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PERFORMANCE EVALUATION OF AFRICAN BREADFRUIT (*TRECULIA AFRICANA*) SEED DEHULLER

Okey Francis Obi*, Clement O. Akubuo

Agricultural and Bioresources Engineering Department, Faculty of Engineering, University of Nigeria, Nsukka, Nigeria

*Corresponding author: e-mail: francis.obi@unn.edu.ng

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ABSTRACT

This paper reports the effect of the parboiling time on dehulled kernel out-turns (DKO) of African breadfruit seeds, and the most recent effort to upgrade an existing dehuller and its performance. Two common and readily available varieties – *Treculia var. africana* and *var. inverse* were used in the study. The seeds were parboiled for 0 (control), 2, 5, 8, 11 and 14 minutes and then dehulled. The result revealed that the parboiling time had a significant effect on the DKO of the two varieties of the seed. The DKO increased from 0 to 5 min of the treatment, after which it decreased considerably up to 14 min of the parboiling time. The obtained data were used to develop a non-linear quadratic regression model to predict the DKO as a function of the parboiling time. The performance evaluation of the breadfruit seeds dehuller revealed that it was significantly influenced by the variety.

Introduction

African breadfruit (*Treculia africana*) belongs to *Moraceae* family. It is an evergreen forest fruit tree in tropical Africa countries like Ghana, Sierra Leone, Nigeria, etc. African breadfruit is an underutilized tree crop that produces large round fruits which are covered with rough pointed outgrowths. The seeds are embedded in the spongy pulp of the fruits. Three varieties of *Treculia* have been recognized based on the size of the seed: *var. africana* (large), *var. inverse* (medium) and *var. mollis* (small) (Nwabueze, 2009). African breadfruit is an important food item in various regions of tropical West Africa and is usually consumed as pottage or roasted snack sold with palm kernel or coconut. The breadfruit flour has a high potential usage for pastries production. The *africana* seeds are an important source of vitamins, minerals, proteins, carbohydrates and fats (Enibe et al., 2013). Ellis et al., (2007) reported that the crude protein content, fat, ash, crude fibre, carbohydrates, iron, calcium, potassium and phosphorus content of African breadfruit seed were of 13.35%, 10.12%, 1.96%, 2.83%, 62.01%, 8.70 mg·100 mg^{-1}, 93.90 mg·100 mg^{-1}, 464.60 mg·100 mg^{-1} and 1300.00 mg·100 mg^{-1}, respectively. The seed has been a natural resource, contributing significantly to the income and dietary intake of the people.

Traditionally, processing of African breadfruit seed into its kernel involves parboiling of the seed, cooling and then manual removing of the hull. This is achieved by spreading the parboiled seeds on a cemented floor or mat and rolling a cylindrical object, usually a bottle or pestle over the seeds. This breaks the hulls off the seed and the hulls are then separated from the kernels by a traditional winnowing method – throwing the mixture of hull and kernel into the air and allowing the natural wind to separate the hulls from the kernel. This method is tedious, time consuming and the production output is bound to be low. Etoamaihe and Ndubueze (2010) reported that in the majority of cases there are losses and delays in handling large volumes of the product and the handwork is prone to injury coupled with problems associated with the hygienic condition of the product. Some machines have been designed and constructed for dehulling the African breadfruit seeds as a result of the aforementioned problems (Anosike et al., 2016; Enibe et al., 2013; Etoamaihe and Ndubueze, 2010; Nwabueze, 2009; Nwigbo et al., 2008; Omobuwajo et al., 1999). However, not enough has been done with regard to the extensive performance evaluation of such machines particularly regarding the optimum parboiling time prior to dehulling. At the moment, the local processors who utilize some of the developed dehulling machines, parboil the seed for different periods based on their experiences which could impact the performance of the machines.

