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Adoptive Trials on the Yam Pounding Machine for Cowpea Dehulling

Sanni L. A.[1], Ogunsina B. S.[1,*], Adegbenjo A. O.[2], Ajayi M. O.[1]

[1]Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Nigeria
[2]Department of Bioresource Engineering, McGill University Montréal, Quebec, Canada
*Corresponding author: babatundeogunsina@gmail.com

Abstract The yam pounding machine developed by Makanjuola (1975) was adopted for dehulling steeped cowpea grains. The machine simulates traditional method of dehulling steeped cowpea grains which involves rubbing the steeped grains between two abrasive surfaces until the seed coat becomes loose and gets detached from the endosperm. The main components include the dehulling chamber, the lid, beaters (inclined or vertical) and spline coupling. Performance evaluation of the machine was carried out considering three local varieties of cowpea (red drum, white drum and Ife brown), three steeping time (3, 5 and 10 mins) and two beater orientation (inclined and vertical). The results show that 'Ife brown' for which coefficients of dehulling and yield were 0.9902 and 0.9727, respectively indicated the highest dehulling efficiency (96.3%). With the inclined beaters, the coefficient of dehulling increased as steeping time increased; whereas, a decreasing trend was observed for other performance indices. With the vertical beaters, coefficient of dehulling and dehulling efficiency increased as steeping time increased; whereas, coefficient of wholeness decreased as steeping time increased. For the three varieties of cowpea, coefficients of dehulling and yield increased with steeping time; while a decrease was observed for coefficient of wholeness as steeping time increased. A machine of this nature is a significant development over existing methods of dehulling cowpea and will minimize the drudgery associated with small scale dehulling of cowpea. In addition, it presents opportunities for the manufacture of a dual purpose kitchen appliance with accessories suitable for yam pounding and cowpea dehulling.

Keywords: *adoption, yam pounding machine, cowpea, dehulling, performance evaluation*

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1. Introduction

The need to augment the demand for animal proteins with alternative sources has gained serious global concern in the last few decades because animal proteins are far from the reach of low income earners. Given the rich amino acids profile of most tropical legumes and oilseeds, their consumption and utilization as functional food ingredients have been widely reported [1,2,3]. Among several other legumes, cowpea (*Vigna unguiculata*), popularly called beans is the most important in Central and South America, Southern Europe, Asia and Africa [4,5]. In the above continents, it is a major source of protein and an important source of revenue for farmers [6,7].

Adejumo *et al.* [2] and Taiwo [8] documented the different forms in which cowpea is largely consumed in Nigeria, namely: cooked or mashed beans/porridge, baked beans paste (*ekuru*), fried beans paste (*akara*), curdled beans slurry (*moinmoin*) and gelatinized beans stew (*gbegiri*). Processing of cowpea into any of these food products often require wet or dry dehulling, during which the tannin-rich seed coat is removed. Although, the use of attrition mill to reduce dry cowpea grains into coarse particles, followed by winnowing and dry milling into flour has been an age-long practice [9], it leaves the product partially dehulled, yielding a flour speckled with particles of the seed coat. The product appears unpleasant, unhygienic and often unsuitable for certain food preparations especially because its functional properties get impaired. Ehiwe and Reichert [10] documented the use of certain roller mills and abrasive dehullers. In the study, it was found that the attrition mill was found to be more suitable for dehulling grains with loose seed coats, while abrasive dehuller was suitable for grains with more tightly adhering seed coats. Few dehullers have been reported for cowpea by Adejumo et al. [2], Olotu et al. [11], Audu [12], Prabhakar and Bhole [13], Babatunde [14] and Reichert et al. [15], but they are rarely suitable for kitchen-scale applications. Total removal of seed coat from the endosperm as achievable by wet dehulling is quite rigorous but preferred because it reduces the tannin and phytate contents of cowpea to a very large extent Amonsou *et al.* [16]. Jackson and Varriano-Mattson [17] documented that wet dehulling of cowpea removes up to 98% of the seed coat, reduces cooking time by about 60%, enhances cooking quality and improves protein quality, palatability and digestibility; hence, it is a very vital step in the processing of cowpea for different food applications [18]. The process involves soaking the grains in water for a period during which the seed coat softens, loosens and becomes easy to remove by gentle abrasion on a grinding stone or by tender stir-pounding in a pestle and mortar [10]. Afterwards, complete separation of the seed coat from the endosperm is achieved by agitating and floating the marshy mixture in water. After repeated agitation (about 3-4 times) and decantation, the product is obtained as clean whole or split cotyledons. Despite the existence of various reports on the dehulling of cowpea, doing it on a kitchen-scale is still a manual process in many African countries till today. In this work, the yam pounding machine was modified to dehull cowpea on a kitchen-scale. The mechanism simulates the traditional method in which steeped cowpea grains are rubbed gently between two abrasive surfaces and agitated until the seed coat becomes loose and detached from the endosperm.

