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EFFECTS OF COOKING ON SOME PHYSICAL CHARACTERISTICS OF NERE SEEDS OR AFRICAN LOCUST BEANS (*Parkia biglobosa*)

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ABSTRACT

The major difficulty encountered in processing locust beans or nere seeds (*Parkia biglobosa)* into afitin subsist is the laborious seeds dehusking. Studies were conducted to determine the optimal cooking duration for ensuring the seeds attained 16.14 % (db) water content prior to efficient dehusking. Therefore, the effects of cooking the seeds in water at 102 °C for duration of 1, 2, 3, 4, 5, and 6 hours on the physical characteristics were assessed. Depending on the treatment duration, the cooking induced variable modifications in the physical characteristics of the seeds. The water content, 1000-seeds mass, and 1000-seeds volume of cooked seeds increased with cooking duration, respectively from 16.14 to 284.62 % (db), 231.66 to 508.33 g and 208 to 482 cm^3. Seed porosity rose from 35.6 to 42.2 % during the first hour of cooking, but decreased gradually to attain constant value of 41 % for the remaining 5 h. Although the average size of seeds increased marginally, there was corresponding lengthening, indicated by 20.40 % change in thickness, 14.5 % change in length and 13.5 % change in width, which confirmed the remarkable effects of cooking treatment. However, the true and bulk densities decreased respectively from 1110 to 1055 kg/m^3 and 715 to 625 kg/m^3 as cooking time increased. The data on dimensional changes (seed length and width) and swelling as function of the cooking time provided parameters for designing shelling grids for efficient dehusking.

1. INTRODUCTION

The principal interest of nere seeds exploitation is fermentation of the cotyledons into condiment, known by various local names as afitin, iru, sonru, soumbala, netetou and dawadawa [1]. Accessing the cotyledons has been the major problem encountered in preparation of the snuffed condiment, because the seed husks are extremely hard and firmly attached to the cotyledons. Hence, the dehusking step remains the most labour intensive conversion process of the seeds into afitin.

A dehusking machine was designed, fabricated, and test run by researchers of University of Abomey-Calavi and National Institute of Agricultural Research of Benin [2]. Field tests of the machine on raw dry nere seeds showed the decorticator provided flow rate of 66.7 kg/h, dehusking efficiency of 48.6 % and rate almonds crack of 10 to 11 %; which were acceptable compared with values recorded by the traditional feet pressing method. The unreliability and low efficiency was attributed to heterogeneity of the seeds, which limited adoption of the machine by women users. Also, deficiencies emanated from pre-cooking and other treatments, such as drying or roasting, adopted to condition the raw seeds/beans before dehusking.

In the traditional practice for afitin co--diment production, cooking was the adopted treatment for transforming the seeds, and exceeded duration of 8 h of boiling in water at temperature of 102 °C [3]. Whatever the applied treatment, the process efficiency should be related to that of decorticator. Therefore, the design of equipment for food processing ought to be based on knowledge of the physical, mechanical and chemical properties of the product being handled [4], and the needs of the operators [5].

Knowledge of physical properties of the seeds in relation to applied treatment was essential for designing a decorticator to achieve satisfactory performance and optimization [4, 6]. The design of decorticator integrating the seed characteristics, would achieve higher efficiency in dehusking ratio, significant reduction in labour and time, improvement in productivity, and quality assurance.

In this paper, analyses of changes in the physical characteristics of nere seeds induced by cooking treatment are presented. The models developed based on key design and output parameters to be integrated in the traditional practice to condition the seeds prior to dehulling are also discussed.

2. SEED PHYSICAL CHARACTERISTICS AND DEHULLING

2.1. Seed Hardness

The hardness of nere seeds is a characteristic that exerted major influence directly on dehusking, grinding or crushing processes. The hardness is measured by duration of dehusking to obtaining the end product, and also determines the dehusking output, since during abrasion, a tender seed produces higher rate of cracking than a hard grain.

2.2. Decorticator

The decorticator used in the study consisted of 4 principal components, namely, seed feed hopper of 8 kg capacity; dehusking compartment (containing two main active parts of fixed and mobile perforated grids, with adjustable gap as function of size of the seeds being shelled); 5 CV gasoline thermal engine for driving the perforated motive grid; and separator module of ventilator and channel for cotyledons and hulls separation. The test runs showed that dehusking raw dry seeds was tedious, time consuming and of low efficiency [7, 8].