One of the major processing parameters affecting the dehulling of African breadfruit seeds is the parboiling time prior to dehulling. Parboiling helps to separate the husk from the kernel. Scientific determination of how this thermal treatment does affect the dehulled kernel out-turn (DKO) will serve as a prerequisite to optimizing the dehulling of the seed (Nwabueze, 2009). The DKO is an important criterion in determining the export quality and economic basis for estimating or predicting the income obtainable by processors (Ogunsina, 2013). This has not been determined for breadfruit seeds. It is necessary to determine the quantity of well dehulled marketable breadfruit seeds using a dehulling machine.

Objective, scope, and methods of research

The objectives of this study were: (i) to evaluate the performance of a modified breadfruit dehulling machine based on the effect of the parboiling time on the dehulled kernel out-turn (DKO) of the breadfruit seed and (ii) to determine the optimum parboiling time for each variety of the seed.

Dehulling Machine

A previously developed African breadfruit dehulling machine by Enibe et al., (2013) was modified and its performance was evaluated. The modification made was based on the deficiencies on the previous dehuller. In the previous dehuller, the air from the fan was not sufficient to separate the hulls from the kernel as most of the hulls were collected from the kernel outlet chute. The fan was redesigned to increase the volume of air generated. Also, the previous design was powered by a 1.5 hp motor that runs on a single speed. This was changed to a petrol engine equipped with a variable speed control to vary the speed of the machine. Figure 1 shows the modified African bread fruit dehulling machine.

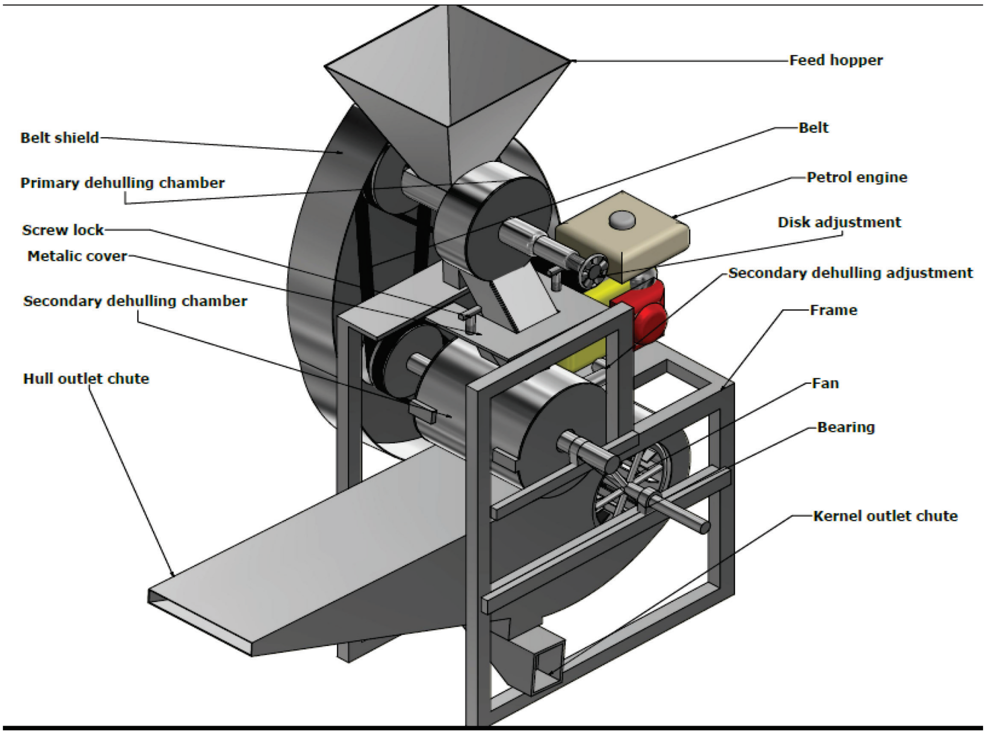

Figure 1. Drawing of the modified African breadfruit dehulling machine

Performance Tests

Dehulled Kernel Out-turn (DKO)

Two commonly consumed and readily available varieties of African breadfruit seed, *Treculia var. africana* (large size) and *Treculia var. inverse* (medium size) were used for the study. Fresh varieties, each of about 30 kg, were extracted from the de-pulped head obtained from farm gates at Ogbede, Enugu state, South-Eastern Nigeria. The average moisture content (MC) of the seed varieties was 32.17±0.24 and 30.17±0.64% wet basis (w.b.) for the large size and medium size seeds, respectively.

