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Design of a Cocoa Pod Splitting Machine

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Abstract: This study outlines the design of a very efficient, highly productive, cost- effective, ergonomic and environmentally friendly cocoa splitting machine that will be used by cocoa Farmers world - wide to increase and boost productivity and enhance the quality of coca products to the highest possible level devoid of any hazards, dangers or perils. This machine can be manufactured from locally available scraps and assembled and maintained at a relatively low cost. The knives which do the splitting are actuated by simple hydraulic mechanisms devoid any major stresses, forces or moments acting on them. These mechanisms are powered by simple low - powered lobe positive displacement or hydrostatic hydraulic pumps of power rating of 87.5 kW (65.625 Hp). The machine can be assembled and/or disassembled easily and quickly, and, therefore can be owned patronized by a group of cocoa farmers who can easily bear the low cost of maintenance of the already relative cheap machine.

Key words: Beans, cash crop, Cocoa, Cocoa Pods, foreign exchange earner, splitting machine

INTRODUCTION

Cocoa merits much economic significance in the producing countries the world over. Cocoa beans contain about 50% fat. It is useful in the production of lightning oil, ointments, candles, soaps and medicines (Opeke, 1987). Cocoa butter, made from the fat extracted from the beans, is a stable fat used in the production of cosmetics and pharmaceutical products. The beans are ground into powder for making beverages, chocolates, ice cream, soft drinks, cakes, biscuits, flavouring agents and other confectionaries. Cocoa husks can be hydrolysed to produce fermentable sugar. Cocoa cake is used as part of feed ingredients for poultry, pig, sheep, goat, cattle and fish after removing the theobramine (Adeyanju *et al*., 1975). The shell (pod) is a good source of potassium and can be used in the production of potash fertilizer, local soap, for biogas and particle boards (Adeyanju *et al*., 1975; Opeke, 1987). Considering all these benefits, cocoa production and processing must be mechanized and properly improved to aid profits and reduce losses. Hence the development of this concept of designing such a cocoa pod splitting machine, which has not been in existence in any part of the world.

World's Cocoa production: Nine countries are reputed to be the world's largest cocoa bean producers. Table 1 gives the production estimates for the 2006/7 seasons from the International Cocoa Organization. The percentage is the proportion of the world's total of 3.5 million tonnes for the relevant period.

Table 1: World's cocoa production for 2006/7 season

Country	Amount produced	World production (%)
Cote d'Ivore	1.3 million tonnes	37.4
Ghana	720 thousand tonnes	20.7
Indonesia	440 thousand tonnes	12.7
Cameroon	175 thousand tonnes	5.0
Nigeria	160 thousand tonnes	4.6
Brazil	155 thousand tonnes	4.5
Ecuador	118 thousand tonnes	3.4
Dominican Republic	47 thousand tonnes	1.4
Malaysia	30 thousand tonnes	0.9

Characteristics of varieties of Cocoa: There are mainly three varieties of cocoa, namely *amezonia*, *amelonado* and the hybrid of the two. The characteristics of these varieties of the cocoa are summarized in Table 2.

The Cocoa fruit: The cocoa fruit comprises of the pod or shell, beans or seeds, husk, placenta and mucilaginous pulp which contains a sweet juice referred to as *'sweating'*. Generally, cocoa pods are oval-shaped and vary in size. The length is normally between 20 and 32 cm. Its colour ranges from yellow or green to red or violet. The surface texture is warty and deep furrowed to nearly smooth in most cases. The husks appear appreciably in thickness. Each bean is surrounded by mucilaginous pulp. The number of beans per pod is usually between 30 and 40. Each bean consists of two convoluted cotyledons and is enclosed in the testa. The cotyledon has its colour varying from white to purple. Figure 1 shows the cocoa fruit, beans with the pulp, as well as the pod or the husk.

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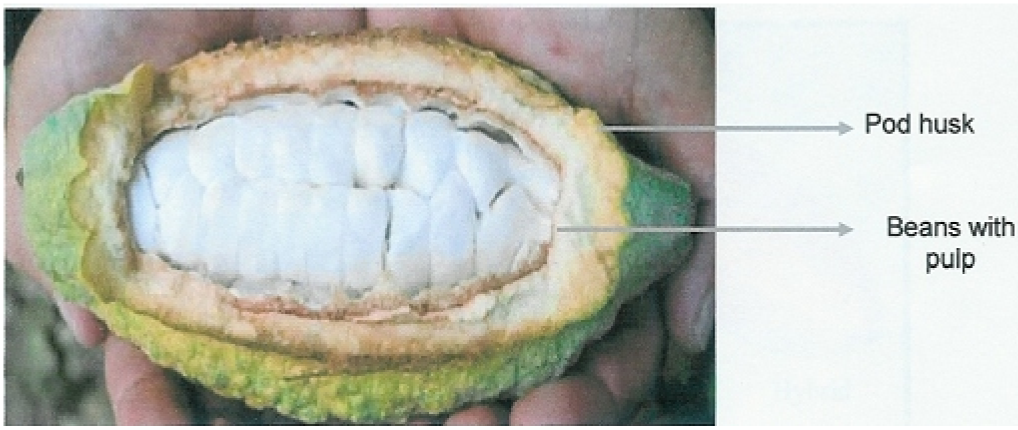

Fig. 1: A Cocoa fruit showing its beans

Table 2: Characteristics of varieties of cocoa

Characteristics	Criollo	Forestero	Trinitario
Texture of Pod Husk	Soft	Hard	Mostly hard and smooth
Colour of Pod Husk	Red	Green	Variable or light
No. of Beans per Pod	20-30	30 or more	40 or more
Colour of Cotyledon	White, ivory or very pale purple	Pale to deep purple	Variable dark purple. White beans rarely occur