Pre-treating the seeds before dehulling by traditional cooking practice induced changes in the properties compared with raw dry seeds. The cooking duration could affect the seed structure, through softening to make dehuller run easier, increase dehusking rate/output and improve technical performance of the decorticator.

Variation of seeds properties due to applied treatment, might also affect the dimensions which are important for adjusting the seeds receiving gap between the two major active parts of the dehuller.

2.3. Seed Dimensions

If l (mm) is length, τ (mm) is thickness and w (mm) is width of a seed, the arithmetic mean diameter (D_A) was expressed as [4],

$$D_A = (l + \tau + w)/3 \tag{1}$$

and the geometric mean diameter (D_G) as,

$$D_G = (l\tau w)^{1/3} \tag{2}$$

Equation (2) gave the closest value to the experimental volume of some seeds [9]. The sphericity of seeds (S) is given by the dimensionless relation,

$$S = l^{-1} \times (l\tau w)^{1/3} \tag{3}$$

The general expression of dimensional lengthening $\Delta(D_t)$ (%) at time t of treatment is

$$\Delta(D_t) = 100 \times (D_t - D_0)/D_0 \tag{4}$$

where D_t may be l(t), τ(t) or w(t) after cooking time (t) and D_0 corresponds to initial dimensions of the raw seeds, i.e. t = 0, D_0 = D (t = 0).

2.4. Mass, Volume, Density, and Porosity

The physical characteristics of seeds were expressed in terms of 1000-seeds mass and volume, true density and bulk density. The 1000-seeds volume was used to derive the volume of one seed (V_Z). The seed density (ρ) and V_Z provided weighted parameters, in terms of equivalent diameter (D_E), seed porosity (P %), and mass ratio of seed ($R_{c/s}$ %) [6, 10].

The equivalent diameter (D_E mm) adopted for seeds and other particulate products of irregular shapes, is equal to that of a sphere having identical volume as unit seed or particle; and is expressed as,

$$D_E = 1.24 \times V_z^{1/3} \tag{5}$$

The seed porosity (P %) is degree of empty spaces contained in a product when not subjected to any external effective pressure, and was calculated as [11, 12],

$$P(\%) = 100 \times (\rho_B - \rho_T)/\rho_T \tag{6}$$

where ρ_T is true density and ρ_B is bulk density of seeds.

The mass ratio of seed ($R_{c/s}$ %) is ratio of mass of cotyledons (M_C) to the mass of entire seed (mass of cotyledon + mass of hull) (M_S), i.e.

$$R_{C/S} = \frac{M_C}{M_S} x100 \tag{7}$$

3. MATERIAL AND METHODS

3.1. Seed Selection and Sampling

Stocks of naturally sun-dried nere seeds were obtained from Dantokpa market in Cotonou. The seeds were winnowed and manually sorted out to eliminate dirty, non-firmed and bad seeds. About 85 kg of the cleaned seeds stock were packed in big plastic containers and stored under ambient conditions in the laboratory. Figure 1 illustrates a picture of the as-received dry seeds, while Table 1 gives the physical characteristics.

Fig. 1. Raw dry nere *(Parkia biglobosa)* seeds

Table 1. Physical characteristics of raw dry seeds (mean values and standard deviation from 6 measurements)

Parameter	Unit	Value
Water content (db)	%	16.14 ± 0.07
Length	mm	10.12 ± 1.26
Width	mm	8.30 ± 1.20
Thickness	mm	4.94 ± 0.72
Arithmetic mean diameter	mm	7.78 ± 0.75
Geometric mean diameter	mm	7.42 ± 0.68
Seeds sphericity	(-)	0.74 ± 0.06
Mass of 1000-seeds	g	231.66 ± 3.58
Mass ratio cotyledons/seed	%	72.03 ±2.87
Seeds porosity	%	35.63 ±0.72
Volume of 1000-seeds	cm^3	208.2 ± 36.0
True density	kg/m^3	1183 ± 52.0
Bulk density	kg/m^3	627 ± 33.0
Specific area of seed	m^2/kg	0.72 ± 0.02
Equivalent diameter	(mm)	7.36 ±0.082

The sampling consisted of packing seeds in batches of 100, randomly taken from the stock, numbered, and sealed in labelled polystyrene sachets and stored at room temperature of 25 °C in the laboratory.

