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Full Length Research Paper

Design, fabrication and performance of a motorized cowpea thresher for Nigerian small-scale farmers

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Based on the results of measurements of moisture content of grains, cowpea grain and pod sizes, grain-pod ratio, angle of friction of grains and some information from literature, a motorized cowpea thresher using a star-shaped beater to which beater belts were attached was designed and locally built. Five varieties of cowpea, K59, Ife-Brown, IT84E-124, Ife-Bimpe and TVX 715 which are fairly representative of the most popular varieties in Nigeria were selected for the measurement of design parameters. The statistical design used in studying the effect of variety on length, width, thickness, equivalent diameter, sphericity, pod weight and grain-pod ratio with 30 replications, moisture content with 3 replications and angle of friction with 5 replications was complete randomized design (CRD). The moisture content for the grain varieties ranged from 11.06 to 12.02% w.b while the size and shape measurement parameters namely; length, width, thickness, equivalent diameter and sphericity ranged from 8.22 to 10mm, 6.04 to 6.83 mm, 4.36 to 5.38 mm, 6.00 to 7.09 mm and 0.71 to 0.79 respectively for grains. For the pods, the length, width and thickness ranged from 124.78 to 194.93 mm, 7.28 to 9.15 mm and 5.27 to 7.86 mm respectively. The pod weight and grain-pod ratios ranged from 1.96 to 3.39 and 0.75 to 0.86 respectively for all the varieties tested while the angle of friction of grains on mild steel ranged from 23.6^{o} to 26.6^{o}. The results of the study as indicated by analysis of variance (ANOVA) show that there is highly significant effect ($P \leq 0.01$) of variety on all the grains and pods measurement parameters except angle of friction where non-significance was observed. Skewness and kurtosis analysis indicates that the frequency distribution curves for grains and pods measurement parameters generally approximated those of the normal distribution. Based on the optimum machine parameters, the machine throughput was determined to be 101.19, 110.86, 74.33, 75.81 and 102.09 kg grains/hour for K59, Ife-Brown, IT84E-124, Ife-Bimpe and TVX 715 respectively. Preliminary performance evaluation tests carried out on the fabricated thresher using IT84E-124 as the test material at recommended beater and fan speeds of 500 rpm and 1400 rpm respectively indicated average threshing efficiency of 96.29%, percentage damage of 3.55% and percentage threshed and undamaged grains of 92.74%. A cleaning efficiency and loss of 95.60 and 3.71% respectively was observed indicating that with the use of a star-shaped beater, drudgery and cost can be reduced to a minimum and yet achieving good quality products.

Key words: Design, fabrication, thresher, cowpea, performance evaluation.

INTRODUCTION

Cowpea, a grain legume appears to have originated from West Africa, very likely in Nigeria where there are many wild and weedy species in both savanna and forest zones (Steele, 1972). Cowpeas are now widely distributed throughout the tropics and sub-tropics. They are grown in India, South Eastern Asia, Australia, the Caribbean, Southern United States and throughout the lowland tropics of Africa. Nigeria alone produces 61% (760,000 tons) of the world's total production (FAO, 1981). Despite this figure, Nigerians, continue to suffer from hunger and malnutrition. This is because the rate of population growth has exceeded the rate of food production with a consequent decline in per capita food in - take (FAO, 1981). This calls for the need to step up food production.

The importance of cowpea lies in its food value as a major source of protein of high biological value, energy, vitamins and roughage. In addition, the crop is important as a source of animal feed (Singh and Hymowitz, 1985). Cowpea is gaining popularity and has several other advantages over other food crops. The reason being its simplicity of preparation and the wide variety of edible forms available, such as tender green shoots, leaves, unripe whole pods, green peas or beans and dry seeds. Cowpea forms a major component of lowland cropping system. This is because it provides its own nitrogen requirements through symbiotic nitrogen fixing bacteria (Rhizobia) and leaves generous amount of nitrogen for a subsequent crop. This is of interest especially in this period of rising fertilizer prices (Parman, 1974). With the growing demand for protein rich food in developing countries, attention has been focused on cowpea production whose protein content ranges from 30 - 45% (Bates, 1963) besides calcium, phosphorus and vitamins B.

Production of cowpea on a large scale is likely to continue to increase with the adoption of improved production technology and availability of wider market. This would mean a higher demand on labour for all farming operations particularly harvesting, threshing, cleaning and grading. Most of the imported threshers are very costly and hence beyond the reach of Nigerian small-scale farmers. Some have been found unsuitable for threshing the local varieties (Choudhury and Kaul, 1978; Adewumi et al., 2007b). If there has to be increased production of cowpea, farmers have to be provided with the means by which their products can be processed with minimum drudgery and cost and yet achieving good quality products.