About 12 kg of fresh breadfruit large and medium sized seeds were divided into six portions of 2 kg each and labeled. Each portion was further divided into four parts of 0.5 kg each to serve as replicates. Each part of the labeled portions was parboiled for 2, 5, 8, 11 and 14 minutes, respectively with 0 min as a control sample. During the parboiling process, the water was brought to the boiling point (100ºC) before the seeds were poured into the pot. This was to help maintain uniformity across the batches and also to ensure that the seeds were not parboiled beyond the stated time. After parboiling, the seeds were poured into a sieve for the water draining for about 20 sec and then were dehulled. The procedure was repeated four times for each of the six portions of the 2 kg seeds and for each variety, only completely dehulled kernels were collected and weighed. The DKO was calculated as the ratio of the weight of completely dehulled seeds (W_{ds}) to the total weight of breadfruit seeds (W_{ps}) poured into the machine for dehulling, as shown in equation (1):

$$DKO = \frac{W_{ds}}{W_{ps}} x\, 100\ (\%) \quad (1)$$

The DKO data were used to develop a non-linear regression model to predict the DKO as a function of the parboiling time.

Performance Parameters

The nine criteria applied for evaluation of the performance of the dehulling machine were: machine capacity, dehulling efficiency, separation loss, blower loss, kernel purity, hull purity, kernel recovery, hull recovery, and screening efficiency. These criteria were adapted from the work of Akubuo (2002) and Akubuo and Eje (2002). The machine capacity was determined as the material output per unit time (kg h^{-1}). The dehulling efficiency (D_e, %) was calculated using equation (2):

$$D_e = \left(\frac{w_1 + w_2}{w_1 + w_2 + w_3}\right) 100\ (\%) \quad (2)$$

where:
w_1 – weight of kernels in the kernel collector, (g)
w_2 – the weight of kernels in the hull collector, (g)
w_3 – the weight of kernels manually dehulled from partially dehulled or un-dehulled seed after the dehulling proces, (g)

Separation loss (S_L, %) refers to the amount of kernels in the dehulling chamber and was calculated from equation (3):

$$S_L = \left(1 - \frac{w_1}{w_1 + w_2 + w_3}\right) 100\ (\%) \quad (3)$$

The blower loss (B_L, %) refers to the kernels in the hull collector and was calculated from equation (4):

$$B_L = \left(\frac{w_2}{w_1 + w_2 + w_3}\right) 100\ (\%) \quad (4)$$

Kernel purity refers to the amount of hulls and un-dehulled or partially dehulled seeds in the kernel collector. The smaller the amount, the higher the purity of the kernels separated. Kernel purity (K_p, %) was calculated from equation (5):

$$K_p = \left(1 - \frac{W_5}{W_1 + W_5}\right) 100\ (\%) \quad (5)$$

where:
W_5 – the sum total weight of partially or completely un-dehulled seed and the weight of hull in the kernel collector, (g)

Hull purity refers to the amount of kernels and un-dehulled or partially dehulled seeds in the hull collector. The smaller the amount, the higher the purity of the hulls separated. Hull purity (H_p, %) was calculated from equation (6):

$$H_p = \left(1 - \frac{W_7}{W_6 + W_7}\right) 100\ (\%) \tag{6}$$

where:
W_6 – weight of hull in hull collector,
W_7 – the sum of the total weight of partially or completely un-dehulled seed and the weight of kernels in the hull collector, (g)

