Important primary factors for efficient pneumatic separation include drag co-efficient, terminal velocity and density as observed by Olukunle (2002) while factors such as area of opening, frequency of oscillation, amplitude are essential for screen separation. High standards being set by importing countries of food and biological materials coupled with the complexity of modern technology necessitates a good understanding of the significant physical properties of these materials (Bart-Plange *et al*, 2012). Physical and engineering properties of seeds are necessary in the design of equipment for handling, processing, harvesting, aeration, drying and storage (Olalusi and Bolaji, 2010).

MATERIALS AND METHODS

Design Considerations, Concept and Selection of Parameters

The design concept includes the use of impact and shearing force by rubber beaters which move coffee seeds against the concave. Design consideration are; minimum friction, minimum power requirement, affordability, simple operational and maintenance requirements and easy transportation and minimum grain damage. Selection of parameters for this work was guided by data obtained from the preliminary investigations of some physical and engineering properties of coffee seeds and beans, supported by information on existing literatures. Physical and engineering properties determined include sizes of axial dimensions, geometric mean diameter, sphericity, co-efficient of static friction, angle of repose, bulk and true density as illustrated in Table 1. The following design parameters were used for the construction;

Table1: Physical and engineering properties of coffee seeds and beans at 10.7% moisture content (w.b.) using 10 replications each.

Properties	Maximum values		Mean values	
	Seed	Bean	Seed	Bean
Length (mm)	10.5	9.40	9.78	8.19
Width (mm)	8.30	7.30	7.24	6.11
Thickness (mm)	6.00	5.30	5.23	4.60
Geometric mean diameter (mm)	-	-	7.18	6.13
Sphericity	-	-	0.73	0.75
Coefficient of static friction on mild steel	0.42	0.36	0.40	0.33
Angle of repose (0^0)	29.6	26.70	25.5	24.8
Bulk density (g/cm^3)	0.42	0.61	0.41	0.60
True density (g/cm^3)	0.86	1.25	0.71	1.06
Porosity	-	-	0.43	0.44

a) Drum of inner diameter 90 mm
b) Drum-concave clearance of 10 mm based on average major diameter of the seeds

c) Concave perforation of 9 mm based on the average major diameter of the beans.
d) Beater dimension of 75 mm x 35 mm x 5 mm
e) Drum operating speed of 700 rpm
f) Effective drum diameter of 260 mm {90 + 2(75) + 2(10)
g) Overal machine dimensions of 680 mm x 500 mm x 1200 mm
h) Desired minimum hulling efficiency of 95% as reported by Raji and Akaaimo (2005)

Machine Components and Description

The machine comprises of 3 main units: the dehulling, the cleaning and the frame. It was constructed from mild steel materials with overall height of about 1.2 m as shown in Figure 1. The components were joined together using arc-welding and bolts and nuts such that the whole machine assembly is detachable and transportable to centralized places near points of export for dehulling operation as being practiced in some coffee producing regions (World Bank, 1985) notable for more developed and commercialized production system. The dehulling unit was constructed considering relevant design theories and equations postulated by Soja *et al* (2004), reported by Raji and Akaaimo (2005), and Adewumi (2005). This component consists of the dehulling drum which is 480 mm long with 18 rubber beaters equally arranged in 3 rows on the circumference along the entire length of a 90 mm hollow pipe. The dehulling drum was housed in a perforated 260 mm wide concave rolled from 4 mm thick mild steel plate. The size of the perforations of the concave was 9 mm diameter based on the average major diameter of coffee bean. Smaller perforations of 8 mm were used at the beginning of the concave to allow little retentive time for dehulling actions before the beans could fall through the concave. Concave was fabricated based on the design theories and principles reported by Adewumi, 2005 which considered the sizes of principal dimensions of the seed and least concave clearance at 95% level of confidence of efficiency. The cleaning unit utilized both centrifugal fan and a reciprocating screen which were fabricated from 3 mm thick mild steel plate and placed below the dehulling unit. The centrifugal fan was employed because of its ability to produce large volume air current and pressure at relatively low power requirement. Relevant principles and equations reported by Olukunle (2002), Adewumi (2005) and Sessiz *et al* (2007) were adopted for this design.