2. Methodology

2.1. Description of the Yam Pounding Machine

In 1975, Emeritus Prof. G. A. Makanjuola [19] developed a machine for preparing pounded yam (Figure 1a). The compact design comprises a cylindrical cast aluminum cup (diameter, 200 mm and height, 110 mm) fitted with four alternate metallic beaters mounted on a shaft (Figure 1b); extending vertically downwards into the cup through the centre of the cover lid (Figure 1c). A vertically installed single phase electric motor is fitted to drive the beaters. Cooked (hot) diced pieces of yam are fed into the cup which is held fixed to the machine base. As the electric motor drives the metallic beaters, the slices of cooked yam get comminuted vigorously until the starch granules gelatinize to form a thick glutinous dough (otherwise known as pounded yam) the colour of which may be white, cream or yellow (depending on the colour/variety of yam used).

The machine having gone through some modifications has become a commercial household appliance in Nigeria and some other places in sub-Saharan Africa where pounded yam is an important local delicacy.

2.2. Modifications Made on the Yam Pounding Machine for Cowpea Dehulling

The commercial version of the yam pounding machine manufactured by Addis Engineering Ltd. was used for this work. The metallic beaters (Figure 1c) were replaced with rubber-lined beaters and a variable speed electric motor was incorporated to regulate speed. The rubber-lined surface of the beaters, the cylinder wall and the steeped cowpea grains rub against each other until seed coat removal is achieved. During the process, some of the cowpea cotyledons become broken into pieces or splits. The clearance between the beaters and the cylinder wall was based on the axial dimensions of cowpea earlier reported by Yalcin [20]. The main components of the modified machine include:

i) *The dehulling chamber:* This is a cast aluminum cup which holds the steeped grains for dehulling. It has a top diameter and height of 200 mm and 110 mm respectively. The inner surface of the cup is lined with an abrasive rubber overlay to increase friction between the cowpea grains and cylinder wall.

ii) *The lid:* The aluminum disc-cover of the yam pounder was modified into a 200 mm circular disc made from 3 mm thick aluminium to serve as lid to cover the cup. The lid has grooves which gives a firm grip on the cup.
Beaters: The beaters are made of brass rods with surfaces lined with abrasive rubber material. There are two beaters which were oriented vertically and alternately at 45 and 60°. As the beaters rotate, the friction developed between the rubber-lined surfaces, the cylinder wall and cowpea grains lead to loosening and removal of the seed coat from the endosperm. The length, the internal and external diameters of each beater are: 50, 10 and 15 mm respectively.

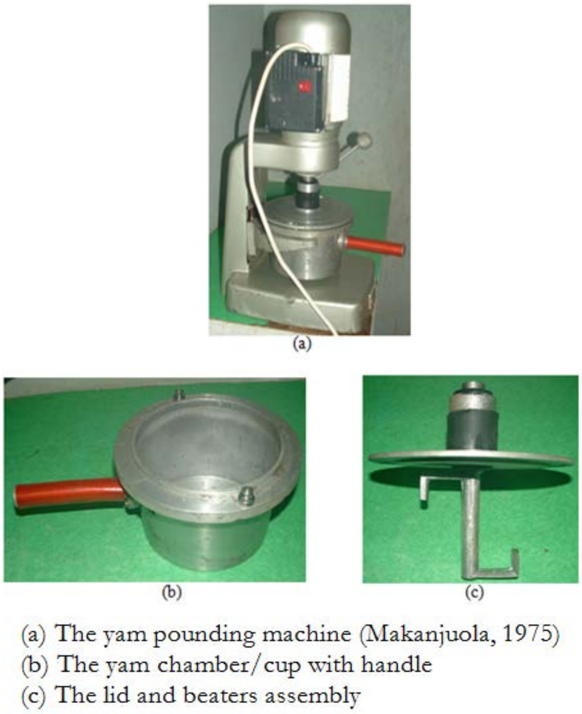


Figure 1. The yam pounding machine by Makanjuola (1975) and its main components [19]

iii) *Spline Coupling:* A 16 mm socket was used as a spline for coupling the central shaft which transmits torque from the electric motor to the beaters.