3.2. Sample Preparation and Conditioning

Random samples from 7 sets of 100-seeds samples in sachets labelled S_0, S_1, S_2, S_3, S_4, S_5, S_6, were selected for determination of bulk density and mass of cotyledons. Sample S_0 represented the control or untreated raw dry seeds. The other 6 samples (S_1, S_2, S_3, S_4, S_5, S_6) were cooked in boiling water at temperature of 102 °C, respectively for 1, 2, 3, 4, 5 and 6 hours duration, and the process was repeated for each set for 7 days.

3.3. Cooking Method

The method of cooking the seeds was replication of the traditional mode adopted by women processors. Aluminium containers, each of 2,500 mL capacity without cover was used to cook the seeds. The seeds were poured onto a steel grid, held up and immersed in water at 30 °C. Due to limited capacity of the vessels, the filling rate was 1 kg of seeds for 2.5 L of water.

From preliminary tests, each cooker unit was brought to 102 °C in 10 minutes. The temperature was maintained constant during the required cooking time by supply of hot water from standby heated units free of seeds. The cooking duration was counted starting from the instant of water boiling. At end of stipulated time, the seeds were drawn out of the boiling water and spread for 2 min on absorbent papers to drain off excess water.

Tests were conducted on portions of the treated samples, while the remaining seeds were packed in 100 x 150 mm polyethylene sachets and stored in plastic bags.

4. MEASUREMENTS OF SEED PHYSICAL CHARACTERISTICS

Measurements of the physical characteristics of the treated seeds in batches of 6 samples of 100-seeds and the control were performed, and replicated 6 times to obtain mean values and standard deviations. The parameters determined were water content, average dimensions, 1000-seeds mass and volume, true and bulk densities, spheroid, and porosity.

4.1. Water Content

The water content was determined following ISO-662 procedure [13]. For the tests, 100-seeds samples were ground using RETCH mill. Three samples each of about 5 g were measured using SARTHORIUS balance (precision of 0.1 mg) and subjected to thermogravimetric analysis at drying temperature of 105 ± 2 °C for 8 h in HE50 Pfeiffer oven. The sample was weighed every hour, after a brief cooling (10 - 15 min), in a seal-cote ISO 9000 desiccator type, until constant mass was attained after 3 consecutive measurements.

The water content (dry basis) of the seeds was calculated as [11, 14, 15],

$$Wc_{db} = (100 \times Wc_{wb})/(100 - Wc_{wb}) \tag{8}$$

where Wc_{wb} is water content (wet basis) calculated from initial mass M_{ts} and final or dried mass M_{ds} of sample as,

$$Wc_{w.b} = 100 \times (M_{is} - M_{ds})/M_{ts} \quad (9)$$

4.2. Seed Dimensions

The length, width and thickness of raw and cooked seeds were measured using a 100 mm digital FACOM slide calliper, with 0.01 mm precision.

4.3. 1000-Seeds Mass and Volume

The 1000-seeds mass ($M_{1000\text{-seeds}}$) and volume ($V_{1000\text{-seeds}}$) were determined in accordance with ISO-520 procedure [16]. An electronic Mettler Toledo SB1600 balance (1 g precision) and a 500 mL Brückner Pycnometer (precision of 0.01 mL) with liquid xylen were used for the measurements on each of the 100-seeds sample. The mass of seeds and volume of displaced liquid were recorded and 10 trials were performed for each measurement.

4.4. True and Bulk Densities

The true density of seeds (ρ_T) was calculated from the measured masses and volumes. The bulk density (ρ_B) was determined following AOAC method [17]. Seeds of mass 500 g were poured in the Pycnometer, volume of displaced liquid was read and the bulk density calculated.

4.5. Mass of Cotyledons

The mass of cotyledons (Mc) was determined by using 250 g seeds taken from each of the 6 trials. The individual seeds were manually shelled using a pair of nippers to break the hardened husk, and separated into two parts, and weighed to obtain the average mass of cotyledons (Mc), and that of the husks.

4.5. Data Analyses

The experimental data were analysed using SPSS 9.0 software. The graphs were plotted using MS Excel 2007, and the trend equations and regression coefficients (R^2) of the mathematical models indicated.

5. RESULTS

The results represented variation of physical characteristics with cooking duration and the general effects of treatment on dehusking with respect to the control samples. The conditioning and induced changes in the physical characteristics of seeds, in terms of, water absorption, dimensional changes, equivalent diameter, 1000-seeds mass and volume, cotyledons/seed mass ratio, sphericity and porosity of nere seeds were presented.

