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Development of Improved Coffee Bean Depulping Machine

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***Abstract* – Coffee, an agricultural commodity with such tremendous growth in supply and demand has a lot of elements which affects its final quality. These elements vary from the crop, variety, climate, cultivation, harvest and post-harvest operations. One of the major post-harvest operations which impact on the quality of the coffee is depulping. This work highlights the design, fabrication and working process of a coffee bean depulping machine, developed at the National Center for Agricultural Mechanization (NCAM) which was improved from an existing machine. The coffee depulping machine was operated by a prime mover running at 800 rpm after being soaked for two hours. Performance evaluation revealed that the machine had an average depulping efficiency of 96.6% with machine throughput of 4.67 kg/sec. More importantly is the fact that the depulped coffee beans was not crushed by the machine which was an improvement over the initial prototype developed.**

***Keywords* – Coffee Beans, Berry, Depulping Efficiency and Machine Capacity.**

I. INTRODUCTION

The popularly known Coffee is a brewed drink which is prepared from roasted seeds of coffee beans that are gotten from berries of a particular type of coffea specie. The coffea species which coffee is extracted from is native to mainly Sudan and Ethiopia (in Africa), Mauritius, Comoros, Madagascar and the Indian Ocean. Coffee plants grow well within this area, which lies between the tropic of Cancer and the tropic of Capricorn, usually termed the bean belt or the coffee belt [1]. For many years, coffee, considered to be the world's most valuable export after rice, has remained one of the most acceptable and consumed food beverages with a huge health advantage.

Coffee is now being produced in well over seventy countries, most especially in many regions of Asia that are in close proximity to the equator, Africa, Indian subcontinent and Americas. The two most common grown specie is the C. Arabica and C. Robusta [2]. Arabica coffee (C. Arabica) is more accepted than the Robusta coffee (C. Robusta) amongst the species. Compared to the Arabica coffee, the Robusta coffee has less flavor and is bitterer but has a better body. As a result, the Arabica coffee is preferred worldwide because about three-quarter of the world coffee farmers cultivate this specie. However, the Robusta coffee has 50% more caffeine than the Arabica coffee, hence it is used as a cheaper alternative to Arabica coffee in a lot of commercial blends. [3].

In Nigeria, the profit realized from coffee farming was below the minimum requirement for a basic livelihood in Nigeria, as the farming experience of the farmers for the cultivation of coffee was low [4]. In recent times, coffee production has been on the increase and the government is putting in place policies that would assist coffee farmers' access to skills, labor, machineries and capital in order to improve the cultivation of coffee bean for commercial purposes in Nigeria. This inputs support to farmers, if followed through, is expected to arouse

their interest and increase the production of coffee bean in Nigeria. Though the coffee production in Nigeria fluctuated between year 1968 and 2017 but increased in recent years with 1,556 tonnes in the year 2017.

Coffee is cultivated in many states across Nigeria but Kogi state stands out as a major producer of C. Robusta specie coffee in the entire Country. Coffee berries undergo several processes before it becomes the familiar roasted coffee which is widely consumed as a beverage. The production of coffee in the state has provided jobs, source of income and development to the cultivating communities. The coffee berries are traditionally selectively plucked by hand which is laborious. Harvesting the best coffee involves the selection of only the berries at the peak of ripeness as against strip picking where all the coffee berries are harvested simultaneously regardless of ripeness by machine or human workers. The later would then involve additional work of separation for it to meet international standard [4].

Moreover, the coffee farmers in Nigeria use the dry method of processing for their coffee beans, as it provides coffee which is easily milled and stored. When dried, the dried berries stay as long as four years in storage in as much as the shells are still intact. In addition, dry processing is the only method known as it is less tedious as the farmers have little information on modern coffee processing technologies. Hence, the low value of coffee beans which is determined by the buyers which are usually agents. This raises serious concerns on the method of the post-harvest operations carried out on the coffee beans which is rarely practiced in Nigeria [5]. In Other developed and developing countries, coffee bean undergoes several procedures before they become the popular commercial beverage. After harvesting is done, coffee is processed by either the dry process or the wet process. The former is a much simpler method which requires much labor and the latter includes the use of fermentation to produce a mild coffee [6].