iv) *The electric motor*: A single phase electric motor (0.8 hp, 1410 rpm) drives the shaft upon which the beaters are mounted. Though 1410 rpm was found suitable for yam pounding, it was higher for dehulling of cowpea as it resulted in grains breakage. In a baseline study, a variable speed transformer was used to vary the speed and a speed limit of 200 rpm was found suitable for cowpea dehulling.

v) *Body/Frame:* The machine body is a welded and machined mild steel structure that holds all the components together as a compact unit.

vi) *Handle:* A 50 x 50 mm^2 wood was machined to a 35 mm diameter rod and fitted as a handle to hold the dehulling chamber.

The orthographic and sectional views of the kitchen appliance for dehulling steeped cowpea grains are presented in Figure 2a, Figure 2b, and Figure 3a, Figure 3b respectively showing the inclined and vertical beaters orientation.

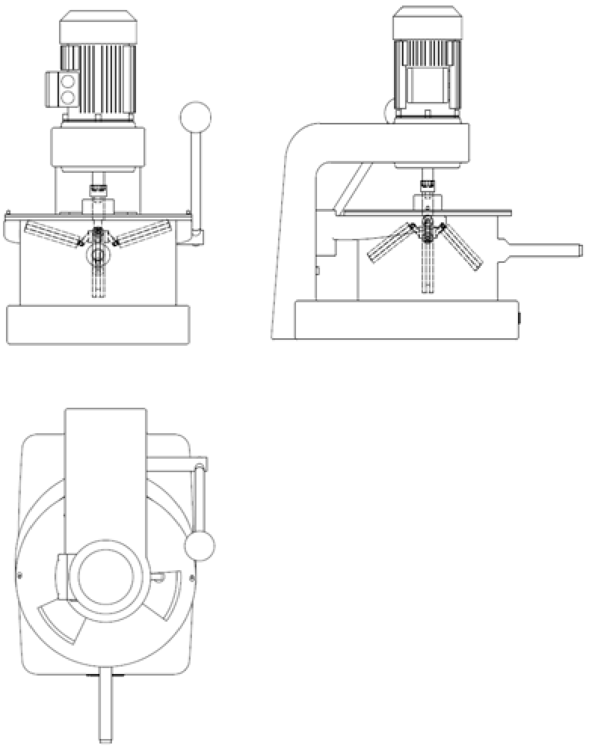


Figure 2a. Orthographic view of the cowpea dehuller with inclined beaters

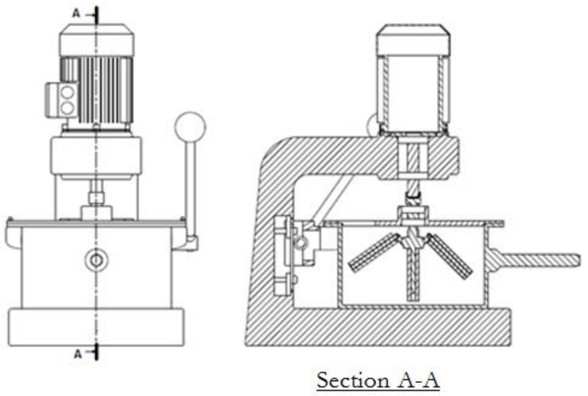


Figure 2b. Sectional view of the cowpea dehuller showing the details of inclined beaters

2.2. Performance Evaluation

About 25 kg each of three varieties of cowpea grains were obtained from the Obafemi Awolowo University teaching and research farm and Sabo market in Ile Ife. The endosperm and seed coat contents of three cowpea varieties (red drum, white drum and Ife brown) were determined following a modified method of Reichert *et al.* [15]. One hundred grams (100 g) of grains from each variety was soaked in distilled water for 10 mins, and afterwards, it was dehulled manually. The endosperm and the hull fractions were air-dried separately until a constant weight was obtained between two weighing successions. The weight of each fraction was determined per 100 g of sample.