Table 3: Average (Net) weight of the varieties of fresh Cocoa Pods

Variety of cocoa	Average weight of Cocoa Pods (Kg)
Amezonia	0.40
Amelonado	0.37
Hybrid	0.48

Table 4: Percentage weight of various components of wet Cocoa Pods

Variety of Cocoa	Components of wet Cocoa Pods (%)		
	Husk	Beans with Pulp	Placenta
Amezonia	70.00	27.00	3.00
Amelonado	74.51	24.93	0.56
Hybrid	66.67	30.21	3.12

Table 5: Percentage weight of various components of dry Cocoa Pods

Variety of Cocoa	Components of dry Cocoa Pods (%)		
	Husk	Beans	Placenta
Amezonia	19.00	7.50	0.50
Amelonado	14.29	10.08	0.57
Hybrid	10.83	15.21	0.56
Average weight	14.71	10.93	0.54

Analysis of the Cocoa Pod: The whole of the cocoa pod was analyzed to find out some parameters of interest including average weight of the types of cocoa and percentage weight of the varieties of wet and dry cocoa pods, in order to determine the amount of waste generated with these varieties of the cocoa during the preparation of the bean. The results are presented in Table 3 to 5.

A fieldwork undertaken on the cocoa farms revealed that among the main varieties of cocoa currently cultivated in Ghana, for example, the Amelonado (also known as Tetteh Quarshie) trees are the oldest, followed by Amezonia and the Hybrid, which is a cross between the first two. Results in Table 3 show that the pods of the Hybrid variety weigh more than the Amezonia and the Amelonado. For example, the average weight of the Hybrid is about 0.48 Kg while the Amezonia and the Amelonado weigh about 0.40 and 0.37 Kg, respectively. The reason may be due to the fact that the Hybrid variety has more beans per pod. However, the husk of the Hybrid variety weighs lesser than those of other two varieties. Furthermore, the Hybrid variety also continues bearing fruits throughout the year while the Amelonado and the Amezonia varieties bear fruits only in the peak season. It is therefore not surprising that farmers prefer cultivating the Hybrid to the others (Addy, 2000).

MATERIALS AND METHODS

- Visits were paid to the farms and farmers to ascertain the way cocoa pods are split manually using machetes, cutlasses and knives.
- Research has been carried out to study what work has been done so far in this area of mechanization of cocoa pod splitting. (Ademosun, 1993; Adewumi and Ayodele, 1997) This research was mainly conducted over the last decade in Ghana, Nigeria and Cote d'Ivoire of the West African sub-region. Figure 2 shows a map of Ghana indicating areas where cocoa is predominantly cultivated. In this respect it has been discovered that other researchers came out with cocoa pod breaking machines. (Audu *et al.*, 2004; Vejesit and Salohkhe, 2004; Adewumi *et al.*, 2006; Jabagun, 1965; Are and Gwynne, 1974; Faborode and Oladosun, 1991).
- Experiments have been conducted to determine to what extent the broken cocoa pod pieces and the cocoa beans that mix up during the breaking can be separated. (Adeyanju *et al.*, 1975)

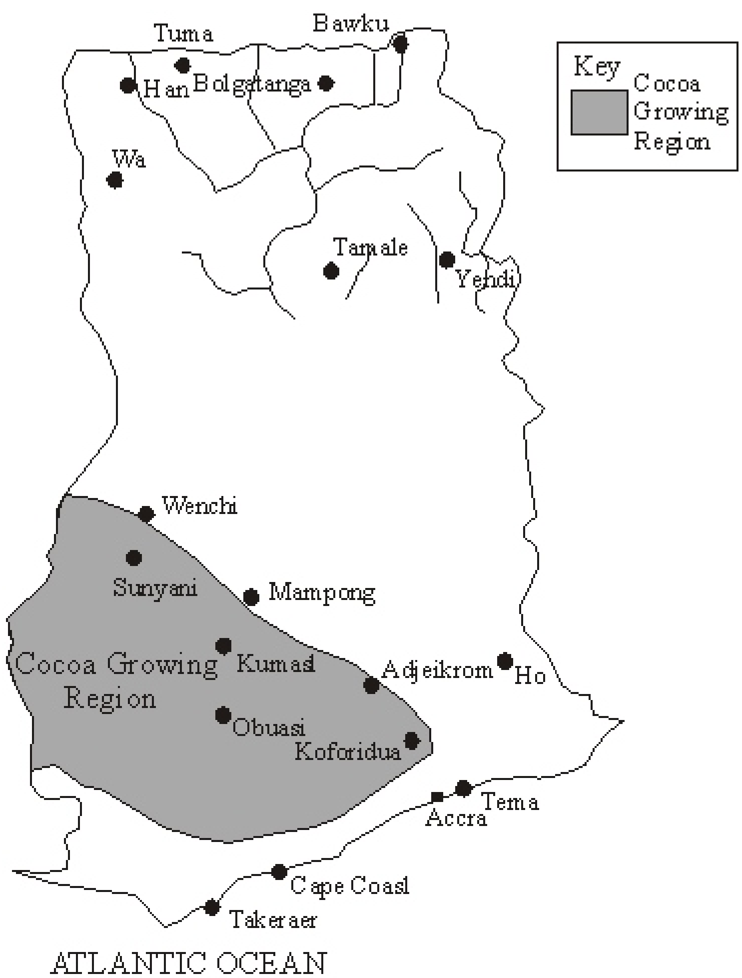

Fig. 2: Map of Ghana showing areas where cocoa is predominantly planted information on Cocoa Pod breaking machines

- The concept of the design of the cocoa pod splitting machine has been developed by designing or selecting each component of the entire machine.
- Plans are underway to have the machine manufactured and tested.

