Prev. Nutr. Food Sci. 2020;25(2):219-224
https://doi.org/10.3746/pnf.2020.25.2.219
pISSN 2287-1098 · eISSN 2287-8602

Optimum Boiling Duration and Its Effect on Nutritional Quality and Acceptability of Mechanically Dehulled Unfermented Locust Bean Seeds

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ABSTRACT: Most locust bean processing is still carried out locally in Africa. Dehulling is one of the major challenges encountered in traditional processing of locust bean seeds. Boiling time prior to dehulling is vital for nutritional status of locust bean. Hence, this study explored the influence of boiling duration before dehulling on the nutritional quality of mechanically dehulled locust bean seeds. The samples were subjected to four different boiling durations (1∼4 h) and the resulting effects on the overall acceptability, proximate composition, mineral content, and pH were evaluated. Locust beans boiled for 2 h and dehulled at the speed of 398 rpm gave the highest crude protein content, crude fiber, crude fat, and ash content. The pH ranged from 5.48 to 5.77, while boiling improved the mineral content ranging from 0.25∼0.48 mg/100 g (potassium), 16.80∼28.00 mg/100 g (calcium), 3.85∼6.73 mg/100 g (sodium), and 40.00∼52.40 mg/100 g (magnesium). The tedious labour during dehulling of locust bean seeds can be reduced at 398 rpm dehulling speed without adversely affecting the slightly acidic status and nutritional quality; thus enhancing quality and overall acceptability. Adoption of boiling raw locust bean seeds for 2 h under pressure prior to dehulling is a valuable procedure to eliminate long hours of boiling and tedious labour during local and industrial production.

Keywords: boiling time, locust bean, mechanical dehulling, nutritional quality, overall acceptability

INTRODUCTION

Locust bean is an indispensable condiment to millions of West Africans. Fermented locust bean is known by different names such as Ogiri-igala (South-East and South-South, Nigeria), Soumbala (Mali, Cote d'Ivoire, Guinea, and Burkina Faso), Dawadawa (Ghana, Niger, and Northern Nigeria), and Iru (Southern Nigeria) (Sanya et al., 2013). Locust bean is collected annually in large quantities, about 200,000 tons in some areas of Nigeria especially in Kwara and Oyo states (Jaiyeoba and Ogunlade, 2017). Processing of locust bean as condiment is an optimistic source of income and investment in these communities (Adeoye et al., 2018). It's a good source of nutrients such as protein, fats, oil, carbohydrate, vitamin B2, and minerals such as calcium (Omodara and Olowomofe, 2015). Dehulling is one of the main operational units that determines the acceptability and its yield (Akabanda et al., 2017). Long hours of cooking (about 15 h) locust bean seeds prior to dehulling is a major hurdle during processing. Traditionally, processing of African locust beans involves the boiling of the beans for 12 h in excess water till it's very soft prior to hand dehulling. Afterward the resultant separated cotyledon will be boiled for an additional 3 h to make it softer. This is tedious, energy consuming and uneconomical (Raheem et al., 2017). The local method of locust bean seed dehulling continues to inflict drudgery on the rural women whose livelihood depend on this business. Current research in developing machinery for processing locust bean in order to combat this has been carried out (Okonkwo et al., 2019). However, the demand for establishing a standard production timeline that will enhance uniform operations for boiling prior to dehulling while not adversely affecting quality, nutritional status, and acceptability of the mechanically dehulled locust beans is needed. Hence, this study focus-

Received 30 December 2019; Accepted 17 March 2020; Published online 30 June 2020

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es on evaluation of the nutritional quality, acceptability, and mineral analysis of mechanical dehulled locust beans in comparison with traditional dehulled locust beans. The study is germane to the industrial production on a large scale.