Kernel recovery (K_r, %) is a measure of the amount of kernels separated to the total amount of kernels contained in the kernel/hull mixture sample, and was calculated using equation (7):

$$K_r = \left(\frac{W_1}{W_1 + W_2}\right) 100\ (\%) \tag{7}$$

Hull recovery (H_r, %) is a measure of the amount of hulls separated to the total amount of hulls contained in the kernel/hull mixture sample, and was calculated using equation (8):

$$H_r = \left(\frac{W_6}{W_6 + W_8}\right) 100\ (\%) \tag{8}$$

where:
W_8 – weight of hull in kernel collector, (g)

Screening efficiency (S_e, %) is a measure of the overall efficiency of the separator in separating the kernels from the hulls and it was calculated as the combined effectiveness of the machine in separating the kernels and the hulls using equation (9) as developed by Otubelu (1989) and Eje (1998):

$$S_e = 100 K_r H_r\ (\%) \tag{9}$$

Results of the performance parameters of the dehulling machine were subjected to statistical analysis with a parametric method of Fisher's least significant difference (FSLD) at 5% significance level using GenStat Analytical Software in order to evaluate the significance of variability between the results.

Results and Discussion

Dehulled Kernel Out-turn of the T. var. africana Variety

The dehulled kernel out-turn (DKO) of the large seed variety *T. var. africana*, parboiled for 2, 5, 8, 11, and 14 min with 0 as control is shown in Table 1. The DKO increased from the 0 min time up to 5 min parboiling time after which it decreased up to the 14 min parboiling time. The DKO ranged from 0.60-67.09%. The mean lowest value was observed for the control (0 min) while the highest mean value of the DKO was observed at the 5 min parboiling time. The steady increase in the DKO of the seed could be attributed to the gradual gain in the moisture content of the seed which made the seed amenable to dehulling. Beyond the 5 min time, the seeds were observed to be softened such that as the parboiling time increased, the DKO reduced drastically. Attempt was made to parboil the seeds beyond 14 min but output was a marshy mix of the kernel and the hull.

Table 1.
Dehulled kernel out-turn of T. var. africana seed variety, machine speed 200 rpm

Parboiling time, p_t (min)	Weight of parboiled seed, W_{ps} (g)	Weight of dehulled seed, W_{ds} (g)	Dehulled kernel out-turn, *DKO* (%)
0 (control)	500	3.01±0.98	0.60±0.20a
2	500	266.36±21.94	53.27±4.39b
5	500	335.47±29.56	67.09±5.91c
8	500	312.49±8.16	62.50±1.63d
11	500	54.41±0.91	10.88±0.18e
14	500	12.26±1.42	2.46±0.28a
		FLSD	4.58

Data reported are mean value of four replicates. [a-e] Mean values with different letters in the same column are significantly different at 5% significant level (p<0.05); FLSD – Fisher's least significant difference

Dehulled Kernel Out-turn of the T. var. inverse Variety

The dehulled kernel out-turn (DKO) of the medium seed variety, *T. var. inverse*, is shown in Table 2. The DKO ranged from 1.70 ± 0.68 to 69.55 ± 3.73%. The DKO, as it was for *var. africana*, increased from the 0 min time up to the 5 min parboiling time, after which it decreased up to 14 min parboiling time. Ogunsina (2013) noted that a slight rise in temperature experienced by kernels in the presence of moisture tends to parboil and toughen them thereby lessening its susceptibility to breakage. The decrease in the DKO after 5 min parboiling time could be attributed to the excessive tenderness of the kernel as was reported for *var. africana.* The lowest mean value of the DKO was obtained at the 0 min (control) parboiling time while the highest mean value was recorded at the 5 min parboiling time (Table 2).