Information gathered from the Internet and other sources have it that there has been a cocoa breaking machine designed, fabricated and tested which is a simple, hand-operated and low cost impact type cocoa pod-breaking machine for the peasant farmers in the rural area where there is no electrical source of power. It has been claimed that the breaking of pods is a size reduction process, which aims at extracting the beans from the pod. The forces involved in breaking the cocoa pods could be compressive, impact or shearing forces depending on the type of machine and process (Audu *et al.*, 2004; Vejesit and Salohkhe, 2004; Adewumi *et al.*, 2006). The first cocoa pod breaker in Nigeria was constructed at the Cocoa Research Institute of Nigeria (CRIN) as reported in Jabagun (1965).

A similar machine built by Messers Christy and Norris Limited of England was tested at Cadbury Brothers Cocoa Plantation at Ikiliwindi, Cameroon (Are and Gwynne, 1974). Two people are required to operate the machine; one feeds the cocoa pods into the machine while the other collects the beans. It breaks the pod by means of a revolving ribbed wooden cone mounted vertically inside a ribbed cylindrical metal drum. The pods fed into the hopper move to the shelling section by gravity. The beans pass through the meshes into a collecting wooden box, while the shell fragments drop out at the open end of the rotary sieve (Adewumi, 1997a, b, 1998).

Another earlier machine, the Zinke machine, uses several rotary jaws or toothed rollers (Faborode and Oladosun, 1991). This machine has the problem of

Table 6: Results for the experiment carried out - variations weights and volumes of Cocoa Beans and their respective broken husks with drying time

Days	Husk		Beans	
	Weight (g)	Volume (mL)	Weight (g)	Volume (mL)
0	69.70	23	69.10	8.5
4	62.65	25	62.05	10
8	24.23	30	55.41	60
12	43.93	50	74.79	80
16	35.16	35	81.18	80

Table 7: Density variations between the Cocoa Beans and the respective Husk with drying time

Days	Density of the beans	Density of the Husk	Difference in density
0	8.107	3.025	5.062
4	6.206	2.506	3.7
8	0.924	0.808	0.116
12	0.934	0.879	0.055
16	1.015	1.005	0.01

crushing the husks further into tiny portions, which mix with the wet beans, and this poses a problem during separation. Faborode and Oladosun (1991) designed, fabricated and tested a machine to break cocoa pods and extract the wet beans (Allen *et al.*, 1998; Adewumi, 2000; Adewumi and Fatusin, 2006).

It consists of hopper, meter plate, hammer and reciprocating sieve .The hammer breaks the pods while the vibrating sieve separates the husk. The bean is collected through the discharge chute. Cocoa beans contain about 50% fat. It is useful in the production of lightning oil, ointments, candles, soaps and medicines (Opeke, 1987). Cocoa butter, made from the fat extracted from the beans, is a stable fat used in the production of cosmetics and pharmaceutical products. The beans are ground into powder for making beverages, chocolates, ice cream, soft drinks, cakes, biscuits, and delicate flavouring agents and other confectionaries. Cocoa husks can be hydrolysed to produce fermentable sugar. Cocoa cake is used as part of feed ingredients for poultry, pig, sheep, goat, cattle and fish after removing the theobramine (Adeyanju *et al.*, 1975). The shell (pod) is a good source of potassium and can be used in the production of potash fertilizer, local soap, for biogas and particle boards (Adeyanju *et al.*, 1975; Opeke, 1987). Considering all these benefits, cocoa production and processing must be mechanized and properly improved to aid profits and reduce losses. However these machines have not and cannot achieve the desired results as intended for the cocoa pod splitting machines as narrated above, and, world over the harvesting and processing of the very essential agricultural produce still remains a big problem and challenge (Bamgboye, 2003; Decabossage, 2006).

In spite of the above, design of a cocoa splitting machine as presented in this study was conceived to provide a more user - friendly machine that will take care of the problems and bottlenecks encountered on the existing cocoa pod breaking machines.

Experimental work on possible separation of broken-up Cocoa Pods from the Beans: The materials used in the experiment were a few (five) fresh ripen cocoa pods and water and the apparatus used to perform the experiment were a two-litre measuring cylinder, an electronic balance and a knife (Wills, 1981).

Procedure for the experiment: Sample preparation: Five fresh ripen cocoa pods were obtained from a nearby cocoa farm, weighed and each allowed drying for some number of days.

Method of the experiment carried out: One of the five cocoa pods was taken fresh and the other four, consecutively, after every four days, split open to separate the beans and the husk. The beans and the broken pieces of the pod (husk) were weighed separately to determine their respective masses, using an electronic balance. The respective volume of the samples of the beans and husk were determined using Archimedes principle. This was done as follows: A two-litre measuring cylinder was filled with water to about the 500 mL mark. Each sample was dropped in the cylinder containing water and the increase in volume noted and taken to be the volume of the sample. Thereafter, the densities of the respective samples were determined using the relations:

$$\text{Density of the pod} = \frac{\text{Mass of the pod}}{\text{Volume of the pod}}$$

$$\text{Density of the beans} = \frac{\text{Mass of the beans}}{\text{Volume of the beans}}$$

Determination of the differences in densities between the Cocoa Beans and the Husk: The results for the experiment carried out to determine the weights of the cocoa beans and their respective broken-pods (husk) between an interval of four days of drying time is presented in Table 6 and the density variations between the cocoa beans and the respective husk with the same drying time is also presented in Table 7. In Fig. 7 these results have been plotted.