Among the various ways by which the agricultural production of a country can be increased rapidly, the part played by improving agricultural machineries and equipment became very significant. Since the end of the second world war, considerable amount of money and a great deal of human effort has been expended in introducing mechanization to peasant farmers (Abdoun, 1976). New crop rotations, better manuring and increased potential arable acreage may have produced more grain to be sold at greater profit in the buoyant grain market of the late eighteenth and early nineteenth centuries, but the importance of the essential linking process - THRESHING - seems to have escaped comparable attention (Macdonald, 1975). The development of mechanical thresher for the purpose clearly has edge over conventional methods and had reduced the drudgery of work to a greater extent (Olmstead and Rhode, 1988).

From the earliest time that man had used grains as food, the problem of removing the unwanted unedible glume, straw or husk from the actual seeds had existed (Sutton, 1974). Until the middle of the 19th century, the principal methods of threshing grains were flailing by hand or spreading the ripe crop on a floor and beating with sticks, clubs, etc or treading by animals (Culpin, 1974). Hopfen (1960) stated that grains threshed by local methods need considerable cleaning before use. This local way of separating seeds from straw was hard, dirty, inefficient, uneconomical, time consuming and slow at a time when agriculture was undergoing rapid technological advancement in most developed countries (Olmstead and Rhode, 1988).

The first step in the mechanization of the threshing process came in the 17th century when fanning mills were developed for winnowing. In 1636, Sir John Van Berg produced a thresher which consisted of several flails operated by cranks (Encyclopedia Britannica, 1969). In 1976, Andrew Meikle built a threshing machine which combined the blow of the flails with the robbing action of the threshing floor (the prototype of the present day thresher), in which beaters were fastened to the revolving drum forcing the grain against the ribs of a concave sieve placed below the drum. This machine was capable of relieving arable agriculture from it's annual epic drudgery (Macdonald, 1975).

Probably, the best known of the early American machines was developed by Hiram and John Pitts of Winthrop which combined the threshing, separating and winnowing processes in a single machine (Encyclopedia Britannica, 1969). The threshing machines of the period 1790 - 1840, with it's complex gearing, could occupy two floors of a barn. The threshing machine could be an exceedingly elaborate piece of equipment. The more elaborate it was, the greater it's potential usefulness seems to have been and the greater the doubts expressed by some farmers (Macdonald, 1975). Researchers continued their work on improving threshing machines until the 'COMBINE' was invented but the needs of the small scale farmers remained unmet. This was because the small holdings do not justify investments in such big machines (Ige, 1978).

A good amount of work has been reported on the thresher comparing generally their performance on different crops. Choudhury and Kaul (1978) carried out some tests on Alvan Blanch threshers to thresh some of the local varieties of grain crops and the machines were found unsuitable. Sharma and Devnani (1978) reported that threshing of cowpea can be done by means of a squeezing action, a rubbing action or a combination of the two and it is found to be a combination of the crop and machine variables. The crop variables are related to the type, maturity and moisture content. Thresher variables include the type of beater, the screen, the beater tip speed and the beater - screen clearance. The use of power thresher would require the knowledge of optimum operating conditions in respect of the machine variables (Sharma and Devnani, 1978). Researchers have also experimented on various forms of threshers. These threshers range from plain roller to torsion spring tooth cylinder and spike tooth cylinder rotating in a stationary concave to effect the threshing.

Ige (1978) built a cowpea thresher using a drum with a square cross-section in order to give a fanning effect inside the threshing unit. Teeth were welded along each edge and between two edges of the square-based prism with the concave forming a quadrant around the drum. Three rows of teeth were equally spaced on the concave. The diameter of the circle formed by the drum was 150 mm. A straight bladed type of centrifugal fan was used in the design. Evaluation of the threshing and separation performance indicated that the highest percentage of threshed and undamaged grains were obtained at 500 rpm drum speed for the three varieties of cowpea studied; Ife-Brown, IVU-37 and H64-3 while fan speed of 1400 rpm was found to correspond to the least separation loss at which there was little or no clogging. Higher threshing efficiencies were obtained at lower moisture contents. Vejasit (1991) compared the performance of the raspbar and peg-tooth threshing drums of an axial flow thresher for soybean crop. The results indicated that amount of grain retained on threshing unit for both cylinder at all cylinder speeds and feed rates were not significantly different. Allen (1998) designed a belt thresher for cowpea beans since a conventional cylinder and concave thresher could not be used to thresh cowpeas (var. Minica), due to the sensitive pericarp of the beans and their brittle nature.