Fig 1. The coffee dehulling machine

They stated that the velocity of the cleaning air must be less than the terminal velocity of crop to be cleaned in order not to blow away the crop. Terminal velocity of coffee bean was determined to be 12.9 m/s, considering the pre-determined mean values of 6.13 mm, 1.06 g/cm^3 (1060 Kg/m^3) and 0.75 respectively for geometric mean diameter, particle density and spericity. Air velocity, flow rate, width and depth of 10m/s, 0.144m^3/s, 480 mm and 30 mm respectively at 1000 rpm of the fan were assumed for this construction. The dimensions of the fan were 300 mm x 100 mm welded to a 20 mm mild steel solid shaft which was supported by a ball bearing each at both ends and housed in a circular cylinder of 260 mm which opened at both ends. The design and construction of the screen considered relevant design principles and factors such as amplitude, frequency of oscillation and distance between successive holes. The reciprocating screen was 480 mm x 420 mm in dimensions using coefficient of open area of 0.44 for a circular punched screen. Circular holes of 8.5 mm with distance between successive holes of 5 mm based on mean major axial dimension of 8.19 mm of coffee beans were drilled throughout the area of the screen. Two ball bearings were welded to each of the two sides of the screen support frame which slides inside one open square pipe welded to each of the two opposite sides of the mainframe to reduce friction and power requirement. The screen assembly was reciprocated by an eccentric cam forced into a 50 mm ball bearing to give amplitude of 22 mm during rotation of 300rpm caused by a 20 mm mild steel solid shaft. The inclination of the walls of the cleaning unit was guided by the angle of repose of the beans

The hopper was constructed following the principle of angle of repose reported by 0zugven (2005). A square frustum of sides 280 mm and height 250 mm which opens at the base to hold and deliver the right quantity of coffee seeds into the hulling unit and inclined to the concave cover to avoid the possibility of coffee seeds jumping out of the hopper due to hitting by beaters was used. In order to achieve free flow under gravity, the angle of inclination of the sides was made higher than the mean angle of repose and coefficient of friction of coffee seeds which had been earlier determined to be 25.5^o. The frame which was constructed from 4 mm thick angle iron of 50 mm x 50 mm dimension included 4 upright members and reinforced members for stability. It was 600 mm x 320 mm at the top and 680 mm x 500 mm at the base with the legs spread out, for better stability, to hold other machine components in the right relative positions.

Belt drive was employed because of its adaptability to relatively high speeds, ability to tolerate small misalignment, ease of maintenance and relatively low cost. A total of 3 belts and V-pulleys of different sizes which derived power from a 4.5Hp SI engine were used adopting relevant theories and principles stated by Mott (2003) and Sadhu (2005). A solid shaft of 25 mm diameter and 710 mm length was used to rotate the drum, considering the point loads and belt tensions acting on it by applying ASME code equation reported by Hall et al (1980). The equation considered allowable shear stress, bending moment, torsion moment, combined shock and fatigue factor for bending and combined shock and fatigue factor for torsion. Dehulling was by a combination of impact, rubbing and stripping actions. Dehulled beans and chaffs fall through the concave perforations onto the screen while air stream from the fan underneath blew away chaffs and other light materials from the top of the screen as the beans and other dense materials passed through the screen holes into the grainoulet. Dense materials and coffee seeds that could not pass through the screen fell to the front of the machine.