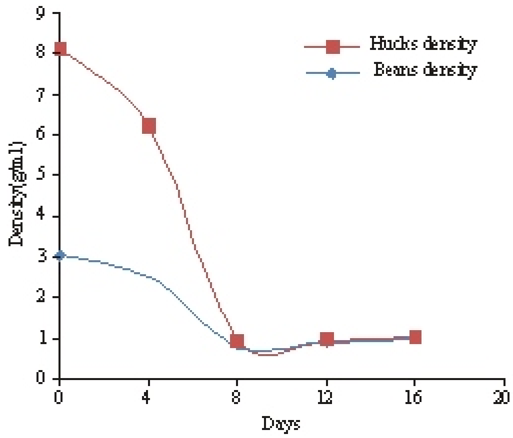

Fig. 3: Graphs showing the influence of drying on densities of Cocoa Beans and Husk

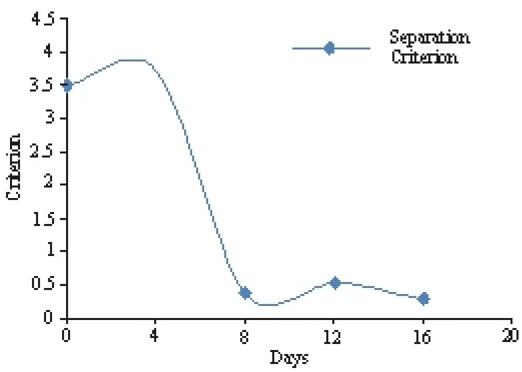

Fig. 4: Graph showing the effects of number of drying days on separation of the Cocoa Beans and the Husk

Discussion of the Results of the Experiment Carried out on the Cocoa Pod and Husks: The outcome or results of the experiment carried out on the possibility of separation of the broken-up pieces (husks) of the cocoa pods reveal a lot of uncertainties and discrepancies about the feasibility of the processes, even if the best method is adopted; these are as follows:

- The ripe cocoa pods were "split" not actually "broken" as suggested.
- The pods were so "split one at a time" but not all put together and broken" as proposed or premeditated.

The results obtained in the experiment do not follow any consistency: The weights of the husk and the beans on 'Day 0', (the first day when the ripe cocoa pods are fresh) are virtually the same. The same can be said about that of 'Day 4' (having dried the pods for four days). Figure 3 and 4 show, respectively graphs of the influence of drying on densities on cocoa beans and husks.

The result obtained on 'Day 8' is quite ironical if not ambiguous: the weights of husk sharply declined from 62.65 to 24.23 g, rose to 43.93 g and dropped to 35.16 g on 'Day 12' and 'Day 16' respectively. In the case of the cocoa beans the drop in weight to 55.41 g from 69.1 and 62.05 g of 'Day 0' and 'Day 4' respectively a difference about 7 g between these values shows some consistency but the sharp rise to 79.79 g on 'Day 12' and at 81.18 g is some phenomenon yet to be understood.

Similar thing can be said about the volumes: a sharp increase in volume from 10 mL for 'Day 4' (giving a very high density of the beans on that day) to 60 mL (exhibiting a sharp drop in density for 'Day 8' is inexplicable.

In the case of the husk the sharp increase in volume from 30 mL of 'Day 8' to 50 mL on 'Day 12' and dropping again to 35 mL on 'Day 16' thus making the densities of the husk and that of the beans on the same 'Day 16' and 'Day 12' virtually a "unity" (1).

These analyses alone prove that separation of the husk and the cocoa beans when the ripe cocoa pods are broken by such and only known method is not feasible and therefore cannot be recommended for anybody especially the farmers or manufacturers in any circumstance, let alone for commercial purposes or large scale production for such an important crop as cocoa which is undoubtedly the most useful cash crop of all the agricultural produce the world over.

Moreover, if the separation is something to drive home at all, then according to the results obtained and presented graphically, the breaking of the cocoa pods and the purported separation can only be done around 'Day 5' before and after which the exercise is not possible or feasible. For that reason a separation experiment is deemed to be carried out for that particular day, but it can be predicted that no desirable results will be obtained.

Another important feature about the method of the breaking of cocoa pods that needs to be noted is that if the pods are to be broken en masse by which ever method, there is the high likelihood that most of the cocoa beans would be smashed together with the husk (broken pieces of the pods) which will definitely assume amorphous shapes and having the cocoa beans (whether smashed or not) stuck to them, and this will compound and complicate the separation process.

Development of the concept of the design of the Cocoa Pod splitting machine: A fieldwork was carried out by way of paying visits to the cocoa farms and farmers in the Wassa West District in the Western Region of Ghana to ascertain how the cocoa is harvested: plucking and splitting of the ripe cocoa pods manually. Figure 5 shows farmers (sitting) and Fig. 6 shows a farmer (bending) splitting cocoa pods with knives and cutlasses.