MATERIALS AND METHODS

Production of dehulled locust bean

Dehulling of locust bean seeds was carried out as described by Okonkwo et al. (2019). Locust bean seeds procured from Landmark University Teaching and Research Farm, Omu-Aran (latitude 8° 9° 0" N, longitude 5° 61° 0" E), Kwara State, Nigeria; were sorted, weighed and divided into 4 batches. The boiling time samples were varied as follows: boiled for 1 h, 2 h, 3 h, and 4 h using pressure pots/jackets. Resultant boiled locust bean seeds were then cooled for 10 min and dehulled at 398 rpm with a newly developed locust bean dehuller (Fig. 1), which was constructed by the Agricultural and Biosystems Engineering department of Landmark University, Omu-Aran, Kwara State, Nigeria. Clean water was let into the machine from the hopper. Dehulling was attained from the entry point to the exit point. Control was boiled for 12 h and dehulled manually as described by Omafuvbe et al. (2004) for traditional processing of locust bean. Samples were collected, packaged into containers, and labeled for further analysis.

Sensory evaluation

A panel of 35 judges who are regular consumers of locally produced locust beans conducted sensory evaluation on the mechanically dehulled beans for the different boiling durations and compared these to the unfermented sample from the traditional method (cooked for 12 h). The judges scored colour, appearance, texture, flavor, and overall acceptability of the coded samples using 9-point hedonic scale scores ranging from 1 to 9 signifying dislike extremely and like extremely respectively (Ifesan et al., 2017). The Landmark University research ethics boards approved this study (LUAC-0045B).

pH determination

Calibration of the pH meter (model 6505, Jenway, Staffordshire, UK) with standard buffer solutions (4.0, 7.0, and 9.2) was carried out before taking the readings. Dehulled locust bean sample (10 g) was weighed into 100 mL beaker and 20 mL of distilled water was added to the sample. The suspension was stirred continuously with glass rod for 30 min at 5 min interval. pH was measured by immersing the glass electrode well into the partly-settled suspension [Association of Official Analytical Chemists (AOAC, 2010)].

Determination of proximate composition and mineral content

The proximate composition (moisture content, total ash, crude fiber, crude protein, and carbohydrate content) and mineral contents of the locust bean were determined using the standard methods of the AOAC (2010).

Moisture content determination

Moisture content of the mechanically dehulled locust beans was determined by drying in a Gallenkamp forced hot air oven. The determination was carried out in triplicate. Each sample (5 g) was weighed into pre-weighed moisture content cans. The samples were dried for 3 h at 105°C and the weight taken. Drying continued until their weights were constant. The samples were cooled to room

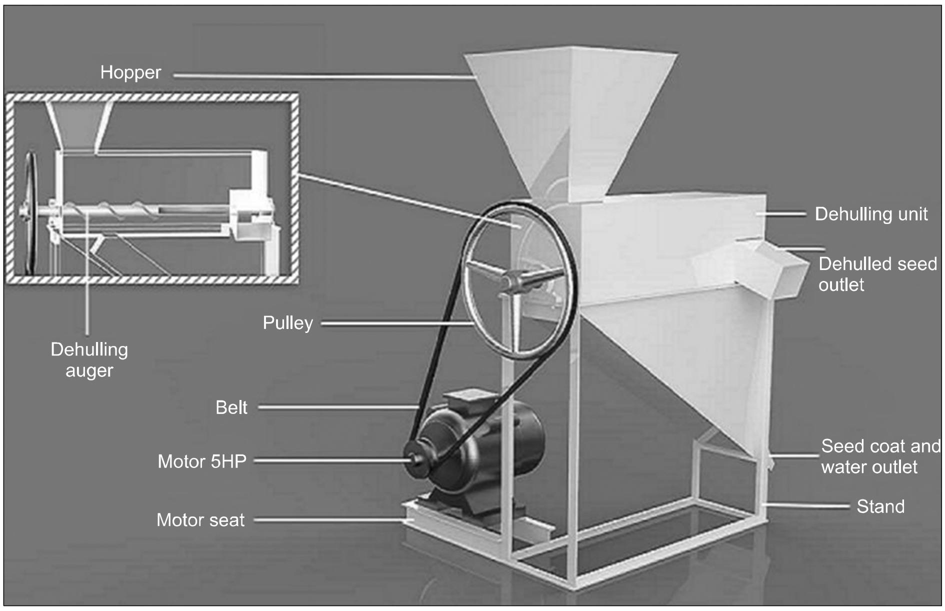

Fig. 1. Locust bean seed dehulling machine (Okonkwo et al., 2018).

temperature in a desiccator, weighed, and recorded. The final weight of each sample was determined and the moisture content was calculated from the weight loss equation below (AOAC, 2010):

$$\text{Moisture content (\%)} = \frac{w_1 - w_2}{w_1} \times 100$$

where w_1 is weight of sample before drying (g) and w_2 is weight of sample after drying (g).