Testing and Evaluation

Tests were carried out on the machine to determine its performance on dehulling, and cleaning at different drum, fan and screen speeds. The tests were conducted at drum speeds and fan speeds ranging from 800 - 1400 rpm and 1400 - 1900 rpm respectively. Each trial was replicated 3 times and the average values obtained were used for the evaluation of the machine. The berries used for the test were harvested from CRIN plantations in Ibadan, Nigeria when they were matured and ripe. Necessary primary processing operations involving sorting, soaking, pulping, washing and drying of berries were manually carried out. The moisture content of the samples of the dried parchment coffee used for the tests was 10.7% wet basis (w.b) which is the average of 5 replicates measured by an electronic moisturemeter. Samples of parchment coffee were fed manually into the machine hopper; they were not sorted as this is the normal practice at processing points in many producing regions. In this practice, beans are sorted in subsequent separation/grading operations prior to roasting. Outputs from the grainoutlet were collected, labelled and weighed with an electronic weighing balance (KERRO BL5002) of 0.01g least count. Unhulled seeds collected from hulling unit, grain and chaff outlets were hulled manually and weighed. Damaged beans were also separated from the beans collected from these places, using visual inspection, and weighed. Damaged bean was determined in the context of broken beans and skin damage as recommended by Srivastava *et al* (1993). The machine was evaluated based on hulling efficiency, cleaning efficiency and percentage bean damage. Dehulling Efficiency (HE) was determined using the criterium recommended by FAO (1994) as reported by Raji and Akaaimo (2005):

$$HE(\%) = \frac{Weight\ of\ dehulled\ seeds}{Total\ weights\ of\ seeds} \times 100$$

Cleaning Efficiency (CE) was determined by adopting the approach used by Simonyan and Yiljep (2008):

$$CE(\%) = \frac{G_o}{G_o + C_g} \times 100$$

Where, Go - weight of pure grain at the grainoutlet and Cg – weight of contaminants in the pure grain

Percentage Bean Damage (BD) was determined by:

$$BD(\%) = \frac{Weight\ of\ damaged\ beans}{Total\ weight\ of\ pure\ beans} \times 100$$

Data collected from the test were analysed through graphs using Excel 2007 and Least Significant Difference (LSD) using SAS 2000.

RESULTS AND DISCUSSION

Dehulling Efficiency

The efficiency was relatively high, above 95%, at 800 rpm drum speed and the minimum average hulling efficiency achieved by each drum speed was over 92 per cent as indicated by Fig. 2. This is an indication that the rubber beater mechanism is very efficient for dehulling wet-processed coffee which agrees with the report of Adewumi (2005) that rubber strip mechanism was efficient for threshing legumes. The dehulling efficiency increased with increase in drum speed. Dalha and Dangora (2011) said the threshing efficiency varies with increase in cylinder speed at different feed rates with similar results reported by Raji and Akaaimo (2005), Adekanye and Olaoye (2013) and Adekanye *et al* (2016). Abo El-Naga *et al* (2013) who also postulated the same result, observed that threshing efficiency of Lentil decreased by increasing drum speed further from 11.78 m/s. However, there was no much increase per unit increase in drum speed (< 1%) as shown by the slope of the graph in the equation. The increase in the efficiency may be justified by the fact that dehulling is by impact force which increased due to increase in drum speed (Raji and Akaaimo, 2005 and Gbabo *et al*, 2013 and Adekanye *et al*, 2016) and had the tendency of making more materials to collide with the beaters and one another as earlier observed. Relative low corresponding change in efficiency due to increase in drum speed suggests that the initial drum speed was sufficient to cause reasonable collision and stripping of materials fed into the machine. The LSD in Table 2 which indicates no significant difference at 0.05 level among the drum speeds further confirms this. However, Raji and Akaaimo (2005) observed significant difference in threshing Prosopis africana at the same Sig. level using similar mechanism: the situation experienced in this work may be attributed to what was mentioned earlier that the initial drum speed was enough to cause reasonable dehulling efficiency or difference in crop properties.

Table 2: Effects of drum speed on dehulling efficiency and bean damage

Variables DSD (rpm)	Dehulling Efficiency Mean Values (%)	Bean Damage Mean Values (%)
800	95.147a	2.533a
1000	95.360a	3.800a
1200	95.810a	5.133a
1400	97.587a	6.167a
LSD	3.637	4.072

*DSD – Drum speed.

*Means within the same column followed by the same letter(s) are not significantly different from each others at 5% level of significant (Fisher LSD Test).