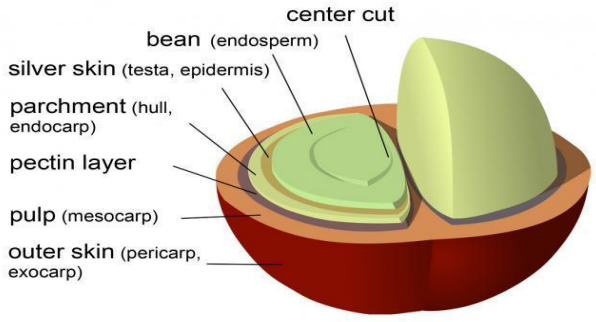

Fig. 1. Structure of the Coffee bean.

It was reported that the wet processing method requires processing equipment (for the initial cleaning classification-pulping-fermentation-washing and drying) [7], with abundant supply of clean water and ripe fruits only. The berries are loaded into a tank that has a syphon to transport the heavy berries to the depulper which provides better products of higher quality. This system performs several functions of separating floating berries from non-floating berries, eliminating sticks, stones and sand, and removing leaves/twigs, etc.

The National Coffee Association removes pulp from coffee cherry by drying the bean with only the parchment skin left on. The berries are passed through a pulping machine which separates the skin and the pulp, as they pass through water channels, the bean is separated by its weight. The beans are then moved into large tanks after separation to ferment within 12 to 48 hours to remove the slimy layer of parenchyma which is still left on it, then rinsed off and prepared for drying [8].

The concluding processes include the removal of the final layer of dry skin and the fruit from the dried coffee. This step is called wet milling as reported by [9]. In wet milling, the first step is the removal of the fruit from the brittle membrane of skin commonly referred to as hulling. Hulling operation is carried out by using machines which may vary from simple millstones to more refined machine that gently peel the exocarp from the coffee fruits [8].

1.1. *Objectives*

The aim of this research is to develop and fabricate a coffee bean depulping machine based on an already existing machine with a better performance output than the previous design.

1.2. *Justification*

The National Centre for Agricultural Mechanization, (NCAM), developed a coffee depulper, however, it was discovered that the depulping worm crushes the coffee beans while depulping thereby reducing the quality of the coffee bean. Thus, the need to review the design and re-evaluate the improved depulping coffee machine.

II. METHODOLOGY

2.1. *Description of the Depulping Machine*

The coffee bean depulping machine kiln was designed and constructed using stainless steel. Its frame was fabricated using 40 mm angled iron for its stand and that of the prime mover. It consists of a depulping chamber which is fed from a hopper measuring 220 x 220 at the top and 80 x 80 at the bottom which has been designed to compensate for its flow rate. The dehulling chamber has a depulping/conveying shaft which depulps the coffee bean while driving it along the walls of the depulping chamber. Immediately after the conveying shaft are four (4) horizontal bars which does the depulping operation while the depulped coffee and the chaff drop through the output hopper by gravitational force. The machine is operated by a 5 hp petrol engine.

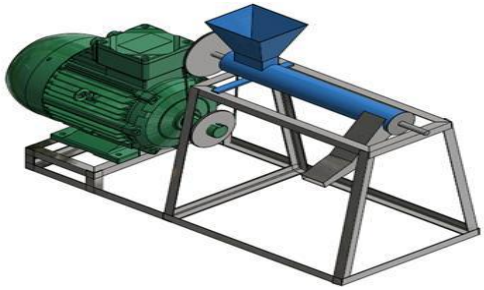

Fig. 1. Isometric design view of coffee depulping machine.

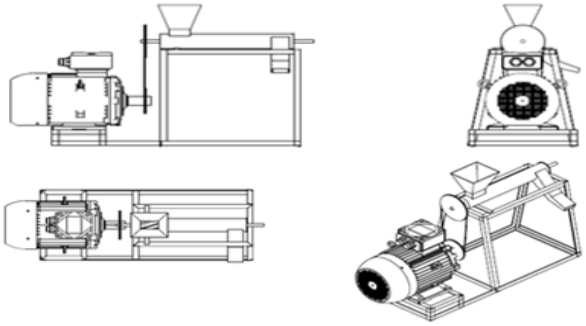

Fig. 2. Orthographic view of coffee depulping machine.