Crude protein determination

Crude protein was evaluated using Kjeldahl nitrogen determination method as described by AOAC (2010). Sample (1 g) was weighed into digesting tubes and a tablet of Kjeldahl was added. Sulphuric acid (12 mL) was added through a dispenser and mixed thoroughly. Labeled samples in a rack of 8 were then placed on a digester for 1 h to digest the samples. The samples were allowed to cool, and on cooling down, samples were then taken to the automatic distillery (Foss™ KJeltec™ 8200 Auto Distillation Machine, FOSS, Hilleroed, Denmark) for 5 min. The distillate was titrated against 0.01 M HCl with an automatic titrator. Percentage nitrogen was then calculated; crude protein content was estimated by multiplying with the factor 6.25.

Crude fat content determination

Fat content for all dehulled locust bean samples was determined by a continuous extraction liquid-solid method using Soxhlet extractor with a reflux condenser and a distillation flask (previously dried and weighed). Weighed (2 g) sample into an extraction thimble/filter paper was labeled and recorded (W_1) while weighed fat free 500 mL round bottom was recorded as W_2. The Soxhlet flask with sample was weighed and placed into the Soxhlet apparatus. The distillation flask was filled to two third capacities with petroleum ether (300 mL) and fitted on the Soxhlet extractor with a reflux condenser. Adjustment of the heat source to ensure that the solvent boils gently was done, and it was left to siphon 6 h. After siphoning the petroleum ether, the condenser was detached and the thimble or filter paper removed. Drying of the flask containing the fat residue was performed in an air oven at 100°C for 5 min, cooled in a desiccator, and then weighed (W_3). The difference in the final and initial weight of the distillation flask represented the oil extracted from the sample (AOAC, 2010).

Crude fibre determination

Crude fibre was determined using the weighed (W_1) defatted samples. Each sample was transferred into conical flask and 100 mL boiling 1.25% H_2SO_4 added. Each beaker was heated for 30 min with periodical rotation to prevent adherence of solids to the sides of the beakers. The solution was filtered and rinsed with 50 mL portions boiling water; repeated four times then dried. Boiling 1.25% (w/v) NaOH (Sigma-Aldrich Co., St. Louis, MO, USA) solution (200 mL) was added and the mixture was boiled for 30 min after which the contents of each beaker was removed and filtered through muslin cloth and washed with 25 mL boiling 1% sulphuric acid, three portions of 50 mL boiling water and 25 mL ethanol. The residue was dried at 100°C to a constant weight followed by cooling in a desiccator to room temperature and weighed (W_2). The weighed residue was ignited at 600°C in a Gallenkamp muffle furnace for 30 min, cooled in a desiccator and reweighed (W_3) (AOAC, 2010).

The percentage crude fibre in each sample was calculated as:

$$\text{Crude fibre (\%)} = \frac{W_2 - W_3}{W_1} \times 100$$

Total ash determination

Crucibles to be used for the determination were placed in the oven at 105°C for about 30 min, cooled in a desiccator to room temperature and weighed (W_1). The total ash (inorganic residue from the incineration of organic matter) was determined by dry ashing procedure. The samples (2 g) were weighed into a pre-weighed dry porcelain crucible. The samples were incinerated in a Gallenkamp muffle furnace at 550°C for 6 h. After ashing, the remains were removed from the furnace, cooled to room temperature in a desiccator and weighed. The porcelain crucible was weighed and the % total ash weight was obtained by using the equation below:

$$\text{Total ash (\%)} = \frac{\text{weight of ash (g)}}{\text{weight of sample}} \times 100$$