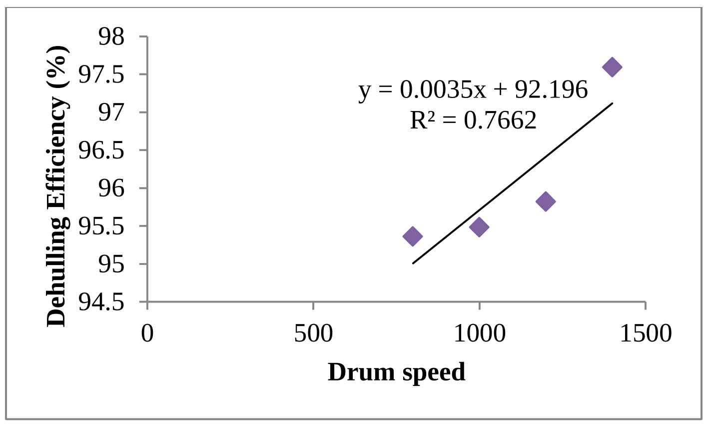

Fig 2. Effects of drum speed on dehulling efficiency at 10.7% w.b. moisture content

Bean Damage

Mean bean damage ranges from 2.5 – 6.2 per cent for drum speeds of 800 – 1400 rpm. Although percentage bean damage increased with increase in drum speed, the corresponding increase with an increase in drum speed is very low as implied by the equation of the graph in Fig. 3. According to Adekanye and Olaoye (2013) and Adekanye *et al* (2016), percentage grain damage increased slightly with an increased drum speed and decrease in moisture content. They attributed the occurrence to increased frequency of impact between the crop and threshing members, hence more severe rubbing of the crops. The percentage of damaged grain increased by increasing the drum speed (El-Nono and Mohamed,

2000) as a result of increased impact force (Abo El-Naga *et al*, 2013). This implies that using high drum speed for this machine would result in high bean damage which may render hulling operation worthless. Most of the damaged beans were those initially infected or broken during pulping. Most of the beans considered damaged were ‘truncuated beans’ which were observed to be more than half the average size. Coste (1992) stated that any piece of bean smaller in size than a half average bean may reasonably be called broken bean. In this context, it could be said that there were little or no damaged beans. Moreover, the average highest dehulling efficiency and damaged beans obtained implied that 100 kg of parchment coffee produced 89 kg of clean beans which is similar to 84.6 kg (26 kg of parchment coffee: 22 kg of clean beans) reported by Coste (1992). Table 2 shows that there was no significant difference in bean damage among drum speeds at tested levels which further proves the suitability of the machine for producing quality beans even at high drum speeds. Dalha and Dangora (2011) had observed that the effects of variables (including cylinder speed) on grain damage were not significant at 5% level.

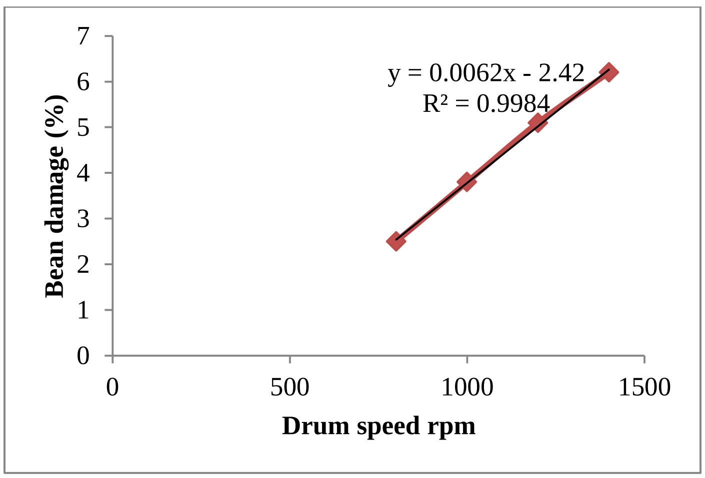

Fig 3. Effect of drum speed on bean damage at 10.7% w.b moisture content.