2.2. *Machine Evaluation*

The fresh coffee beans that were sourced locally from Cocoa Research Institute of Nigeria (CRIN), Ibadan, Oyo State. Sorting was done to ensure that only healthy and stone free berries were used for the evaluation. The berries used were soaked in water for two hours and divided and weighed into three parts of 5 kg each. This was done to aid the depulping process of the berries. The machine throughput capacity, (M_{tpc}), measured in kg/sec was obtained by expressing the mass of both depulped and undepulped coffee bean per unit time.

$$M_{tpc} = \frac{p_1 + p_2}{t} \quad (1)$$

Where,

M_{tpc} = Machine throughput capacity.

P_1 = Weight of depulped coffee seeds.

P_2 = Weight of undepulped coffee seeds.

t = Time taken to depulp.

The performance index which is the determination of the overall performance of the coffee de-pulping machine is calculated by finding the average depulping machine using the formula:

$$\eta_p = \frac{p_1}{p_1 + p_2} \times 100\% \quad (2)$$

Where,

η_p = Machine throughput capacity.

P_1 = Weight of depulped coffee seeds.

P_2 = Weight of undepulped coffee seeds.

2.3. *Depulping Process*

The machine was operated without load at a speed of 800 rpm for a period of five (5) minutes to allow for smooth operation without interference of moving part. The speed was measured using a tachometer. The soaked berries were then fed into the machine through the hopper while time taken to depulp each batch was taken using a stop watch. Water was added to the process while depulping so as to reduce the friction between the depulping barrel and the housing. The water cools down the heat generated through the friction that occurred between the barrel and the depulping shaft. The fruits were then separated and strained and the weight of the chaff and seed was weighed and recorded. The weight of un-depulped coffee seed was measured in order to estimate the percentage efficiency of the depulper.

Fig. 3. Isometric view of depulping bar showing spiral and horizontal groove.

III. Results and Discussion

The results derived from the design calculations showed that the required force, torque and power for the machine was 210N, 31.5Nm and 2639.7W respectively. The machine throughput capacity was determined to be 4.67 kg/sec. The depulping machine was evaluated using freshly harvested coffee beans and the result of the depulping operation is as presented in the table below.

Table 1.

Sample	Weight of Undepulped Berry (kg)	Time taken to Depulp (sec)	Seed weight (kg)	Chaff weight (kg)	Undepulped berries (kg)
1	5.0	30.1	4.5	0.3	0.2
2	5.0	26.8	4.6	0.3	0.1
3	5.0	26.2	4.5	0.3	0.2
4	5.0	25.0	4.6	0.2	0.2
5	5.0	25.5	4.7	0.2	0.1
Total	25.0	133.6	22.9	1.3	0.8

The mass of coffee berry produced from 25 kg of coffee cherry was 22.9 kg in 133.6 seconds and the total chaff produced was 1.3kg leaving a total of 0.8kg of undepulped berries. From the analysis, it revealed that the machine was very efficient and depulped without crushing the coffee beans. The efficiency varies between 95.7 and 97.9 percent thus giving an average efficiency of 96.6 %.

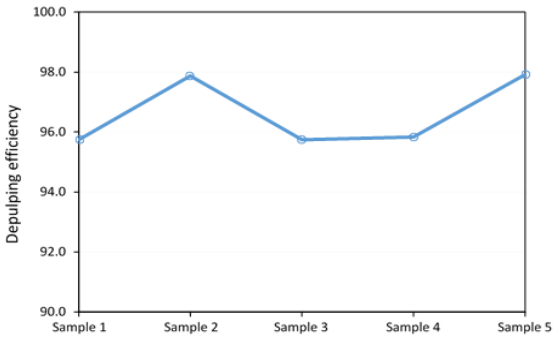

Fig. 4. Graph of depulping machine efficiency.

It can be deduced from the performance evaluation result that the machine is very suitable for the depulping of fresh coffee beans as there was no crushing with high performance index and high depulping efficiency.

IV. Conclusion

A coffee depulping machine was developed and tested. The machine has proven to be efficient, having an average depulping efficiency of 96.6% at a throughput of 4.67 kg/sec. The machine is portable and easy to maintain, operate and repair as and when required. The depulping rate of the machine proved to be better than the previous design and had improvements made to its depulping screw. The depulping chamber is now replaced with screw and horizontal bars at the end of the conveyor rather than the initial whole screw design, which was found to be crushing the beans against the end wall of the depulping chamber. The quality of the bean also improved with less impurity coming from the rust of the mild steel as in the previous design.

V. RECOMMENDATION

Effort should be geared towards automation of the green coffee processing machines in order to eliminate drudgery and contamination of the coffee so as to meet international standard.

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