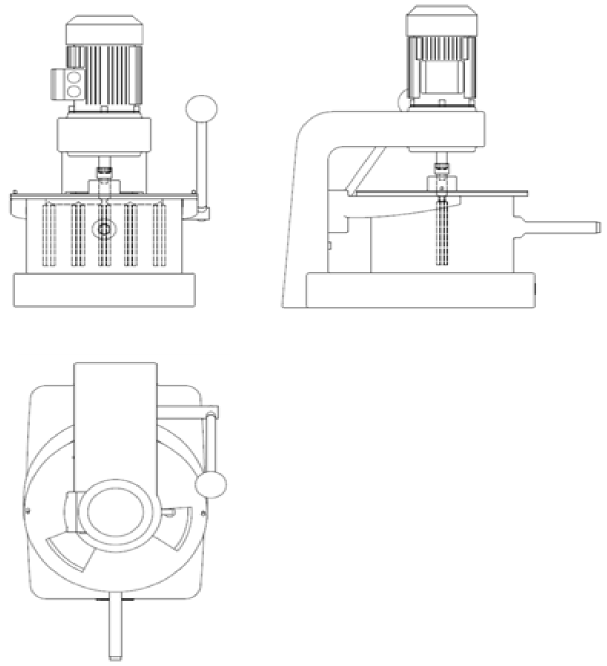


Figure 3a. Orthographic view of the cowpea dehuller with vertical beaters

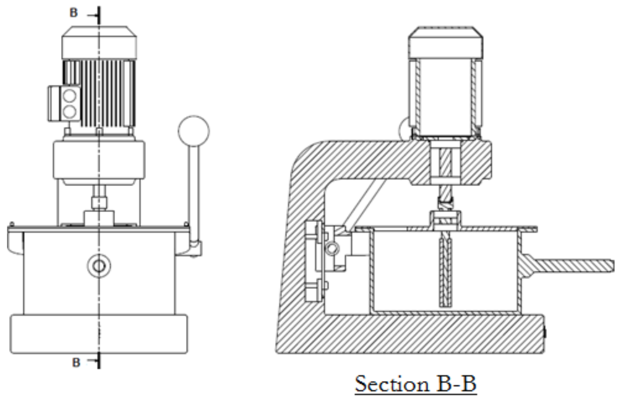


Figure 3b. Sectional view of the cowpea dehuller showing the details of vertical beaters

The machine was subjected to preliminary tests with each of the three varieties of cowpea (red drum, white drum and Ife brown) steeped for 5 mins using the inclined beaters and considering two resident times (10 and 15 s). The chamber was filled with water to ¾ of its volume and about 1 kg of steeped cowpea grains was fed into the cup and the machine was allowed to run for 10 s. The dehulling chamber was opened after each experimental run and the content was evacuated for analysis. The dehulled mass of grains was sorted into fractions as dehulled whole grains, dehulled split grains, partially dehulled grains, dehulled but broken pieces and un-dehulled grains. Each fraction was weighed in a precision electronic balance having an accuracy of 0.01 (GT 2100, Made in Germany). Machine performance indices: coefficient of wholeness, C_w; coefficient of dehulling, C_n; coefficient of yield, C_y; dehulling efficiency, E_d and the overall performance efficiency of the machine, E_o were calculated using equations (1) – (7) as documented by Lazaro [21].

$$C_w = \frac{M_{wk}}{M_{wk} + M_b} \quad (1)$$

$$C_n = \frac{M_p}{M_w} \quad (2)$$

$$C_y = \frac{Y_a}{Y_e} \quad (3)$$

$$Y_a = \frac{M_d}{M} \quad (4)$$

$$Y_e = (100 - M_w) \quad (5)$$

$$E_d = C_n \times C_y \quad (6)$$

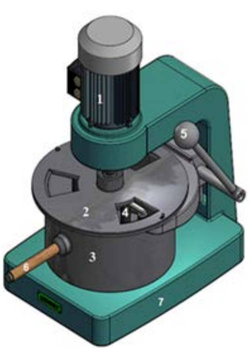
$$E_o = C_n \times C_y \times C_w \quad (7)$$

where, M_{wk} = mass of whole kernels in the final product; M_b = mass of broken kernels in the dehulled grain sample; M_p = seed coat removed by the dehulling process; M_w = seed coat content of undehulled grain; M = mass of grain sample before dehulling. M_d = mass of the dehulled grain recovered; Y_a = actual yield obtained; Y_e = maximum expected yield of dehulled grains.