Cleaning Efficiency

Increasing fan speed from 1400 to 1900 rpm at screen speed of 250 rpm changed cleaning efficiency from 89.0 to 93.3%. Raji and Akaaimo (2005) had earlier reported that increase in fan rotation increased cleaning efficiency while increase in air blowing rate increased cleaning efficiency (Bello and Odey, 2011), using centrifugal fan. According to Muhammad *et al* (2013), fan speed exhibited positive linear relationship with cleaning efficiency with co-efficient of determination of 0.93 – 0.97 for three different crops. All the results can be justified by the report of Simonyan and Yiljep (2008) that grain conveyance on the sieve is influenced by air velocity which leads to initial distribution of grains from MOG. The contribution of fan and screen to cleaning efficiency in this work is shown in Fig. 4. Although there was increase in the efficiency as fan speed increased at constant screen speed, the average increase per unit increase in fan speed is very low (>1 per cent) considering the equation of the graph. This could be attributed to increased velocity of air current above the terminal velocities of dirt/chaffs due to increase in fan speed assisted with diffusion of materials due to screen agitation which led to proper drag of MOG.

Table 3: Effects of fan speeds on the cleaning efficiency

Variables FSD (rpm)	Mean Values (%)
1400	89.033 b
1600	89.400 b
1800	90.733 ab
1900	93.300 a
LSD	2.765

*FSD – Fan speed
*Means within the same column followed by the same letter(s) are not significantly different from each others at 5% level of significant (Fisher LSD Test).

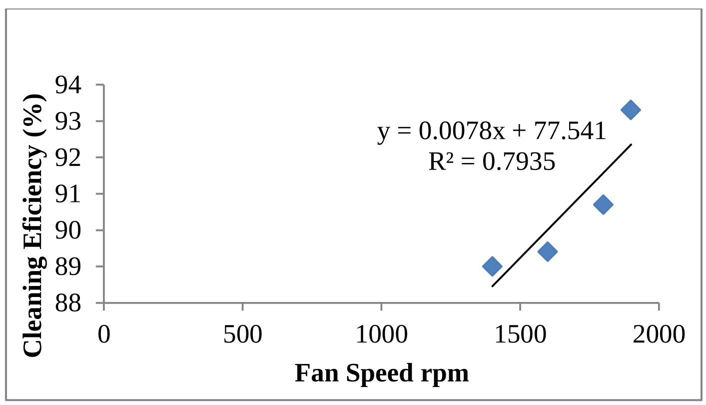

Fig 4. Effects of fan speed on cleaning efficiency at a constant screen speed and 10.7% w.b moisture content

Therefore, it may be said that a combination of reciprocating screen and blowing fan was effective for cleaning coffee beans. The trend may be attributed to better diffusion and spread of materials achieved at moderate screen speeds which resulted in efficient removal of MOG by air current from the blowing fan.

The cleaning efficiency was not significant at relatively low fan speeds but was significant at higher fan speeds at 0.05 sig. level as shown in Table 3. This indicates that relatively high fan speed is necessary for good cleaning efficiencies of coffee beans. Raji and Akaaimo (2005) observed there was significant difference among fan speeds at 5% level. The significant difference observed at high fan speeds in this work may be caused by better dispersion achieved at these speeds.

CONCLUSION

Evaluation of the machine indicated that rubber strip beater mechanism is very efficient and effective for dehulling parchment coffee at about 10.7% w.b. moisture content, using relatively low drum speeds. Combining appropriate relative speeds of both fan and screen is also effective for cleaning the dehulled beans. Damaged beans were not significantly affected by increased drum speed which also confirmed the effectiveness of rubber beater for this coffee processing operation. However, dehulling efficiency, cleaning efficiency and percentage bean damage were dependent on drum and fan speeds as the case may be. More importantly, the reasonable functional efficiencies achieved at wide range of the operating conditions are indication that this is a promising approach for dehulling and cleaning parchment coffee. Notwithstanding, further investigation on the optimum speeds and crop conditions to obtain the highest efficiencies and least bean damage may be required. The machine which is portable is also easy to operate and affordable by low income earners as the cost of construction is about NGN 150 000 with low maintenance requirement.

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