Carbohydrate determination

The carbohydrate content was determined by difference. The sum of the proximate composition of the respective samples was subtracted from 100 to obtain percentage carbohydrate:

$$\text{Carbohydrate (\%)} = 100 - (\text{\% moisture} + \text{ash content} + \text{crude fibre} + \text{crude fat} + \text{crude protein})$$

Determination of minerals

The amount of minerals present in the sample was determined as described by AOAC (2010). The ash of the sample obtained was dissolved in 10 mL of 2 M HNO_3 and boiled for 5 min, and filtered through a Whatman no.1 filter paper into a volumetric flask. The filtrate was made up with distilled water to 50 mL and used for determination of mineral content. Calcium, phosphorus, and magnesium were determined by atomic absorption spectrophotometer (Model 220 GF, Buck Scientific, East Norwalk, CT, USA). The standard curve for each mineral was prepared from known concentrations of mineral and the mineral content of the samples was estimated from the standard curve while sodium and potassium content were determined using Jenway Flame Photometer PFP7 (Cole-Parmer Instrument Co., Ltd., Eaton Socon, UK) (AOAC, 2010).

Statistical analysis

Analysis of variance (ANOVA) and Duncan's test were used for calculating the means from the replicate data in Microsoft Excel (version 2016, Redmond, WA, USA) for sensory analysis, proximate composition, and mineral content separately. Level of probability ($P<0.05$) was used to indicate the significance statistically.

RESULTS

Boiling duration effects on sensory characteristics of dehulled of locust bean

There were significant differences in the sensory characteristics of dehulled locust beans as the boiling duration increased. Samples boiled for 1 h before dehulling were the least preferred in terms of colour, appearance, flavour, texture, and overall acceptability (Table 1). Generally, an increase in boiling duration from 1∼2 h improved the colour of the mechanically dehulled locust beans samples (7.50) and compared favorably with samples produced using the traditional method (7.75) as there was no significant difference. Increasing boiling under pressure to 3∼4 h reduced the acceptability of the mechanically dehulled samples. Similar trends were recorded in appearance, flavour, and overall acceptability. The texture of samples however becomes more preferable as the boiling duration before dehulling increases, though there was no significant difference between samples boiled for 2 h, and 3 h, and control, respectively. Samples boiled for 2 h before mechanically dehulling were the most preferred and no significant difference was recorded when compared with samples produced by the traditional method. It was also observed that after 2 h, the overall acceptability of the samples decreased from 8.50 to 7.56 after boiling for 3 h.

pH of dehulled locust beans at different boiling time

The pH of all dehulled locust beans samples was between 5 and 6 making it acidic as presented in Table 2. The highest pH among the mechanically dehulled was recorded in samples boiled for 2 h (5.77) while samples boiled for 1 h had the lowest pH of 5.48. There was no significant difference between the pH values of dehulled locust beans samples at 3 h (5.68) and 4 h (5.63). Despite the change in boiling time, all samples retained a slightly acidic status. Thus, variation of boiling time did not affect the acidity of locust bean during dehulling.

Table 1. Effects of boiling time on sensory attributes of mechanically dehulled locust bean

Boiling time (h)	Colour	Appearance	Flavour	Texture	Overall acceptability
Control	7.75±0.03^{a}	8.71±0.02^{a}	8.25±0.01^{a}	8.00±0.04^{a}	8.25±0.05^{a}
1	5.50±0.05^{d}	3.00±0.05^{d}	6.00±0.03^{d}	6.01±0.08^{c}	6.00±0.04^{d}
2	7.50±0.02^{a}	8.55±0.03^{a}	8.00±0.01^{a}	7.75±0.01^{b}	8.50±0.02^{a}
3	7.00±0.01^{b}	7.00±0.02^{b}	6.32±0.03^{c}	7.87±0.02^{b}	7.56±0.01^{b}
4	6.00±0.03^{c}	6.50±0.01^{c}	6.52±0.04^{b}	8.25±0.03^{a}	7.25±0.05^{c}

Values are means±standard deviation (n=35).
Means followed by different letters are significantly different ($P<0.05$) along columns according to Duncan's multiple range test.
Control: produced using traditional methods.