5.1. Water Content

The effect of cooking duration on water content of the seeds was plotted as shown in Fig. 2. When nere seeds were cooked from 0 h (control) to 6 h, the water content increaseed from 16.14 % (db) at control state to 284.62 % (db) at the end of the 6 h treatment.

The water absorption $W_a(t)$ % of the seeds during cooking was modelled as a function of time (t), by a polynomial equation of the form,

$$W_a(t) = -0.776t^6 + 15.19t^5 - 112.7t^4 + 389.5t^3 - 613.4t^2 + 398.3t + 16.14 \quad R^2 \approx 1 \quad (10)$$

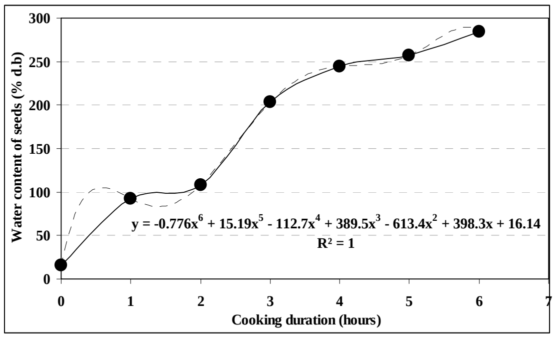

Fig. 2. Changes in water content of nere seeds with cooking duration

5.2. Dimensional Parameters

Raw dry seeds of *Parkia biglobosa* at 16.14 % water content (db) had average length of 10.11 mm, width of 8.30 mm and thickness of 4.94 mm. The dimensions after cooking are shown in Table 2.

The induced lengthening was represented as change (Δ) of length (l), width (w) and thickness (τ) of the seeds as plotted in Fig. 3. When the cooking time was increased from 0 to 6 h, Δl = 1.47 mm, Δw = 1.04 mm and $\Delta\tau$ = 1.01 mm, while the arithmetic and geometric mean diameters changed by 15.42 % and 15.90 % respectively. From Fig. 3, the thickness was most drastically affected by the cooking treatment with ~ 20.4 % rise, while the length and width only increased by 14.5 % and 13.5 %.

The mathematical models describing relationships between Δl, Δw, $\Delta\tau$ and cooking duration (t) were respectively,

Table 2. Dimensional changes of nere seeds with cooking time up to 6 h (Control was uncooked).

Applied treatments	Variation of dimensional characteristics of nere seeds (mm)					
	Length	Width	Thickness	Arithmetic mean diameter	Geometric mean diameter	Sphericity (-)
Uncooked t =0	10.12±1.26	8.30±1.20	4.94 ±0.72	7.78 ±0.75	7.42 ±0.68	0.74 ±0.06
Cooked for 1h	10.40±1.45	8.69±1.41	5.23 ±0.97	8.12 ±1.07	7.76 ±1.05	0.74 ±0.06
Cooked for 2h	11.02±1.47	8.98±1.37	5.53 ±0.03	8.51 ±0.98	8.13 ±0.98	0.74 ±0.07
Cooked for 3h	11.24±1.41	9.16±1.47	5.60 ±0.99	8.67 ±0.89	8.26 ±0.91	0.74 ±0.08
Cooked for 4h	11.42±1.47	9.24±1.39	5.86 ±1.11	8.84 ±0.98	8.47±1.00	0.75 ±0.18
Cooked for 5h	11.45±1.39	9.36±1.34	5.90 ±0.85	8.90 ±0.93	8.55 ±0.90	0.75 ±0.06
Cooked for 6h	11.59±1.42	9.34±1.24	5.95 ±1.04	8.98 ±0.78	8.60 ±0.80	0.75 ±0.09

$\Delta l = 6.365 \ln(t) + 3.558$ R^2=0.971; (11)

$\Delta w = 4.60 \ln(t) + 4.931$ R^2=0.983; (12)

$\Delta \tau = 8.356 \ln(t) + 5.780$ R^2=0.972; (13)

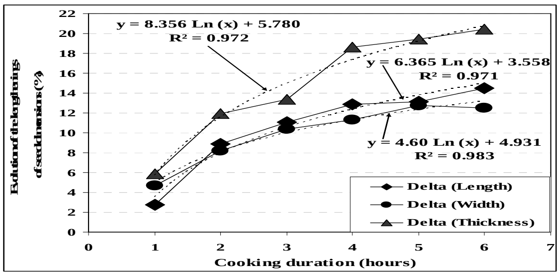

Fig. 3. Dependence of dimensional lengthening of nere seeds on cooking duration

The seed sphericity was independent of the cooking process, as the change was only 1.4 % after 6 h of treatment.