Following the procedure above, the machine was subjected to performance evaluation considering the three cowpea varieties listed above; three steeping times (3, 5 and 10 mins) and two orientation of beaters (inclined and vertical). The effect of beaters orientation and steeping time on the performance indices was investigated using 'Ife brown' (on the basis that it had the highest coefficient of dehulling). Furthermore, the effect of steeping time on the coefficients of dehulling, wholeness and yield for the three cowpea varieties was investigated.

3. Results and Discussion

Figure 4 shows the isometric drawing of the experimental machine and machine parts description; while pictorial views of the inclined and vertically arranged beaters are shown in Figure 5a and Figure 5b, respectively.



Item	Quantity	Part name	Material
1	1	Electric motor	Composite
2	1	Cover lid	Cast aluminum
3	1	The dehulling chamber	Cast aluminum
4	1	Spline coupling/Beater assembly	Mild steel/Rubber lined hollow cylindrical pipe
5	1	Lever to grip the cup	Stainless steel
6	1	Wooden handle	Wood
7	1	Machine base	Mild steel

Figure 4. Isometric drawing of the experimental machine showing machine parts

The seed coat and endosperm fraction of red drum, white drum and Ife brown cowpea varieties were found to be: 89.5, 11.5; 87.2, 12.3; and 84.9, 15.1 g/100 g, respectively. This shows that for the same weight of grains, Ife brown had the highest seed coat fraction while red drum had the least. Ehiwe and Reichert [10] affirmed that the amount of seed coat removed from the seed and yield are desirable indices in explaining the quality of dehulled grains.

Figure 5a. The rubber-lined inclined beaters

Figure 5b. The rubber-lined vertical beaters

From the results of preliminary tests (Table 1), it was observed that Ife brown for which coefficients of dehulling and yield were 0.9902 and 0.9727 respectively indicated the highest dehulling efficiency (96.3%). More whole grains were obtained for red drum and the machine was most efficient with white drum (E_o = 87.66%). Table 2 shows the effect of beaters orientation and steeping time on the performance indices. It was observed that for the inclined beater orientation, the coefficient of dehulling (C_n) increased as steeping time increased; whereas, a decreasing trend was observed for other indices. From statistical analysis, no significant difference was indicated by all the values. With the vertical beaters orientation however, the coefficient of dehulling and dehulling efficiency (E_d) showed an increasing trend as steeping time increased; whereas, coefficient of wholeness (C_w) decreased as steeping time increased. No significant changes were observed in the yield and machine performance efficiency. With higher values of C_n indicated for inclined beaters orientation, it may be inferred that this orientation is more suitable for dehulling steeped cowpea. Coefficient of dehulling is an index which defines the degree of hull removal achieved during the dehulling process. Although higher values of C_w were observed with vertical beaters orientation, wholeness of the grains may not be considered as an important quality index in cowpea dehulling. This is because milling or cooking is usually the next food process to which the dehulled grains will be subjected, depending on the desired food product. The effect of steeping time on C_n, C_w and C_y for the three cowpea varieties using the inclined beaters at 10 s resident time is shown in Figure 6. The results showed that for the three varieties of cowpea, coefficients of dehulling and yield increased with steeping time; whereas, a decrease was observed for coefficient of wholeness as steeping time increased. However, no difference was observed in the coefficients of dehulling and yield for the three varieties; hence, to preserve the wholeness of grains, 5 mins of steeping time was considered the most suitable.

Table 1. Results of preliminary tests using three varieties of cowpea, 5 mins steeping time and 10 s resident time with inclined beaters

Samples	C_n	C_w	C_y	E_d (%)	E_o (%)
Red drum	0.9728	0.9118	0.9672	94.09	85.79
White drum	0.9755	0.9260	0.9705	94.67	87.66
Ife brown	0.9902	0.8824	0.9727	96.32	84.99

C_n, C_w,and C_y represents the coefficients of dehulling, wholeness and yield; while E_d and E_o are dehulling efficiency and machine efficiency respectively.

Table 2. Effect of beaters orientation and steeping time on performance indices using Ife brown variety of cowpea

Steeping time (min.)	C_n		C_w		C_y		E_d (%)		E_o (%)	
	X	Y	X	Y	X	Y	X	Y	X	Y
3	0.9734	0.9696	0.9457	0.9586	0.9686	0.9647	94.28	93.54	89.16	89.67
5	0.9738	0.9720	0.9232	0.9256	0.9683	0.9662	94.29	93.92	87.05	86.93
10	0.9740	0.9721	0.9055	0.9139	0.9661	0.9657	94.10	96.57	85.21	88.26

X = inclined beaters orientation; Y = vertical beaters orientation; C_n, C_w,and C_y represent the coefficients of dehulling, wholeness and yield; while E_d and E_o are dehulling efficiency and machine efficiency respectively.