Table 2.
Dehulled kernel out-turn of T. var. inverse seed variety, machine speed 200 rpm

Parboiling time, p_t (min)	Weight of parboiled seed, W_{ps} (g)	Weight of dehulled seed, W_{ds} (g)	Dehulled kernel out-turn, *DKO* (%)
0	500	8.51±3.38	1.70±0.68a
2	500	276.11±18.36	55.22±3.67b
5	500	347.74±18.64	69.55±3.73c
8	500	310.24±8.79	62.05±1.76d
11	500	50.74±6.91	10.15±1.38e
14	500	11.51±3.48	2.30±0.70a
		FLSD	3.50

Data reported are mean values of four replicates. [a-e] Mean values with different letters in the same column are significantly different at 5% significant level (p<0.05); FLSD – Fisher's least significant difference

The DKO values in Tables 1 and 2 for different varieties were subjected to analysis of variance and Fisher's Least Significant Difference (FLSD) test. Table 3 revealed that the DKO of *T. var. africana* and *var. inverse* varieties at different parboiling times were all significantly different (p<0.05) from each other except at the 0 and 14 min parboiling times. The high level of a significant difference observed among the DKO recorded for the seed varieties suggests that the parboiling time plays a major role in the ease with which African breadfruit seed is dehulled. The highest numerically and significantly different (p<0.05) mean value of the DKO was recorded at the 5 min parboiling time for both varieties; 67.09 ± 5.91% for *var. africana* and 69.55 ± 3.73% for *var. inverse*. However, the lowest mean value of the DKO was recorded for the raw African breadfruit seed varieties; 0.60 ± 0.20% for *var. africana* and 1.70 ± 0.68% for *var. inverse*. Ogunsina (2013) also made a similar observation for the crackability of cashew nuts. He reported that raw nuts gave the least values of whole kernels out-turn of 62%, 33.9%, and 44.7%, respectively, for large, medium and small cashew nut sizes in comparison to heat treated cashew nuts.

Table 3.
DKO of African breadfruit seed varieties at different parboiling times

Parboiling time, p_t (min)	Dehulled kernel out-turn, *DKO* (%) (*T. var. africana*)	Dehulled kernel out-turn, *DKO* (%) (*T. var. inverse*)
0	0.60±0.20a	1.70±0.68a
2	53.27±4.39b	55.22±3.67b
5	67.09±5.91c	69.55±3.73c
8	62.50±1.63d	62.05±1.76d
11	10.88±0.18e	10.15±1.38e
14	2.46±0.28a	2.30±0.70a
FLSD	4.58	3.50

[a-e] Mean values with different letters in the same column are significantly different at 5% significant level ($p<0.05$); FLSD – Fisher's least significant difference

The DKO values of each variety were used to develop regression models for the prediction of DKO as a function of the parboiling time. The regression models developed were non-linear of a quadratic type. Equations (10) and (11) are the equations for *T. var. africana* and *var. inverse,* respectively, with the corresponding correlation coefficients of 0.91 and 0.92:

$$DKO = -124.2 + \left(\frac{125.4 + 27.4P_t}{1-0.022P_t + 0.01777{P_t}^2}\right) \quad R^2 = 0.91 \tag{10}$$

$$DKO = -112.9 + \left(\frac{115.2 + 25.9P_t}{1-0.037P_t + 0.01966{P_t}^2}\right) \quad R^2 = 0. \tag{11}$$

where:
DKO – Dehulled kernel out-turn, (%)
P_t – parboiling time, (min.)

The equations could be used in predicting DKO of *Treculia africana* seeds as a function of time.

Performance Results

The moisture content of both the *Treculia var. africana* and *var. inverse* seed varieties at the optimum parboiling time of 5 min as determined from the DKO test were 32.17% w.b. and 30.74% w.b., respectively. The data used for calculation of the performance parameters earlier described were only those obtained from the optimum parboiling time of 5 min and machine speed of 200 rpm in the DKO test of each variety of the breadfruit seed.