5.3. Equivalent Diameter

The effect of cooking duration on equivalent diameter of the seeds is illustrated by Fig. 4. As the cooking time increased from 0 to 6 h, $D_E(t)$ increased from 7.36 to 9.72 (~ 32.07 %). The change induced was described by the trend equation,

$$D_E(t) = -0.009t^4 + 0.132t^3 - 0.616t^2 + 1.471t + 7.356$$

R^2 = 0.999, (14)

5.4. 1000-Seeds Mass and Volume

Figures 5 and 6 show dependence of 1000-seed mass and volume on cooking duration. The mass of 1000-seeds increased from 231.66 to 508.33 g when the cooking time was increased from 0 to 6 h.

The trend equations of dependence of $M_{1000\text{-}S}$, and $V_{1000\text{-}S}$ on cooking time were respectively,

$$M_{1000\text{-}S} = 0.152t^5 - 3.813 \cdot t^4 + 31.66t^3 - 110.4t^2 + 194.4t + 231.67$$

$R^2 \approx 1$ (15)

$$V_{1000\text{-}S}(t) = -0 \cdot 001t^4 + 0.013t^3 - 0.060t^2 + 0.144t + 0.208$$

R^2 = 0.9883 (16)

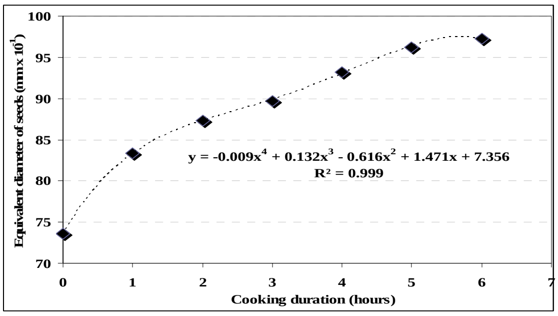

Fig. 4. Variation of equivalent diameter of nere seeds on cooking time.

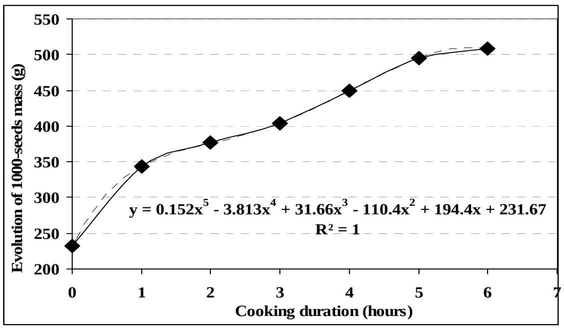

Fig. 5. Increase in 1000-seeds mass of nere on cooking time

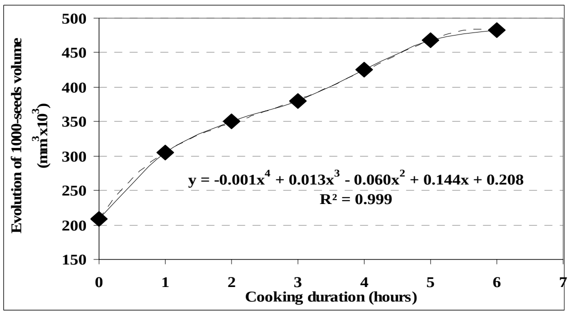

Fig. 6. Increase in 1000-seeds volume with cooking time

5.5. Mass Ratio of Cotyledons

Effect of cooking on mass ratio ($R_{C/S}$)

is shown in Fig. 7, and during the first hour of treatment, $R_{C/S}$ increased from 72 % to 89.3 %, and then decreased quasi-linearly to 64.94 % at end of 6 h. The trend equation of dependence of $R_{C/S}$ on cooking time was,

$$R_{CS} = 0.125t^5 - 2.092t^4 + 13.15t^3 - 38.38t^2 + 44.33t + 72.01$$

$R^2 = 0.999$ (17)

