



## Full Length Research Paper

# Performance evaluation of NCAM developed coffee depulping machine

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## Abstract

Despite the fact that Coffee (*Coffea arabica*) is one of the most consumed beverages in the world and it is second largest traded commodity after petroleum (Mussato *et al.*, 2011). It is highly economical but its production in Nigeria is fast declining as a result of inadequate processing technologies necessary to help eliminate the high level of drudgery associated with manual dehulling and polishing of coffee beans (Gbabo *et al.*, 2013). For the purpose of eliminating the drudgery, increasing both the quantity and quality of coffee beans production, the National Centre for Agricultural Mechanization (NCAM) Ilorin designed and developed a machine for depulping freshly harvested coffee and a machine for polishing dried coffee beans.

**Keywords:** Coffee, Performance, Depulping and Efficiency.

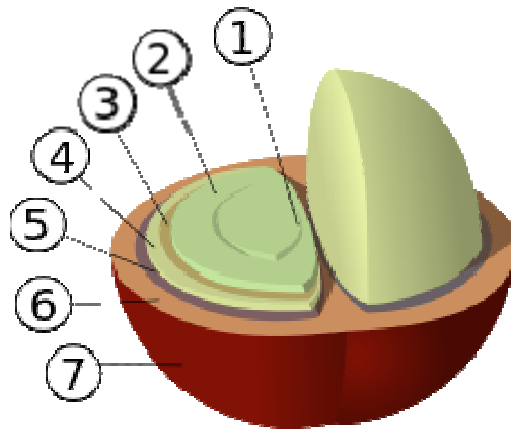
## INTRODUCTION

Coffee (*Coffea arabica*) is one of the most consumed beverages in the world and it is the second largest traded commodity after petroleum (Mussato *et al.*, 2011). It is the major crop export in Kenya and highly economical but its production in Nigeria is fast declining as a result of inadequate processing technologies necessary to help eliminate the high level of drudgery associated with manual dehulling and polishing of coffee beans (Gbabo *et al.*, 2013). Coffee plant is reported to be native to Africa with its origin traced Ethiopia, while Robusta coffee was believed to come from Central to West Africa (Williams, 2008; Opeke, 2005; and Ngussie and Dererse, 2007).

According to Williams, (1998) the preparation and cultivation of coffee was first carried out by the Arabs and was later introduced to most parts of Africa during the colonial era. It was reported that the annual production of African coffee in the last 10 years fluctuated between 14 and 19 million (60kg) bags, with an average of about 16 million bags; which has since fallen considerably due to varied factors (Surendra, 2002). In Nigeria, *C. arabica* is grown mainly by small scale farmers in the highland area of Mambilla plateau in Taraba State, as well as

Nasarawa, Abia, Kogi, Kwara, Ondo, and Ogun States (Williams, 2008); and it used to be one of the major cash crops constituting the backbone of Nigerian economy before the emergence and predominance of oil. Trends have shown decline in coffee production over the period between 1960 and 2008 in Nigeria; from 18,000 bags [of 60kg bag] in 1961 to 50,000 bags in 2008, with the highest production level of 95,000 bags in 1964, 1988 and 1990 (Williams, 2008). Over 80% of coffee from developing countries, particularly Nigeria, is produced by small scale farmers who lack adequate technical education and are faced with low market price leading to poor management, poor productivity and abandoned farms (Williams, 1989; Mutua, 2000; and Agbongiarhuoyi *et al.*, 2006). Arabica coffee accounted for 4% of export in Nigeria, and less than 2% of world coffee in 1989; and while other producing countries such as Ivory Coast have in recent time significantly increased their production level despite the collapse of world price of coffee, Nigeria no longer has a place at all in coffee production on a global scale (Williams, 1989).

National Centre for Agricultural Mechanization in collaboration with Cocoa Research Institute of Nigeria



**Figure 1:** Structure of a Coffee Berry

carried out the performance evaluation of the developed technology at the Equipment and Scientific Services of the National Centre for Agricultural Mechanization.