Statistical analysis included t-test for the comparison of the means. Table 4 presents a summary of the performance parameters for each of the breadfruit varieties at 5 min parboiling time and the corresponding moisture contents. The result shows that most of the parameters were significantly affected by the variety, except the hull purity and kernel recovery. This was expected because of the required disc adjustment for dehulling a variety with respect to the size. However, the performance of the machine was generally satisfactory based on the dehulling efficiency of 98.50% and 90.83% for the large and medium varieties, respectively. This means that the machine can be used to dehull the local varieties of breadfruit seeds as against an earlier one that can dehull only one variety of a breadfruit seed at the 7 min parboiling time (Enibe et al., 2013). Observations show that the best DKO was obtained at a machine speed of 200 rpm for each variety.

Table 4.
Summary of dehulling performance parameters for T. var. africana and var. inverse breadfruit seed varieties; parboiling time – 5 min; dehuller speed – 200 rpm

Performance parameter	*T. var. africana*	*T. var. inverse*
Seed moisture, (%)	53.81±0.24a	50.72±0.43b
Machine capacity, ($kg \cdot h^{-1}$)	75.5±1.00a	98.55±0.86b
Dehullling efficiency, (%)	98.50±0.70a	90.83±0.92b
Separation loss, (%)	1.85±0.14a	10.55±0.74b
Blower loss, (%)	0.66±0.01a	1.26±0.04b
Kernel purity, (%)	81.71±1.10a	74.56±0.64b
Hull purity, (%)	75.72±0.88a	76.79±0.45a
Kernel recovery, (%)	99.35±0.95a	98.53±0.35a
Hull recovery, (%)	29.07±0.29a	18.46±1.25b
Screening efficiency, (%)	28.49±1.21a	17.70±0.79b

[a-b] Mean values with different letters in the same row are significantly different from each other at $p<0.05$ while mean values with the same letter in the same row are not significantly different ($p>0.05$)

Conclusions

From the results of this study, the following conclusions were drawn:

1. Parboiling as a pre-dehulling heat treatment had a significant effect on the dehulled kernel out-turn (DKO) of African breadfruit seeds.
2. The optimum DKO values of 71% for the large (*T. var. africana*) variety and 75% for the medium variety (*T. var. inverse*) were obtained at 5 min parboiling time for corresponding the moisture contents of 53.81% (w.b.) and 50.72% (w.b.), respectively.
3. The effects of the majority of the parameters on the performance of the modified machine were generally satisfactory. The dehulling efficiency as an index of good performance was 98.5% and 90.83% for the large and medium varieties, respectively.
4. The important implication of the results of this study is that the dehulling machine indicated suitability in comfortable dehulling of African breadfruit seed varieties as against an earlier one that can dehull only one variety of breadfruit seed at 7 min parboiling time.

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OCENA DZIAŁANIA ŁUSKARKI DO NASION AFRYKAŃSKIEGO DRZEWA CHLEBOWEGO (*TRECULIA AFRICANA*)

Streszczenie. Artykuł ten przedstawia wpływ czasu gotowania na uzysk łuskanego ziarna afrykańskiego drzewa chlebowego oraz niedawne wysiłki w kierunku ulepszenia istniejącej łuskarki i jej działania. Do badań użyto dwie pospolite i dostępne odmiany *Treculia var. africana* oraz *var. inverse.* Ziarna gotowano przez 0, 2, 5, 8, 11 i 14 minut a następnie łuskano. Wyniki pokazały, że czas gotowania miał istotny wpływ na uzysk ziarna łuskanego dwóch odmian ziarna. Uzysk ziarna łuskanego zwiększał się w ciągu 0-5 minut obróbki, po czym po 14 minutach gotowania drastycznie zmalał. Uzyskane dane zostały wykorzystane do przygotowania nieliniowego kwadratowego modelu regresji służącego do przewidywania uzysku ziarna łuskanego w funkcji czasu gotowania. Ocena działania łuskarki wykazała, że było ono uzależnione od odmiany.

Słowa kluczowe: ekstrakcja ziarna, uzysk ziarna, czas gotowania, obróbka wstępna

Identification data Authors:

Okey Francis Obi –

Clement O. Akubuo –