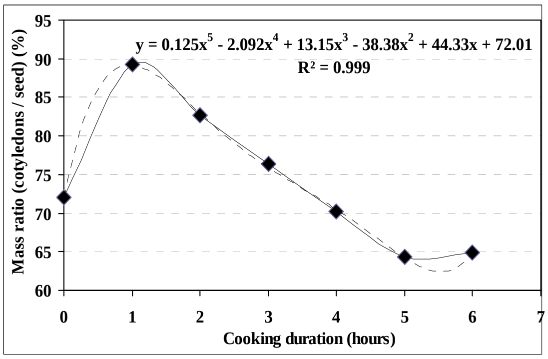

Fig. 7. Mass ratio of cotyledons to seeds versus cooking time

5.6. Porosity of Seeds

The change of porosity of seeds in Fig. 8 showed increase from 35.6 to 42.2 % during the first hour of cooking, and then slightly decreased to about 40.78 %, and remained nearly constant for the next 5 h of treatment. The seed porosity (P) as function of cooking time (t) was expressed as,

$$P = 0.056t^5 - 0.970t^4 + 6.046t^3 - 16.40t^2 + 17.80t + 35.63$$

$R^2 \approx 1$ (17)

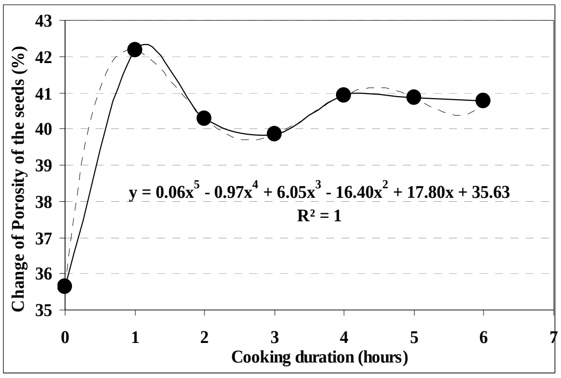

Fig. 8. Changes in porosity of nere seeds on cooking time

5.7. Density

Figures 9 and 10 represent the variation of true and bulk densities of the seeds. The true density increased from 1109.8 to 1127.9 kg/m^3 in the first hour, and then decreased to a constant value of 1053.9 kg/m^3. The bulk density decreased from 714.3 kg/m^3 to 624.1 kg/ m^3 after 4 h of cooking and attained a constant value. The trend equations were,

$$\rho_T(t) = -0.20t^6 + 4.17t^5 - 34.03t^4 + 135.6t^3 + 259.5t^2 + 172t + 110$$

$R^2=1$, (18)

$$\rho_B(t) = -0.1t^6 + 1.51t^5 - 7.15t^4 + 6.21t^3 + 38.3t^2 - 100.8t + 7142$$

$R^2=1$, (19)

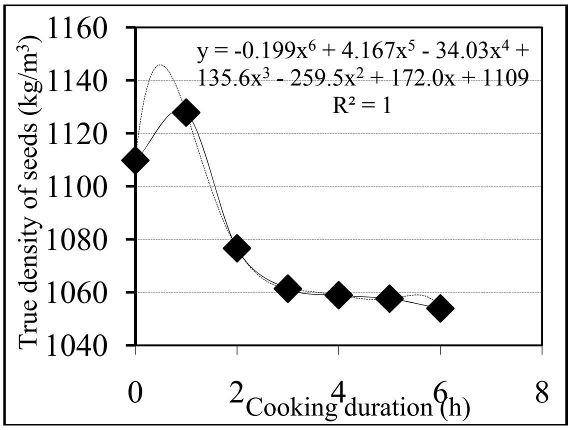

Fig. 9. Variation of true density of nere seeds with cooking time

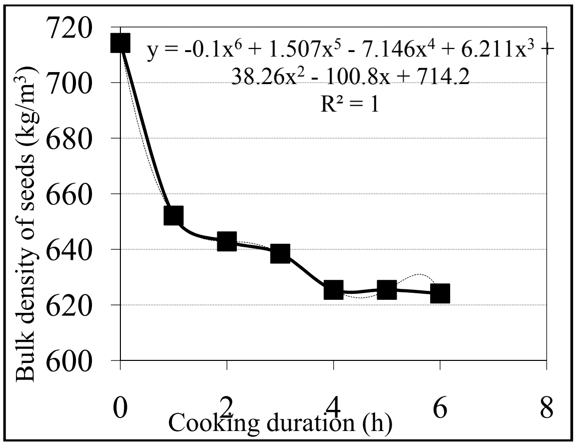

Fig. 10. Dependence of bulk density of nere seeds on cooking time

6. DISCUSSION

The major impacts of cooking of *Parkia biglobosa* seeds were dimensional changes and swelling, as observed on *Parkia fillicoidea* [18]. The cooking treatment generated discernible modifications at seeds size level, but the notable effects were lengthening of the seeds.