1: Center cut, 2: Bean (endosperm), 3: Silver skin (testa, epidermis), 4: Parchment (hull, endocarp), 5: Pectin layer, 6: Pulp (mesocarp), 7: Outer skin (pericarp).

## MATERIALS AND METHOD

The test was carried out at the Engineering and Scientific Services Complex of the National Centre for Agricultural mechanization (NCAM), Ilorin in collaboration with the Cocoa Research Institute of Nigeria (CRIN). Materials used for the evaluation of the machine are,

- i Freshly harvested coffee bean, obtained from the Cocoa Research Institute of Nigeria (CRIN),
- ii Fresh and clean water,
- iii Storage bowls,
- iv Digital Tachometer, contact type, range: 0-5000 rpm;
- v Digital stop watch (Capacity: 60 minutes) Accuracy: 0.1 second
- vi Digital Moisture sensor
- vii Weighing scale. Capacity: 100 kg; scale divisions: 0.5 kg

### Sample Preparation

The fresh coffee berries that were harvested from the research farm of CRIN were first sorted so as to ensure that only healthy and stone free berries were used for the evaluation. The berries were then weighed in four batches of 1 Kg each and labeled ( $U_s$ ,  $S_1$ ,  $S_2$ , and  $S_3$ ) in three replications. The groups were subjected to different length of soaking time, ranging from one (1) to three (3) hours. The labelling acronyms are as listed below.

$U_s$  stands for unsoaked berry,  
 $S_1$  stands for berry soaked for an hour,

$S_2$  stands for berry soaked for two hours,  
 $S_3$  stands for berry soaked for three hours,

After the designated soaking times, the berries were again weighed and the moisture content determined while the values obtained recorded.

The berries were soaked so as to assist in the determination of the effect of the moisture content of the fresh berry on the operation of the machine and to determine the moisture absorption rate of the berries.

### Determination of Operating Speed Variation

Preliminary test was carried out on the machine for the determination of the optimum operating speed and selection of the speed variation to be used in the evaluation. The operating speed variations derived for the evaluation are;

- 600 rpm
- 700 rpm,
- 800 rpm,
- 900 rpm.

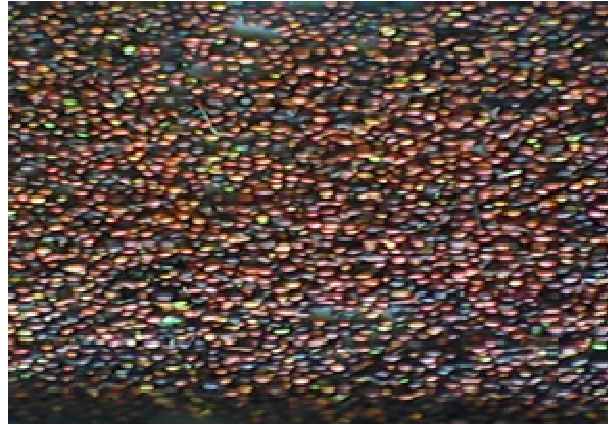
The operating speed was measured with the help of a contact tachometer (figure 2),

### Moisture Content Determination

The moisture content of the various samples were determined using the oven method where the samples were weighed and oven dried at 105 °C for 24 hours and was double checked by the use of a universal moisture sensor. The operating time, depulping time and feeding time were recorded as noted on a digital stop watch.

### Determination of Bean to Chaff Ratio

The ratio of the bean to the chaff was determined by



**Figure 2.** Fresh Coffee berries



**Figure 2.** Speed measuring contact Tachometer

weighing 500 g of fresh berry and then manually remove and separate the bean from the chaff. These are then weighed separately. The value of the weights are then used to compute the bean to chaff ratio, the average bean to chaff ratio obtained was 1:7.

### Evaluation Method

After operating the machine at a zero load condition using the minimum and maximum allowable speed by the prime mover for two hours, fresh sample of berry was loaded into the machine and the optimum operating speed determined, after which the machine was washed with clean fresh water.