Dauda (2001) designed, constructed and evaluated the performance of a manually operated cowpea thresher for small scale farmers in Northern Nigeria. Results obtained gave a threshing effectiveness of 85.9, 84.6 and 84.1% for Kanannado, Borno Brown and Aloka local, respectively. Seed damage was 1.8, 2.3 and 1.9% for Kanannado, Borno Brown and Aloka local, respectively. Winnowing efficiency at 372 rpm fan speed was 92.75, 92.5 and 92.35% for Kanannado, Borno Brown and Aloka local, respectively. Throughput capacity was 95.4, 93.5 and 92.8 kg/h for Kanannado, Borno Brown and Aloka Local, respectively, and is not statistically different at 5% significance level. Vejasit and Salokhe (2004) fabricated a threshing unit to study the effect of machine-crop variables on the performance of an axial flow thresher for threshing soybeans.

Test results indicated that the threshing efficiency varied from 98 to100%. The grain damage and grain loss were less than 1 and 1.5% respectively at drum speeds of 600 to 700 rpm and 540 to 720 kg (plant)/h feed rates and at 14.34 to 22.77% (w.b.) seed moisture contents. Adewumi et al. (2007a) designed and fabricated a medium scale thresher-cleaner with conveyor, thresher, fan and cleaning units for grain legume. The machine which was subjected to preliminary test using cowpea ('Ife Bimpe' variety) with a pod moisture content of 14.0 to 22.0% gave threshing efficiency in the range of 67.5-97.7% for the same moisture content values. The cleaning unit had an effectiveness rate of 98 - 100%. Mulleriyawa (2008) reported an invention by Mr. M. T. Ismahoon, a star product called "Mahaweli Agro Multi Thresher", a highly versatile machine which threshes winnows and cleans grains in one operation.

The machine can be used for a variety of crops such as greengram, blackgram, cowpea and soybean. It can also thresh corn by changing the drum. Despite these efforts, rural and poor farmers in Nigeria continue to face challenges in accessing threshers because of prohibitive costs of the machines or because the machines are not locally available (Adewumi et al., 2007b). There is need therefore to experiment with threshing unit designs that provide lower costs and yet achieving good quality products. The objective of this work therefore is to:

(a) Measure some design parameters affecting the handling losses of some cowpea varieties which are fairly representative of the most popular varieties grown in Nigeria.
(b) Design and fabricate a cowpea thresher using a lower cost star shaped beater based on measured parameters and some information from literature.
(c) Evaluate the performance of the thresher at the recommended beater and fan speeds of 500 rpm and 1400 rpm respectively.

MATERIALS AND METHODS

Measurement of physical parameters of the grains

Five varieties of cowpea - K59, Ife-Brown, IT84E-124, Ife-Bimpe, TVX 715 which are fairly representative of the most popular varieties in Nigeria were selected for study. For each variety, bulk samples were obtained from the teaching and research farm, Federal University of Technology, Akure. The moisture content was determined by the standard oven method according to American Society of Agricultural Engineers standards (ASAE Standards, 1998). Each variety was replicated 3 times.

From the bulk sample, 30 randomly selected pods and grains were obtained for the physical measurement of the three (3) major perpendicular dimensions and the results analyzed to provide the necessary basic information for the design of the cowpea thresher. A ruler of 1.0 mm calibration was used to measure the length of cowpea pods while a vernier caliper of 0.01 mm calibration was used for measuring all other axial dimensions. From these axial dimensions, the equivalent characteristic length or diameter, D_p for the grains were determined as the geometric mean of the three dimensions given as (Mohsenin, 1970):

$$D_p = (abc)^{1/3}$$

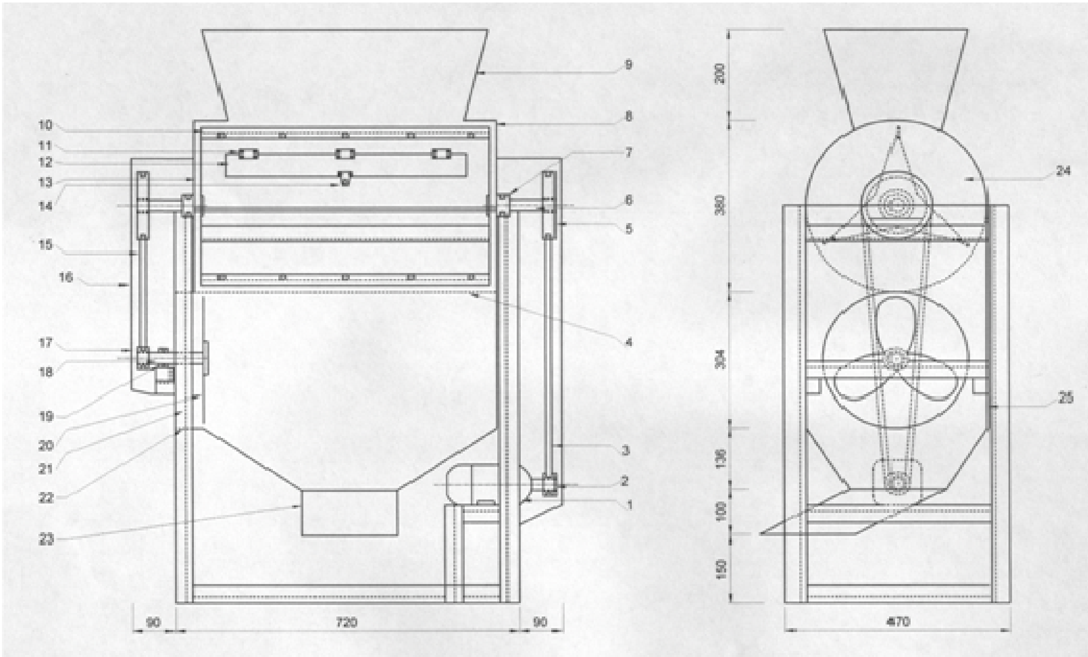
where a = length, b = width and c = thickness. The sphericity, ψ for the grains was determined by using the relationship (Mohsenin, 1970):