Fig. 5: Farmers (Sitting) Splitting Cocoa Pods with Cutlasses and Knives

Fig. 6: A Farmer (Standing) Splitting Cocoa Pods with a Knife (http/www.etawu.com/HTML/ Cocoa/CcoaTree/ CocoaVillage)

Fig. 7: Getting the Cocoa Beans out of the Cocoa Pod

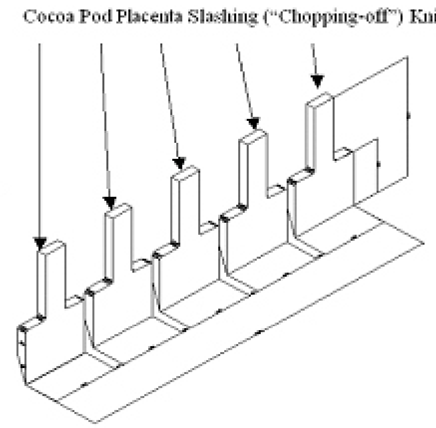

Fig. 8: Array of five tentative Cocoa Pod placenta slashing ("chopping - off") knives (with dimensions)

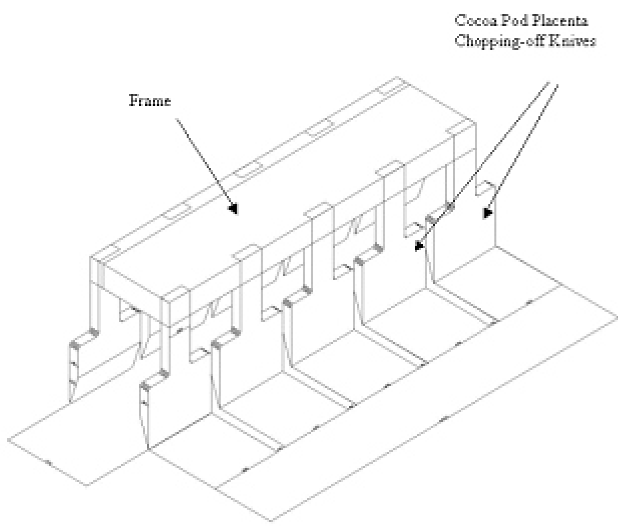

Fig. 9: Assembly of the Cocoa Pod Placenta Slashing ("Chopping-off") Knives with the Frame

The components of the cocoa pod spitting machine, their functions and operations have been designed on the basis of the information gathered on the splitting of the cocoa pod manually.

After plucking, the pods are allowed to stay or cure for about five days before they are transferred to the splitting machine. This will enable the beans to free themselves and ease their separation from the pods after the splitting

Components and operation of the Cocoa Pod splitting machine: The machine comprises a rectangular container (1) constructed with simple material of light plywood or thin galvanized plates. The tentative size of the container is 4 m wide by 6 m long and 2 m high. The container is partitioned into five (5) tentative compartments (2), the width of which is just about 2 cm larger than the average diameter of the cross-section of the middle part of the pods. The height of the partitions is about 15 cm lower than that of the container. The container is also inclined at about 30º to the horizontal. This is so because when the cocoa pods are dumped into the container they should find their ways into the various partitions and align themselves in these partitions. They then move gradually under gravity along the inclined paths into corresponding cavities (3) placed just below the level of that end of the container towards which the pods move.

To facilitate this downward movement of the cocoa pods a light vibration mechanism is attached to the container to give it intermittent vibrations. The inside of these cavities are provided with some sharp projections to hold the cocoa pods in position and in check. The width of the frame of the cavities is shorter than the full length of the pods. This is so because both ends of the pods, where the placentas of the cocoa pods are located, will be projected outwards along these cavities. At that position

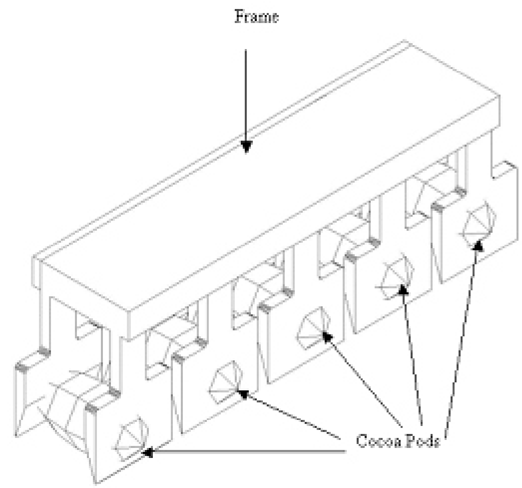

Fig. 10: Assembly of the Cocoa Pod slashing ("chopping-off") knives ready to "chop-off" the ends of the Cocoa Pods

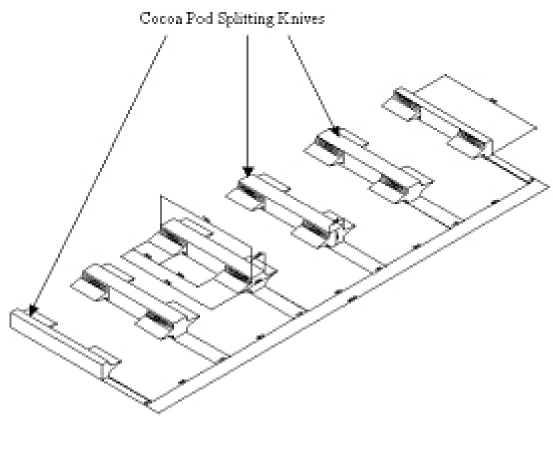

Fig. 11: Array of Cocoa Pod splitting knives (with dimensions)

the placentas of the cocoa pods, by the action of the hydraulic mechanism (4), are slashed simultaneously by a pair of knives (7) fixed at the positions at the end of the pods where the placentas are located. Figure 8 shows an array of five tentative cocoa pod placenta slashing (chopping - off) knives, and Fig. 9 shows a complete assembly of these knives with the frame. Also Fig. 10 shows the knives "chopping - off" the ends of the cocoa pods.