Table 2. Effect of boiling time on pH and proximate composition of mechanically dehulled locust bean (unit: %)

Boiling time (h)	pH	Crude fat	Crude fibre	Crude protein	Ash	Moisture	Carbohydrate
Control	6.00±0.45^{a}	17.39±0.09^{c}	5.27±0.05^{a}	30.43±0.04^{d}	3.39±0.07^{c}	18.39±0.02^{a}	19.13±0.35^{d}
1	5.48±0.01^{c}	15.45±0.82^{d}	4.47±0.05^{b}	35.50±0.12^{c}	2.55±0.05^{d}	7.55±0.53^{e}	34.48±0.59^{a}
2	5.77±0.03^{b}	20.87±0.07^{a}	5.55±0.61^{a}	37.70±0.06^{a}	5.13±0.25^{a}	8.05±0.12^{d}	23.40±0.04^{c}
3	5.68±0.01^{bc}	20.72±0.05^{b}	4.46±0.08^{b}	36.40±0.03^{b}	3.82±0.75^{b}	8.80±0.15^{c}	30.52±0.79^{b}
4	5.63±0.01^{bc}	18.51±0.15^{c}	3.13±0.11^{c}	35.00±0.01^{c}	3.74±0.50^{b}	9.45±0.17^{b}	30.17±0.98^{b}

Values are means±standard deviation (n=3).
Means followed by different letters are significantly different ($P<0.05$) along columns according to Duncan's multiple range test.
Control: produced using traditional methods.

Effects of boiling variation on proximate and minerals composition of dehulled locust beans

Crude fat content was between 15.45∼20.87%. It increased from 15.45% to highest content with 20.87% recorded in samples boiled for 2 h, then became relatively stable for another one hour (3rd h) then decreased to 18.51% when boiled for 4 h resulting to continually decrease as the boiling time increases (Table 2). The ash content ranging from 2.55 to 5.13 followed a similar trend as observed in fat content. Highest crude fiber content was recorded in samples boiled for 2 h (5.55%) and lowest was 3.13% in samples boiled for 4 h showing a probable impact of longer period of boiling on the crude fiber content. Crude protein for all samples ranged between 35.00% and 37.70%; samples boiled for 2 h were the highest (37.70%) followed by 3 h (36.40%), 1 h (35.50%), and 4 h (35.00%) respectively. The moisture content of the samples increased from 7.55∼9.45% equivalent to a 25% increase as the boiling time increases before dehulling the locust beans. The carbohydrate content was lowest in the samples boiled for 2 h (23.40%). Moisture content for traditionally dehulled locust bean samples was significantly different and the highest at 18.39%. However, it was lower in crude protein (30.43 %) and carbohydrate compared with all mechanically dehulled samples boiled at different times (Table 2). The results inferred that boiling of locust beans before dehulling for 2 h improved crude protein, crude fiber, crude fat, and ash contents compared to boiling for 3 h and 4 h, respectively. There were significant differences in mineral content of all samples at $P<0.05$ (Table 3). The phosphorus content increased from 44.38 to 74.01 mg/100 g for 1∼3 h of boiling followed by a sharp decrease to 47.91 mg/100 g in samples boiled for 4 h as shown in Table 3. The sodium content ranged from 3.85∼6.73 mg/100 g and the values were not stable as the boiling time increases. The optimum value 6.73 mg/100 g was recorded in locust beans samples boiled for 3 h before dehulling; magnesium followed a similar trend. A decrease in potassium from 0.48∼0.25 mg/100 g occurred as the duration of boiling increased while calcium increased in samples from 16.80∼28.00 mg/100 g for boiling locust bean before dehulling from 1 to 3 h. However, it decreased to 18.40 mg/100 g after 4 h of boiling. Mineral content of samples produced using the traditional method were also lower compared to the mechanically dehulled samples.