$$\psi = \frac{(abc)^{1/3}}{a}$$

The representative value of the axial dimensions a, b, c and equivalent diameter and sphericity was taken as the average of thirty samples.

The grain-pod ratio was determined by taking the weight of 30 pods of each variety and the weight of clean grains from each pod. The ratio of the weight of clean grains to the pod weight gives the grain-pod ratio, thus if the weight of unthreshed cowpea is known, the weight of clean grains can be determined. A mettler E200 balance of 0.01gm calibration was used for weighing.

The angle of friction on material surface was determined by pouring some cowpea grains on a 14 gage, mild steel metal of rectangular cross-section and tilting the metal at one end. The



Weight: 90 kg; Overall size = 900 × 470 × 1270 mm; Power Drive: 0.75 hp petrol or diesel engine. Application Potential: For threshing Cowpea and on replacement of beater belts rice, soybeans, sorghum, millet, groundnuts and maize; Advantages: Compact design for easy operation and easy maintenance, highly portable, grain collection feature minimizes spillage, easy collection of biomass and minimum breakage; Status: Research and development stage

Figure 1. Design drawing of the motorized cowpea thresher (Dimensions in mm). (1) ¾ hp motor, (2) 50 mm motor and fan pulley, speed =1,400 rpm, (3) B60 v-belt 16 mm x 1562 mm, (4) screen, (5) 140 mm beater pulley, speed = 500 rpm, (6) beater shaft, (7) bearing housing, (8) beater upper housing, (9) feed hopper, (10) beater – canvas, (11) discharge gate hinges, (12) discharge gate cover plate, (13) star shaped beater, (14) discharge gate locking unit, (15) B60 v-belt 16 mm x 985 mm, (16) moving parts protective wire mesh, (17) pulley sleeves, (18) fan shaft, (19) 25 mm inside diameter bearing, (20) fan blades, (21) frame system, (22) fan housing, (23) discharge chute, (24) beater upper housing end plates, (25) side cover sheets.

angle the metal sheet makes with the horizontal at the point the grains start to slip from the metal sheet gives a rough estimate of the angle of friction between the metal and grains. A protractor was used for all angular measurements. For each variety, 5 replications were carried out and the average angle of friction calculated.

The experimental design for the study of effect of variety on the length, width, thickness, equivalent diameter, sphericity, pod weight and grain-pod ratio is Complete Randomized Design (CRD) with 30 replications, moisture content with 3 replications and angle of friction with 5 replications. Microsoft Excel 2007 for Windows was used for skewness and kurtosis tests, summary statistics and single factor analysis of variance (ANOVA).

Design, fabrication and testing of the machine

Based on the data collected on cowpea and other information from literature, the cowpea thresher was designed and the machine components were fabricated and assembled as per detailed drawing shown in Figure 1. IT84E-124 at 11.06% moisture content was used in testing the performance of the machine. Bulk samples were supplied by the teaching and research farm, Federal University of Technology, Akure for the testing of the machine and subsequent seasonal threshing activity. Samples of 200 gm of cowpea pods were obtained from the bulk sample and fed into the machine. The threshed cowpea were collected and weighed (W_1) after removal of contaminants (chaff). This was then separated into threshed but damaged - splits (those with checked or cracked skins), cuts (those with sharp narrow indentation in the skins and cotyledons) and smashed (those with crushed cotyledons), W_2 and threshed and undamaged - sound beans, W_3. The contaminants (chaff) in the grains and the grain in the chaff outlet were weighed as W_4 and W_5 respectively. The total weight of the grain (W) was given by:

W = 200 gm × grain-pod ratio for IT84E-124 at 95% confidence level = 200 gm × 0.6039.
= 120.72 gm.