The slashed placentas fall into another container (6) placed below these cavities, the longitudinal ends of which are left open to let the slashed placentas drop. After slashing the placentas the knives will move up from the pods by means of the hydraulic mechanism (4), acting in the opposite direction of that of the slashing. By the action of another hydraulic mechanism (5) the pods are now split open along the sides by another pair of knives (8) (one on each side of the pod). Figure 12 shows the cocoa pod splitting knives with the frame. After the splitting sideways the bottom parts of the half-split pods are turned downward through an obtuse angle (not less than 90º), by means of spring mechanism (hidden) for the beans to drop by gravity into another container (9), linked to the other container (6) by a middle container (10) to serve as a buffer and which has been shifted by a lever mechanism (11) to the position formerly occupied by the previous container (6), while the other half parts are held in position by the splitting knives. The empty half pieces of the cocoa pods are then brought together again by means of the same spring mechanism (that turned them through the obtuse angle) and are also let to drop into container (6), which is now pushed back to occupy its former position, from where the container (9) for the beans has just withdrawn. The container (6) will remain at this

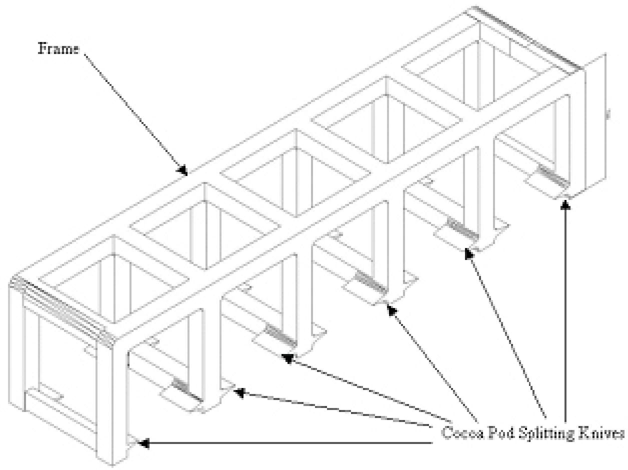

Fig. 12: Cocoa Pod Splitting Knives (with the Frame)

position to collect another set of the slashed placentas before withdrawing for the container (9) to also move in again to collect another set of the cocoa beans. These two containers, (6) and (9) are linked together in such a way that as one is withdrawing from the position the other comes to occupy the same position for the alternate collection of the cocoa beans and the empty pods to repeat the process. The empty cocoa pods are collected and used as raw material for generation of power, for the production of other byproducts of cocoa, and the soot of the burnt husks can be used for the preparation of soap.

Design of the Cocoa Pods slashing ("chopping-off") knives:

Material of the cocoa pods chopping - off knives: Chromium steels containing 12 to 14% chromium and 0.12 to 0.35% carbon, which are first stainless steels, are the types of material selected for the chopping-off knives. Since these steels possess martensitic structure, they are called martensitic stainless steels. These steels are magnetic and may be hardened by suitable heat treatment and the hardness obtainable depends upon the carbon content. These steels can be easily welded and machined. When formability softness etc., are required in fabrication, steel having 0.12% maximum carbon is often used in soft condition. With increasing carbon, it is possible by hardening and tempering to obtain tensile strength in the range of 600 to 900 N/mm^2, combined with reasonable toughness and ductility. In this condition, these steels find many useful general applications where corrosion resistance is required. Also, with high carbon range in the hardened and lightly tempered condition, tensile strength of about 1600 N/mm^2 may be developed with lowered ductility. These steels may be used where the corrosion conditions are not too severe, such as for hydraulic, steam and oil pumps, valves and other engineering components. However, these steels are not suitable for shafts and parts working in contact with non-ferrous metals (i.e., brass, bronze or gun metal bearings) and with graphite packings, because electrolytic corrosion is likely to occur. After hardening and light tempering, these steels develop good cutting properties. Therefore, they are used for cutlery, springs and surgical and dental instruments (Khurmi and Gupta, 2005).

Size and shape of the chopping - off knives of the cocoa pods: All the pair of the tentative five chopping - off knives of the machine are made integral each of which is perpendicular to the axis of revolution of the pods. The sizes are obvious the same and have a width about 20 mm larger than the average diameter of the cross section of the ends of the pods they are supposed to strike in to chop them off completely. The length of each of these knives is 600 mm and a thickness of 80 mm. A gap of 80 mm separates these knives in the longitudinal array, having a total length of 3320 mm. The gap between the pair of the longitudinally arrayed chopping - knives are 630 mm corresponding to the length of the cocoa. The cutting edge of the knives is formed from a right-angled triangle with the hypotenuse and the ordinate converging at a very acute angle about 18^o to make the cutting edge very sharp. Since no tear and wear of the knives is anticipated they can hardly become blunt and for that matter the knives can work for a decade and can be sharpened if need be.

Design of the Cocoa Pod splitting knives:

- Material for the cocoa pod splitting knives: The same as that for the chopping - off knives.
- Size and shape of the cocoa pod splitting knives.

Though the only significant force acting on the set of the splitting knives is longitudinal and effected by a hydraulic mechanism (8) devoid of any stresses or torsional or bending moments, the sharp 90º angle at where the blade itself connects the frame of the splitting knives is filleted with a radius of about 20 mm to forestall or avoid any unforeseeable stresses that might be induced at the critical lines or points of the splitting knives. Each of these knives is actually made of two identical blades, 200 mm in length, with a gap of 300 mm, bringing its total length to 700 mm. These blades are made integral with a frame of 100 mm in cross-section. Tentatively the knives are six in a longitudinal array of a gap of 500 mm in between them. The middle four of the splitting knives have mirror symmetry of the knives on the opposite sides: this means the left hand - side of a knife will split the right – hand side of a pod while the right-hand side of the same knife will split the left-hand side of another pod (Fig. 11). The longitudinal length of these integrated blades is 300 mm, bringing the total length of the array of these knives to 3000 mm. Figure 12 shows the cocoa pod splitting knives made integral with the frame. The shape and the sizes of these similar splitting knives are so determined that they not only split the cocoa pods open into two halves but also hold the upper halves of the split pods in position to enable the cocoa beans to drop by gravity into the container placed beneath it (as described above) having let the lower split halves of the pods to tilt at an obtuse angle. After so letting the beans drop (into the container (9)), the lower half-split pods are made to return to their original position by means of a spring mechanism (hidden). The splitting knives are then withdrawn and the half- split pods pushed forward by means of another set of spring mechanism (also hidden) to drop into container (6) (as also described), which must have been moved to its initial position where the placentas were collected), by the lever mechanism (11).