DISCUSSION

Samples boiled for 2 h before dehulling were the most preferred and compared favorably with the samples produced traditionally. Increase in boiling time before dehulling significantly improved the appearance, colour, and flavor of the locust bean. This constitutes an important factor in the overall acceptability of the final product by consumers. The pH values from the study were within the range reported by Iheke et al. (2017). Thus, variation of boiling time did not affect the acidic nature of locust bean hence the samples met the criteria for further fermentation. Unfermented African locust beans have been reported to be more acidic than the fermented samples (Ajewole et al., 2018). The proximate composition of all the samples were in accordance with some previous researchers (Femi-Ola et al., 2008; Kwaw, 2014; Omodara and Olowomofe, 2015; Ndukwe and Solomon, 2017; Jide et al., 2018). The moisture content of the samples increased by 25% as the boiling time increases; these may result in softness and affect the texture of the locust beans. This could either be desirable or not, depending on the specification of the end product (whole seed or mashed fermented locust bean). High fat content document in the study will enhance the palatability of the final product and this was in agreement with Ohizua et al. (2017). Increase in fiber content after boiling for 2 h before dehulling locust beans is also advantageous. Fibre has been reported as essential for absorption of water and providing roughage for the bowel. It also helps in intestinal transit (Aremu et al., 2015; Ajewole et al., 2018). African locust bean has been recognized as a potential protein supplement in the diets of protein deficient adults and children due to its rich protein content (Ajayi et al., 2015; Iheke et al., 2017). High crude protein content of mechanically dehulled locust bean samples (35.50∼37.00

Table 3. Mineral analysis of mechanically dehulled locust bean (unit: mg/100 g)

Boiling time (h)	Phosphorus	Sodium	Potassium	Calcium	Magnesium
Control	40.03±0.33^{e}	2.95±0.04^{d}	0.20±0.03^{c}	13.55±0.05^{e}	36.50±0.10^{e}
1	44.38±0.11^{d}	6.41±0.00^{a}	0.48±0.01^{a}	16.80±0.07^{d}	52.40±0.15^{a}
2	63.25±0.03^{b}	4.17±0.32^{c}	0.37±0.00^{b}	17.60±0.02^{c}	47.60±0.20^{c}
3	74.01±0.02^{a}	6.73±0.02^{a}	0.36±0.01^{b}	28.00±0.05^{a}	49.20±0.13^{b}
4	47.91±0.15^{c}	3.85±0.00^{b}	0.25±0.03^{c}	18.40±0.02^{b}	40.00±0.11^{d}

Values are means±standard deviation (n=3).
Means followed by different letters are significantly different ($P<0.05$) along columns according to Duncan's multiple range test.
Control: produced using traditional methods.

%) documented in this study was slightly higher than those reported by Akabanda et al. (2017) and in agreement with Iheke et al. (2017). The reduction in ash content of the locust beans after 2 h of boiling with or without pressure could be attributed to leaching of the solute inorganic salt in the samples into water during processing as boiling time increases (Omafuvbe et al., 2004; Doumta and Tchiégang, 2011). There were significant differences in the mineral content of samples as boiling time increased notably potassium and calcium. Increase in boiling time has been reported to be directly proportional to the rate of leaching into the water (Omodara and Olowomofe, 2015; Ajewole et al., 2018).

In conclusion, boiling of locust bean seeds for 2 h prior to dehulling at 398 rpm speed improved the crude protein content, crude fiber, crude fat, and ash content, and was analogous with the traditionally processed samples. The best locust bean sample in terms of nutritional quality was the one boiled for 2 h. Boiling under pressure for 4 h is not recommend as it did not improve the quality and acceptability of the mechanically dehulled locust beans. Hence, long hours of boiling, tedious labour during dehulling of locust bean seed can be eliminated at 398 rpm dehulling speed without negatively influencing the nutritional status and acceptability of dehulled locust bean: thus, improving it. Adoption of this study will create a convenient, energy saving procedure for industrial production of locust beans as well as improve the well-being of the rural dwellers without altering the nutritional quality and overall acceptability of dehulled locust beans.

ACKNOWLEDGEMENTS

I am appreciating Mr. Olajide, Mr. Alake, and all the technologists of Landmark University for their supports during the research work.

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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