Table 1. Summary of data collected to determine the moisture content, grain size and angle of friction of cowpea for the 5 varieties; standard deviation in parentheses.

Variety	*Moisture content, % w.b	**Length, mm	**Width, mm	**Thickness, mm	**Equivalent diameter, mm	**Sphericity	***Angle of friction, degrees
K59	12.02(0.014)	8.22 (0.62)	6.04 (0.31)	4.36 (0.30)	6.00(0.30)	0.73(0.04)	25.0(1.00)
Ife-Brown	11.44(0.095)	9.79 (0.67)	6.83 (0.24)	5.01 (0.26)	6.95(0.37)	0.71(0.03)	25.0(1.41)
IT84E-124	11.06(0.072)	10.00 (0.49)	6.76 (0.38)	5.28 (0.28)	7.09(0.32)	0.71(0.04)	23.6(1.14)
Ife-Bimpe	11.99(0.038)	8.67 (0.45)	6.73 (0.31)	5.37 (0.34)	6.79(0.29)	0.78(0.02)	23.6(1.14)
TVX 715	11.96(0.037)	8.46 (0.63)	6.45 (0.30)	5.38 (0.44)	6.65(0.41)	0.79(0.05)	26.6(1.82)

*Values are means of 3 replications. **Values are means of 30 measurements. ***Values are means of 5 replications.

Table 2. Summary of data collected to determine size and weight of cowpea pods and gain crop ratio for the 5 varieties; standard deviation in parentheses.

Variety	*Length, mm	*Width, mm	*Thickness, mm	*Pod weight, g	*Grain-pod ratio
K59	141.46 (11.89)	7.28 (0.48)	5.27 (0.51)	1.96 (0.40)	0.80 (0.03)
Ife-Brown	124.78 (10.03)	7.99 (0.47)	5.97 (0.52)	2.22 (0.41)	0.86 (0.05)
IT84E-124	194.93 (29.55)	9.15 (0.70)	5.61 (0.48)	2.69 (0.67)	0.80 (0.07)
Ife-Bimpe	171.87 (9.34)	8.58 (0.52)	7.86 (0.66)	3.39 (0.46)	0.75 (0.04)
TVX 715	151.82 (11.37)	7.84 (0.43)	5.87 (0.10)	2.58 (0.61)	0.80 (0.10)

*Values are means of 30 measurements.

Threshing efficiency, T_e was calculated as T_e, % = $100W_1/W$, the percentage damage, P_d as P_d, % = $100W_2/W$ while the percentage threshed and undamaged grains, P_t was computed as P_t, % = $100W_3/W$. Cleaning efficiency, η was computed as η, % = $100W_1/(W_1+W_4)$ while cleaning loss, C_l was computed as C_l, % = $100W_5/W$ (Simonyan and Yiljep, 2008). The efficiencies and percentages were found as an average of 5 replications. The thresher throughput of the machine was determined according to procedure stated by Irtwange (1987).

RESULTS AND DISCUSSION

A summary of the physical measurements (moisture content, angle of friction, length, width, thickness, equivalent diameter, sphericity, pod weight and grain-pod ratio) for the 5 varieties of cowpea studied is given in Table 1 for grains and Table 2 for pods. The summary of the Analysis of Variance (ANOVA) is presented in Tables 3 and 4. The results of the skewness and kurtosis tests are presented in Table 5. The performance test result carried out on the cowpea thresher using IT84E-124 at 11.06% moisture content is shown in Table 6 while the thresher throughput as a function of crop variety is as shown in Table 7.

Physical parameters of the grains

The average moisture content of the grains ranged from 11.06% for IT84E - 124 to 12.02% for K59 (Table 1). This is the average grain moisture content range at which most cowpea varieties are being threshed by the local farmers. Ige (1977) found out that threshing efficiency as high as 99% can be obtained for samples with least moisture content in Ife-Brown, IVU-37 and H64-3 indicating that threshing efficiency has to be stated among others in terms of moisture content of the material being threshed. The size and weight of grains also has been found to be a function of the moisture content. This necessitates moisture content determination as grain resistance to impact and continuous loads depends on moisture content.

A summary of the physical measurements taken to determine the size of the varieties of cowpea studied indicates that for grains (Table 1), the length ranged from 8.23 mm for K59 to 10.00 mm for IT84E-124; width ranged from 6.04 mm for K59 to 6.83 mm for Ife-Brown while the thickness ranged from 4.36 mm for K59 to 5.38 mm for TVX 715. For the pods however (Table 2), the length ranged from 124.78 mm for Ife-Brown to 194.93 mm for IT84E-124; width ranged from 7.28 mm for K59 to 9.15 mm for IT84E-124 while the thickness ranged from 5.27 mm for K59 to 7.86 mm for Ife-Bimpe. Handling losses during threshing of cowpeas are affected by the size of the cowpeas. If the beater - screen clearance is too big, this may result in under threshing while too small a clearance may lead to excessive damage to grains as they are crushed.