6.1. Dimensional Changes and Dehusking

Knowledge of the seed length and wi-dth as function of cooking time provided indi-cators for the design of shelling grids. For co- rrect seed dehusking, the space between the two consecutive perforations of the grids must be less than the smallest seed length and wid-th, i.e. ~ 8.3 mm.

The seed thickness was best indication for adjustment of the breathing gap between the fixed and mobile perforated grids of the machine, hence the possibility of varying the value of arranged gap between the two decorticating grids from 0 mm (touching grids) to 5.95 mm (cooked seeds thickness).

The high value recorded for increase in thickness (lengthening) originated from the sum of thickness of two cotyledons, and slit separation, added to two times the hull and gap between hull and cotyledons. The value of separating gap between cotyledons of seed could be assumed null with regard to the seed length or width as seeds were water engorged.

Upon boiling water treatment, the water engorged seeds exhibited increase of mass from water imbibitions of the cotyledons and hulls (Fig. 6), and the behaviour provided useful indicators on the attainable values for dehusking rate and output capacity versus cooking time. The indicators served to appraise the technical performance of a seed decorticator, through computation of the dehusking output, as evidenced by increase in the seed-particle sizes shown in Table 2. During cooking, the mass of hulls evolved more quickly than that of cotyledons, as the hulls continuously absorbed water which contributed to softening the seeds structure, leading to destruction of walls of the hull. Under combined actions of heat and moisture, the cotyledons absorbed water.

The cooking of the seeds caused dilation of hull and cotyledons (two major components). The phenomenon of swelling might have weakened the seed hulls, inducing efficient dehusking operation.

Knowledge of 1000-seeds volume also facilitated design of some components of the decorticator, such as, seed hopper and shelling compartment.

The effects of cooking might be linked with water engorged seeds that generated increase in mass (Fig. 5), enlargement of diameter causing volume expansion (Fig. 7), and subsequently, variations in values of the true and bulk densities.

5.2. Porosity and Weakening of Seeds

Porosity signifies degree of emptiness or space in the seed when not subjected to an external pressure. The change in seed porosity (Fig. 10) was a function of existing gap between hulls and cotyledons, and might explain adherence reduction of the two major parts of the seeds.

Maximum value of porosity of seeds was reached after 1 h of cooking, which could mark the beginning of adherence weakening between the seed hulls and cotyledons. After 4 h cooking, the seeds porosity recorded minor variations, indicating that no significant changes took place at adherence level of hulls and cotyledons. The corresponding cooking time could be regarded as the appropriate moment or best indicator for accomplishing efficient seed dehusking.

6. CONCLUSIONS

Experiments were conducted to assess influences of cooking treatment on the physiccal characteristics of nere seeds (*Parkia biglobosa)* through analysis of the induced changes.

When the seeds were cooked at 102 °C for 1 to 6 h, the physical characterization parameters underwent various changes. The parameters which increased with cooking time were the water content of seeds (from 16.14 to 284.62 % (db), 1000-seeds mass (from 231.66 to 508.33 g) and treated seeds volume (from 20.80 to 48.20 x 10^3 mm^3). The effect on the seed lengthening was observed in the three main axes as changes in seed thickness (20.4 %), length (14.5 %) and width (13.5 %).

Other parameters showed mixed behaviour that consisted of increase in value at the first hour of treatment followed by reduction for the remaining 5 h. The seed porosity changed from 35.6 to 42.2 % and finally to 40.78 %; the bulk density changed from 1109.8 to 1127.9 kg/m^3 and finally to 1053.9 kg/m^3, while the mass ratio changed from 73.40 to 89.28 % and finally to 64.95 %.

The true density of seeds exhibited decreasing trend from 714.3 kg/m^3 for raw seeds at time zero, to reach constant value of 624.1 kg/m^3 after about 4 h of cooking and maintained for the rest of the period.

The major impacts of cooking *Parkia biglobosa* seeds were dimensional changes and swelling, and variation of the seeds length and width as function of the cooking time provided indicators for the design of shelling grids.

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