In the course of the splitting of the cocoa pods, there is the tendency that a few of the cocoa beans, especially those near the middle portion of the pods could be cut by the splitting knives since they are intended to j sink enough into the pods to cut through the thickness of the pod; but this would not pose any problem.

Design of the cavities holding the Cocoa Pods:

Material of the cavities holding the Cocoa Pods: These cavities are cast from aluminium (because of its lightness) to allow some metallic thorns, just about 5 mm longer than the thickness of the pods to hold the pods in position in the course of the splitting of the cocoa pods and especially during the tilting of the lower half-split pods to give way to the beans to drop by gravity into the container placed beneath them. The prickling of the pods is actuated or effected by another spring mechanism (also hidden) (Khurmi and Gupta, 2005).

Size and shape of the cavities holding the cocoa pods: The cavities are designed to take the size and shape of that of half of the average of the pods.

The prime mover for the Cocoa splitting machine: The simple hydraulic and spring mechanisms of the machine are driven by electric power from a simple portable generator whose average consumption of fuel is between 1 gallon (4.5 L) to 2 gallons (9 L), depending on the length of time the machine is supposed to work.

Selection of the hydraulic mechanisms for the Cocoa Pod splitting machine: A lobe, positive displacement or hydrostatic hydraulic pump, the cross-sectional view of which is shown in Fig. 13 has been selected for this project because of the following reasons:

Hydraulic pumps are generally driven at constant speed by a three phase AC induction motor rotating at 1500 rpm in the UK (with a 50 Hz supply) and at 1200 or 1800 rpm in the a 60 Hz supply) or with a simple portable generator or suitable internal combustion (IC) engine. Often pump and motor (requiring some form of a starter, are supplied as one combined unit (Parr, 2005).

Leakages on the pump are minimal whether the pump stops or not and, therefore, exit pressure is maintained.

The pump delivers a fixed volume of fluid from inlet to outlet each cycle regardless of pressure at the outlet port. As a piston pump, it has no inherent maximum pressure determined by pump leakage: if it drives into a dead end load with no return route (as can easily occur in an inactive hydraulic system with all valves closed) the pressure rises continuously with each pump stroke until either piping or the pipe itself fails.

Allowance is made for high efficiency of about 95% for the pump by specifying its capacity and/or choosing a suitable drive motor by determining its power rating). This is done as follows:

Maximum working pressure (rating) of the pump = 175 bar

Maximum flow (rate) through the pump = 300 l/min

The electric motor power required to drive the pump is determined by the pump capacity and working press

This is given by the expression:

$$Power = \frac{work}{time} = \frac{force \times distance}{time}$$

$$Power = \frac{P \times A \times d}{T}$$ But $A \times d / T$ is flow rate, hence

$$Power = pressure \times flowrate$$

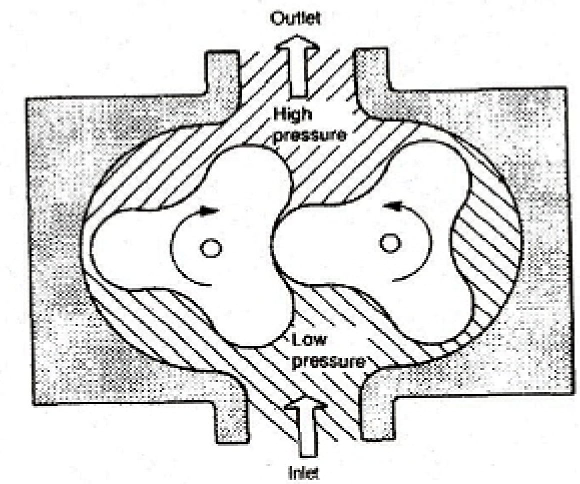

Fig. 13: A cross-sectional view through the Lobe Pump (Source: Parr, 2005)

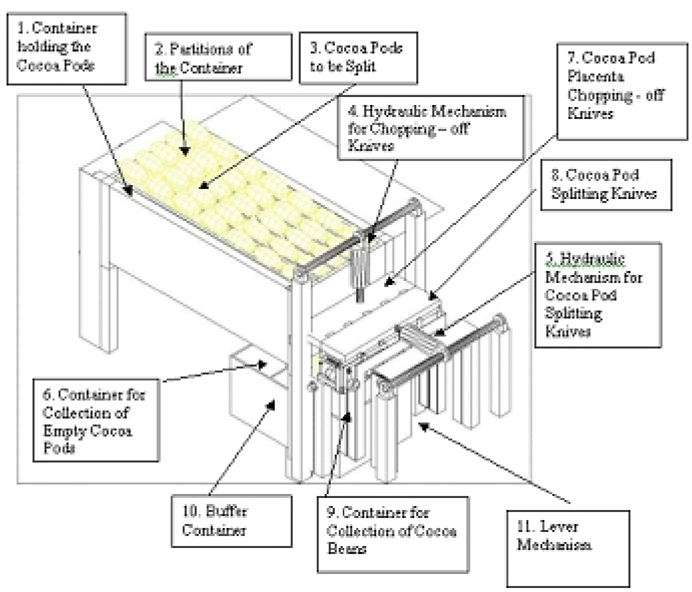

Fig. 14: The Cocoa Pod splitting machine

The pump will force fluid along a pipe of area *A* against a pressure *P*, moving the fluid a distance *d* in time *T*. The force is *PA*, which, when substituted in the above expression, gives:

$$Power = \frac{P \times A \times d}{T} \; But \; A \times d / T$$ is flow rate, hence