Damage will also occur if the sizes of screen perforations are smaller than the size of cowpea as they will be force

Table 3. Summary of ANOVA for physical parameters.

Source of variation	df	Length (mm)	Width (mm)	Thickness(mm)	Equivalent diameter (mm)	Sphericity	5%	1%
Variety (Grains)	4	42.75**	23.80**	37.18**	25.42**	679.04**	2.37	3.32
Error	145							

Source of variation	df	Length (mm)	Width (mm)	Thickness (mm)	Pod weight (g)	Grain-pod ratio	5%	1%
Variety (Pods)	4	62.54**	40.88**	93.55**	23.88**	8.30**	2.37	3.32
Error	145							

**Highly significant difference (1%).

Table 4. Summary of ANOVA for moisture content and angle of friction.

Source of variation	Moisture content (% w.b)				Angle of friction, degrees			
	df	F. cal	5%	1%	df	F. cal	5%	1%
Variety	4	160.84**	3.48	5.99	4	4.35^{NS}	2.87	4.43
Error	10				20			

**Highly significant difference (1%); ^{NS} Non significant difference.

through the tight holes. For optimum performance of a thresher, the beater-screen clearance and the size of perforations have to be carefully selected. The basic information for such selections is the size of cowpea grains. Information on pod size is useful in determining the minimum length of the threshing unit and the length and width of the feed hopper for efficient threshing and convenience in feeding, respectively.

The summary of the pod weight and grain-pod ratios for 30 pods of each of the 5 varieties of cowpea indicate that whereas pod weight ranged from 1.96 g for K59 to 3.39 g for Ife-Bimpe, the grain-pod ratio ranged from 0.75 for Ife-Bimpe to 0.86 for Ife-Brown (Table 2). The grain-pod ratio was used in determining the threshing efficiency of the machine. The angle of friction (in degrees) for the 5 varieties of cowpea was found to range from 23.6^{o} for IT84E-124 and Ife-Bimpe to 26.6^{o} for TVX 715 (Table 1). After threshing of the cowpea, the grains have to be conveyed through the discharge chute. For the grains to move freely out of the machine, the angle of inclination of the discharge chute should be equal to the angle of friction of the grains. The Analysis of Variance (ANOVA) indicates that variety has a highly significant effect ($P \leq 0.01$) on length, width, thickness, equivalent diameter, sphericity, pod weight, grain-pod ratio and moisture content while the effect of variety on angle of friction was found to be non significant (Tables 3 and 4).

The results of skewness and kurtosis tests (Table 5) indicate that the frequency distribution curves for the grain and pod measurement parameters generally approximate those of the normal distribution for all the varieties with their peaks being around their means. Similar results have been presented by Ige (1977) for five varieties of cowpea; Ife-Brown, Black Eye, 1190E, H64-3 and H113-4. Thus, normal distribution tables can be reasonably used to predict the distribution at various confidence levels. The distribution at 95% and 99.5% confidence levels are given by 0∀2.05σ and 0∀ 3.04σ respectively where 0 is the mean and σ is the standard deviation. For instance, the size of screen perforations of at least 0∀ 3.04σ will be desirable to allow 99.5% of the cowpea grains to pass through without damage.

Design, fabrication and performance of the thresher

The cowpea thresher shown in Figure 1 consists of 3 main essential units: (i) Feeding Unit; (ii) Threshing Unit and (iii) Winnowing Unit. The feeding unit provides an opening through which the cowpea is introduced into the machine for threshing. It is located directly above the beater and is welded to the beater upper housing. The hopper spreads through the whole length of the beater and has an opening into the threshing unit. This facilitates easy feeding. The threshing unit consists of a star-shaped beater of length 600 mm and diameter of 350 mm on which is attached beater belts. The beater belts drag the pods against the 12 mm diameter screen located 15 mm below it, thus causing threshing. The separating section consists of a chaff outlet, a screen and a fan. The chaff outlet which is located at the side of the threshing unit is closed when threshing and opened when required to discharge the chaff from the machine. The 300 mm diameter, radial tip, curved blade centrifugal type fan is located below the screen and is designed to suck the chaff material that falls through the screen perforations motorized thresher was 0.75 hp while

Table 5. Skewness and kurtosis tests for size and shape measurement parameters.