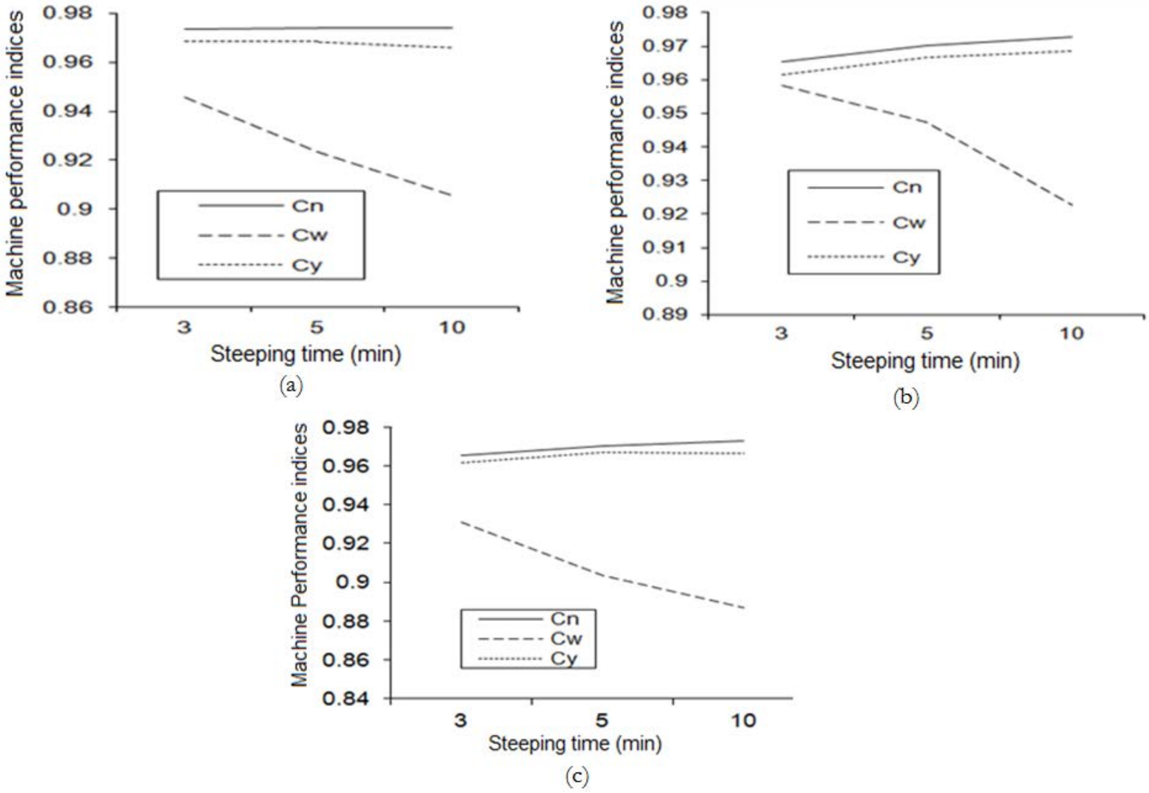


Figure 6. Effect of steeping time on the coefficients of dehulling, coefficient of wholeness and yield for three varieties of cowpea using the inclined beaters at 10 s resident time ((a) = Red drum, (b) = White drum, (c) = Ife brown, C_n = coefficients of dehulling, C_w = coefficients of wholeness and C_y = coefficients of yield))

4. Conclusions

An existing yam pounding machine has been modified for kitchen-scale dehulling of steeped cowpea grains. The modifications made include replacement of metallic beaters with rubber-lined beaters inclined at different orientations to create the required soft abrasion for the removal of seed coat of steeped cowpea grains. The machine indicated its highest dehulling efficiency as 96.3% for 'Ife brown' variety. This work, apart from minimizing the drudgery associated with kitchen-scale dehulling of steeped cowpea grains presents the possibility of developing the yam pounding machine into a dual purpose kitchen appliance with accessories suitable for the preparation of pounded yam and dehulling of steeped cowpea.

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