The prepared test samples were then loaded in the machine in the arranged batches starting with  $U_s$ ,  $S_1, S_2, S_3, S_4$ , and  $S_5$  at operating speeds of 600 rpm, 700 rpm, 800 rpm and 900 rpm in three replications respectively. The sample use was terminated at  $S_3$  due to the fact that after this period there was no further observed moisture absorption by the berry.

The weight of the samples and the moisture content were measured and determined before and after the operation.

### Description of the machine

The machine consists of a hopper, a barrel encasing a pipe with a steel coil wrapped spirally around it and an outlet. The machine rest on a rectangular frame made of 5 mm angle iron and is supported by vertical 5 mm angle iron. Attached to the base of the support is the prime mover sit (figure 3).

The machine is powered by a gasoline engine and power is transmitted through the use of belt and pulley from the prime mover to the depulping unit.

### RESULTS AND DISCUSSIONS

From the results obtained shown in figure 1, it is gathered that the moisture content of the berries raises as the soaking time increases, nevertheless the berries reach a point of equilibrium moisture content after been soaked for three hours. The machine attained its highest performance level when it was operated at 800 rpm with coffee berries that were soaked for two hours, at this operating condition a depulping efficiency of 98.8% was attained. At this condition the machine also had the



**Figure 3.** Operating speed measurement using a contact tachometer



**Figure 4.** Universal Moisture Sensor



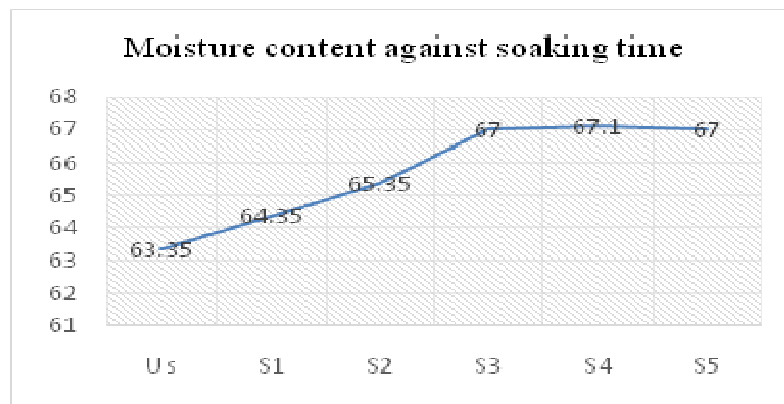
**Figure 5.** Berry Moisture Content determination using the Universal Moisture Sensor

highest output of 26.6 Kg/hr. when loaded at a feed rate of 23 Kg/hr.

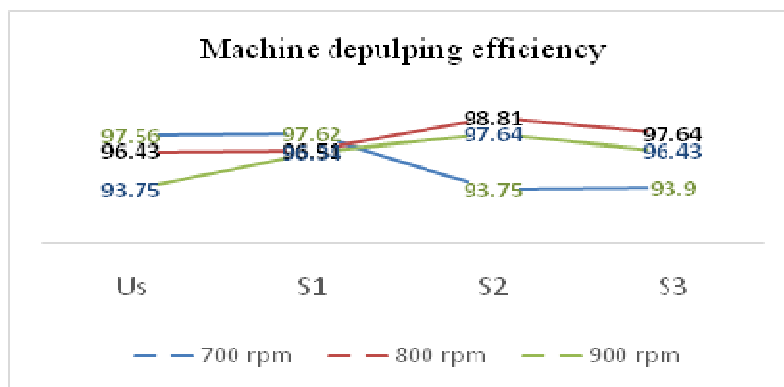
The performance index which is the determination of the overall performance of the coffee de-pulping machine



**Figure 6.** NCAM Coffee Depulping Machine



**Figure 7:** Moisture absorption pattern of fresh Coffee berry



**Figure 8.** Machine Depulping Efficiency

displayed in figure 9 shows that the highest performance index of 98.26% was attained when the machine was

operated at 800 rpm with berries soaked for two (2) hours. From figure 8 it is shown that the highest