Crop Type	Measurement parameters	K59[a]		Ife Brown		IT84E-124		Ife Bimpe		TVX 715	
		Γ[1]	Γ[2]	Γ[1]	Γ[2]	Γ[1]	Γ[2]	Γ[1]	Γ[2]	Γ[1]	Γ[2]
Grains	Length, mm	0.46	-0.41	0.41	0.02	-0.15	0.20	-0.69	-0.23	0.04	-0.51
	Width, mm	0.24	-0.51	0.46	-0.33	-0.61	-0.19	-0.43	-0.25	-0.52	0.38
	Thickness, mm	0.14	0.44	0.06	-0.55	-0.50	0.18	0.45	0.09	-0.47	-0.05
	Equivalent diameter, mm	-0.17	0.22	-0.28	-0.70	0.39	-0.52	0.13	0.10	-0.02	-0.02
	Sphericity	-0.27	-0.60	-0.70	0.06	0.56	-0.78	-0.33	0.17	0.12	-0.72
Pods	Length, mm	0.02	0.32	0.51	-0.03	0.42	0.32	0.32	0.30	-0.45	0.61
	Width, mm	0.05	-0.41	0.42	-0.04	0.61	-0.23	0.41	-0.37	0.62	-0.72
	Thickness, mm	0.07	-0.72	-0.72	0.42	-0.51	0.41	-0.52	0.42	0.71	0.02
	Pod weight, g	-0.65	-0.20	-0.95	-0.02	-0.53	-0.32	-0.08	0.37	-0.12	0.09
	Grain-pod ratio	-0.51	0.64	0.63	0.71	0.42	0.52	0.62	0.61	-0.09	0.05

[a] Γ[1] = skewness which characterizes the degree of symmetry of a distribution around its mean. Positive skewness indicates a distribution with an asymetric tail extending towards more positive values (skewed to the right) Negative skewness indicates a distribution with an asymetric tail extending towards more negative values (skewed to the left). Zero values indicate symmetrical distribution. Γ[2] = kurtosis which characterizes the relative peakedness or flatness of a distribution compared to the normal distribution. Positive kurtosis indicates leptokurtic distribution. Negative kurtosis indicates platykurtic distribution. Zero values indicates normal or mesokurtic distribution.

Table 6. Test result carried out on the cowpea thresher using IT84E-124 at 11.06% moisture content.

Test Number	Threshed cowpea, W_1(g)	Threshed but damaged, W_2(g)	Threshed and undamaged, W_3(g)	Weight of contaminants in the grain, W_4 (g)	Weight of grain in the chaff outlet, W_5 (g)	Threshing efficiency, T_e (%)	Percentage damage, P_d (%)	Percentage threshed and undamaged grains, P_t (%)	Cleaning efficiency, η (%)	Cleaning loss, C_l (%)
1	116.35	4.25	112.10	5.92	4.37	96.38	3.52	92.86	95.16	3.62
2	115.27	5.29	109.98	6.55	5.45	95.49	4.38	91.11	94.62	4.51
3	117.08	3.38	113.70	4.92	3.64	96.98	2.80	94.18	95.96	3.02
4	116.45	6.13	110.32	5.73	4.27	96.46	5.08	91.38	95.31	3.54
5	116.08	2.38	113.70	3.65	4.64	96.16	1.97	94.19	96.95	3.84
Average	116.25	4.29	111.96	5.34	4.47	96.29	3.55	92.74	95.60	3.71
Variance	0.43	2.22	3.17	1.25	0.43	0.29	1.52	2.17	0.80	0.29
Standard deviation	0.66	1.49	1.78	1.12	0.66	0.54	1.23	1.47	0.89	0.54

beater and fan shaft diameters of 25 mm were selected. To provide the recommended beater speed of 500 rpm and fan speed of 1400 rpm, beater pulley of 140 mm and fan and motor pulleys of 50 mm were selected.

The performance test result carried out on the cowpea thresher is shown in Table 6. The results indicated a threshing efficiency of 96.29%. Sharma and Devnani (1978) reported threshing efficiency of

Table 7. Thresher throughput for the various cowpea varieties.

Machine parameters	K59	Ife-Brown	IT84E-124	Ife-Bimpe	TVX 715
Volume of hopper, m^3	0.036	0.036	0.036	0.036	0.036
Volume of opening into the threshing chamber, m^3	9.6×10^{-5}	9.6×10^{-5}	9.6×10^{-5}	9.6×10^{-5}	9.6×10^{-5}
Volume of pod, m^3	5.36E-06	5.95E-06	1.00E-05	1.16E-05	6.99E-06
Hopper holding capacity, number of pods	6723	6048	3598	3106	5153
Number of pods that can be fed into the threshing chamber/second	17.93	16.13	9.59	8.28	13.74
Time taken to thresh 1# hopper full of cowpea pods, seconds	375	375	375	375	375
Number of pods threshed/hour	64,536	58,064	34,539	29,817	49,464
Weight of one cowpea pod, g	1.96	2.22	2.69	3.39	2.58
Weight of cowpea pods threshed, g /hour	126.49	128.90	92.91	101.08	127.62
Grain-pod ratio	0.8	0.86	0.8	0.75	0.8
Thresher capacity, kg grains/hour	101.19	110.86	74.33	75.81	102.09