Power = Pressure x flow rate

The expression above is specified in impractical SI units (pressure in Pascal, time in seconds, and flow in cubic metres). We may adapt the expression to use more practical units (pressure in bar, flow rate in L/min) with the expression:

$$Power = \frac{Pressure \times flow\ rate}{600} = \frac{175 \times 300}{600} = 87.5 kW$$

For Imperial systems (pressure in psig, flow rate in gallons per mm), the expression becomes:

$$Power = \frac{pressure \times flow\ rate}{1915} = \frac{175 x 14.5 \times 300 \times 0.2200}{1915} = 87.5 kW$$

For fully Imperial systems, motor power in horsepower can be found from:

Horsepower = 0.75 x power in kW
= 0.75 x 87.5 = 65.625 Hp

Table 8: Estimated cost of the Cocoa Pod splitting machine

No.	Component	Quantity	Estimated unitcost ($)	Total cost ($)
1	Frame of the machine	1	250	250
2	Cocoa Pods and Beans collecting containers	3	12	36
3	Cocoa Beans placenta chopping-off knives	1	80	80
4	Cocoa Pod splitting knives	1	60	60
5	Hydraulic system	2	180	360
6	Prime mover	1	200	200
7	Miscellaneous			200
	Total			1186

With these specifications or power ratings the lobe positive displacement or hydrostatic hydraulic pump has been selected to actuate the knives for the cutting off of the placentas and subsequent splitting of the cocoa pods as described above.

Estimated cost of the Cocoa Pod splitting machine: The total estimated cost of the cocoa splitting machine the assembly of the components of which is shown in Fig. 14 was been arrived at after estimating the cost of each of the major components of the machine. This comprises the cost of the material of which the component is made, the cost of its construction or fabrication and other items necessary to make the component complete. These components are the cocoa pods and the beans/collecting containers, the cocoa beans placenta chopping-off knives, and the cocoa pod splitting knives. The costs of the other components as the prime mover and the hydraulic systems, consisting of the selected pumps and their accessories have been gotten in the market. A miscellaneous amount of about 20% of the total cost so far has been added to take care of the contingencies. These values have been summarized in the Table 8.

RESULTS AND DISCUSSION

The design concept, of a very efficient, highly productive, cost-effective. ergonomic and environmentally friendly cocoa pod splitting machine has been developed. This has been a result disproving, through conduction of experiments, the claims and assertions of some earlier designers and researchers who worked on a cocoa pod breaking machines. This research work on a cocoa pod splitting machine brought out most of the lapsed ad inefficiencies embedded in the concept of the cocoa pod breaking machines paramount among them is the difficulties inevitably encountered in the separation of the coco beans from the broken pieces of cocoa husks, which can be further used as by - products for soap making, in particular, and other allied products in general. Other advantages the cocoa pod splitting machine will have over the cocoa pod breaking machines are:

- Absence of stresses, forces and moments on the components of the cocoa pod splitting machine such as the knives during the cutting and splitting of the cocoa pods as these knives are made integral with the frames which are moved by hydraulic mechanisms. These frames do not rotate on any bearings and the sharp bends of the knives and the frames are "rounded - off" with smooth fillets.
- The machine itself can be easily and quickly mounted or assembled and/or disassembled. This situation aids its movement from one spot or place, and for that matter, from one form to the other. This implies that a machine can be owned, used, maintained and patronized by a group of cocoa farmers who can easily bear the cost of the machine as well as the cost of running and maintenance.
- The machine is rum on a simple two-stroke internal combustion (IC) engine with very low fuel consumption.

Observations: The following observations, among many others, were made during this research work:

A lot of the cocoa farmers contacted to gather information about the idea of having such a cocoa pod splitting machine in place were enthused about the conception of this idea, since it will go a long way of cutting down the cost they incur, the intensive labour they endure, the risk and danger they are exposed to in the process of splitting the cocoa pods during harvest time.

They also realized that productivity will also be immensely increased with the use of the machine in a more conducive environment.

Manufacture, assembly and disassembly, operation, maintenance of the machine will be very easy and cost - effective.

Recovery of by -products of the cocoa beans like the empty cocoa pods or husks, which are also useful materials for other purposes like preparation of soda, an essential ingredient in the production of soap and other products, will be greatly enhanced.

CONCLUSION

This study has intensively and extensively dilated on the dire need to have an efficient, cost-effective, highly ergonomic, environmentally friendly cocoa splitting machine that will be used by cocoa farmers to increase and boost productivity and enhance the quality of cocoa products to the highest possible level, devoid of any hazards, dangers, perils or risks.

RECOMMENDATION

We strongly recommend the manufacture of this cocoa pod splitting machine to manufacturers, industrialists, entrepreneurs and all the other stake holders, with the believe that they will reap the full benefit for the purpose for which the machine has been designed.

We also recommend any modifications to any part(s) of the machine by any designer, manufacturer, industrialist, entrepreneur or any stake holder, if the need be.

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