Table 1. Field results for the evaluation of the coffee depulping machine

Soaking time (hr.)	Moisture content (%)	Operating speed (rpm)	Weight of input (Kg)	Feeding time (hr)	Feed rate (Kg/h)	Weight of output (Kg)	Weight of berry retained in machine(Kg)	Weight of undepulped berry (Kg)	weight of depulped berry (Kg)	Depulping time (min)	Depulping time (hr)	Depulping efficiency (%)	Output Capacity (Kg/h)
0	63.35	700	1	0.0833	12.00	0.91	0.07	0.02	0.82	4.9	0.0817	97.561	11.14
0	63.45	800	1	0.0817	12.24	0.92	0.05	0.03	0.84	4.41	0.0735	96.429	12.52
0	64.7	900	1	0.0617	16.21	0.9	0.05	0.05	0.8	3.5	0.0583	93.750	15.43
1	64.35	700	1	0.0608	16.45	0.92	0.06	0.02	0.84	3.35	0.0558	97.619	16.48
1	64.7	800	1	0.0728	13.74	0.93	0.04	0.03	0.86	4.03	0.0672	96.512	13.85
1	64.6	900	1	0.0630	15.87	0.91	0.06	0.03	0.82	3.61	0.0602	96.341	15.12
2	66.7	700	1	0.0663	15.08	0.9	0.05	0.05	0.8	3.62	0.0603	93.750	14.92
2	67	800	1	0.0428	23.36	0.92	0.07	0.01	0.84	2.08	0.0347	98.810	26.54
2	65.3	900	1	0.0783	12.77	0.93	0.05	0.02	0.86	4.3	0.0717	97.674	12.98
3	67	700	1	0.0663	15.08	0.91	0.04	0.05	0.82	3.5	0.0583	93.902	15.60
3	66.9	800	1	0.0612	16.34	0.93	0.05	0.02	0.86	3.1	0.0517	97.674	18.00
3	67	900	1	0.0665	15.04	0.92	0.05	0.03	0.84	3.5	0.0583	96.429	15.77

Table 2. Table of Performance Index of Coffee Depulping Machine

Soaking time (hr.)	Moisture content (%)	Operating speed (rpm)	Weight of damaged bean (g)	Performance index	Percentage bean recovery (%)	Percentage bean loss (%)
0	63.35	700	0.01	96.59	90.65	5.5
0	63.45	800	0.02	94.50	92.86	4.2
0	64.7	900	0.021	91.78	88.44	6.8
1	64.35	700	0.009	96.74	92.86	4.2
1	64.7	800	0.0076	95.78	95.07	2.9
1	64.6	900	0.0098	95.40	90.65	5.5
2	66.7	700	0.009	92.91	88.44	6.8
2	67	800	0.0056	98.26	92.86	4.2
2	65.3	900	0.0089	96.81	95.07	2.9
3	67	700	0.0067	93.27	90.65	5.5
3	66.9	800	0.009	96.80	95.07	2.9
3	67	900	0.0095	95.51	92.86	4.2

depulping efficiency of 98.81% was obtained when the machine was operated under the same conditions that produced the optimum performance index. However the highest percentage bean recovery of 95% was obtained as shown in table 2, when the machine was

operated at an operating speed of 800 rpm with soaking times of one (1) and three (3) hours while it was 92% at a soaking time of two (2) hours; based on an average seed to hull ratio of 1:1.7 the expected weight of bean to be recovered is .588 kg while it is expected that the expected weight

of hull should be .42 kg.

CONCLUSION

From the results obtained on the performance



of the NCAM developed Coffee depulping machine, it could be concluded that the machine is very suitable for the depulping of fresh coffee bean, judging by the low percentage of mechanically damaged bean, high performance index, its high depulping efficiency and low percentage bean loss.

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