91.7% corresponding to cylinder tip speed of 288.5 mpm for seed purpose and threshing efficiency of 95.6% corresponding to cylinder tip speed of 496 rpm for consumption using a specially developed variable speed thresher with a rasp cylinder of a length of 30.5 cm and 20 cm in diameter and a cam arrangement to vary the concave clearance from 4 mm to 12 mm. Dauda (2001) presented a threshing efficiency between 84.1% to 85.9% for a manually operated cowpea thresher while Adewumi et al. (2007a) reported a threshing efficiency in the range of 67.5 - 97.7% for a motorized medium scale thresher-cleaner. Vejasit and Salokhe (2004) reported 98 to100% for axial flow soybean thresher. The damage to grains was 3.55% of the threshed grains (Table 6).

This may have been due to the crop or machine variables. However, it thus appears that the drum speed for highest percentage of threshed and undamaged grains is a function of drum (beater) type, shape and material of construction. Losses due to the machine (unrecovered grains from the threshing unit) and the unthreshed cowpea accounted for 3.71%. Dauda (2001) reported grain damage of 1.8 - 2.3% for a manually operated cowpea thresher while Vejasit and Salokhe (2004) reported grain damage and grain loss of less than 1 and 1.5% respectively at drum speeds of 600 to 700 rpm for soybeans. Despite the fact that some good results were obtained, further studies still has to be carried out on the thresher with the view to determining the optimum crop and machine variables for least damage to grains.

A cleaning efficiency of 95.60% was observed as a result of the combined action of the 300 mm diameter, radial tip, curved blade centrifugal type fan and the star shaped beater. A high percentage (93.61%) of the chaff was blown out through the feeding unit and the chaff outlet by the action of the star - shaped beater and that which fell through the screen perforations was sucked by the fan while the remaining which fell into the collection basin placed under the machine was blown out as the star-shaped beater blows in air through the screen perforations to the winnowing chamber. It thus appears that the fan speed of 1400 rpm was optimum for the thresher as cleaning loss observed for the variety tested was 3.71%. Ige (1978) stated that the speed of about 1400 rpm corresponds to the least separation loss for Ife-Brown and H64-3 varieties but recorded a loss of 16% for IVU-37 variety whose grains are small compared with those of Ife-Brown and H64-3. Dauda (2001) reported a winnowing efficiency at fan speed of 372 rpm in the range of 92.35 to 92.75% while the cleaning unit of the medium-scale thresher cleaner reported by Adewumi et al. (2007b) had an effectiveness rate of 98-100% for Ife-Bimpe.

The thresher throughput for the various cowpea varieties ranged from 74.33 kg grains/hour for IT84E-124 to 110.86 kg grain/h for Ife-Brown (Table 7). Dauda (2001) reported throughput capacity for a manually operated cowpea thresher of 95.4, 93.5 and 92.8 kg/h for Kanannado, Borno Brown and Aloka Local, respectively. The thresher which costs ₦874.14 or $125.00 @ 1$ = ₦7.00 (cost of materials and workshop services - July, 1987 Akure prices) less the power unit, labor cost and profit can be adapted to handle other crops such as rice, soybeans, sorghum, millet, groundnuts and maize by replacing the beater belts with plywood and for use in areas where there is no electricity by the use of foot pedaling, hand operation or diesel/petrol powered motors. Adewumi et al. (2007b) has provided a list and description of 24 rice threshers manufactured or used in Nigeria with the prices ranging between ₦20,000.00 to ₦750,000.00 or $134.00 to $5,000.00 (1$ = ₦150.00) based on 2007 market prices and currency exchange rate.

Conclusion

The study concludes as follows:

(a) Based on the data collected on popular cowpea varieties grown in Nigeria and some information from literature, a cowpea thresher using a star-shaped beater to which beater belts were attached was designed and locally built to meet the needs of Nigerian small-scale farmers.

(b) The test performance at recommended beater and fan speed of 500 rpm and1400 rpm respectively indicated a threshing efficiency of 96.29%, percentage damage of 3.55%, percentage threshed and undamaged grains of 92.74%, cleaning efficiency of 95.60% and cleaning loss of 3.71%. The drum speed for highest percentage of threshed and undamaged grains is found to be a function of type of drum. The star-shaped beater is cheaper and hence the overall cost of the machine. It has a fanning effect, thus causing improved cleaning of grains.
(c) Based on the optimum machine parameters, the machine throughput was determined to range between 74.33 to 110.86 kg grains/h for the cowpea varieties.

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