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Optimization of shelling efficiency of a *Moringa oleifera* seed shelling machine based on seed sizes

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ABSTRACT

Moringa oleifera seed is an oil bearing seed which contains substantial quantity of lipid acid. The seed is usually shelled before oil extraction. In this study the shelling efficiency of a moringa seed shelling machine was optimized based on seed sizes (small, medium and large). Response Surface Methodology was applied in the optimization of the shelling efficiency of the machine. Seed condition (moisture content), operation parameters (cylinder-concave clearance, cylinder speed and feed rate) and design parameter (cylinder bar inclination) were considered as the independent factors while the response variable was shelling efficiency. The experimental design adopted was five factors, five levels Central Composite Rotatable Design (CCRD) of second order polynomial model. The optimization of the moringa seed shelling machine has optimum moisture content, cylinder-concave clearance, cylinder speed, feed rate and cylinder bar inclination values of 13.75%,7.62 mm, 303.50 rpm, 30.00 kg/h, 42.76° for small moringa seed size; 11.75%,7.87 mm, 291.79 rpm, 29.80 kg/h, 40.0° for medium moringa seed size; 11.75%,8.00 mm, 248.65 rpm, 30 kg/h, 40.0° for large moringa seed sizes respectively. Shelling efficiencies for the three sizes (viz. small, medium and large seed sizes) have optimum values of 99.17%, 100% and 100% with desirability values of 0.73, 0.67 and 0.76 which indicated the nearness of the response to the predicted values and adequacy of models established in describing the observed values. The optimization of moringa seed shelling process showed the optimal processing conditions for small, medium and large sizes of moringa seed. The optimization of the moringa seed shelling machine would provide necessary information on combination of seed, operation and design parameters for enhanced shelling efficiency based on seed sizes.

1. Introduction

*Moringa oleifera*is a forest crop (non-timber crop) which belongs to moringaceae family. It is a non-toxic natural organic polymer (Ramachandran et al., 1980; Bichi, 2013; Vieira et al., 2010). It produces oil bearing seed which has several industrial uses.There are 13 species of moringa trees in the family of Morigaceae. The plant produces fruit having the shape of a drumstick which contains the seeds (Price, 2007; Aviara et al., 2013). These species are native to India and some part of Africa. It is a very important plant in the northern part of Nigeria. In Nigeria moringa plant is native to Northwestern zone which is the most promising ecological zone in the country for the crop (Ambi et al., 2011; Yakasai, 2006). Ndubuaku et al. (2014) reported a mean annual pod and seed production capacity of 37.69 t/ha/yr and 16.74 t/ha/yr for rainforest vegetation, forest-derived savannah vegetation and arid derived savannah vegetation in Nigeria.

Moringa seed has several potentials which can be exploited by applying appropriate technology in its processing; moringa shell has been discovered to be an excellent feed constituent for animals. Moreover, moringa seed shell has industrial application in production of bio-composites because of its lightness. The flocculant present in*Moringa oleifera* seeds improve water quality; the kernels are known to remove cyanobacteria, lead, iron and cadmium ions from contaminated water. The shell of moringa seed has also been reported to be used in production of high quality activated carbon (Khawaja et al., 2010; Lürling and Beekman, 2010). This necessitates the shelling of moringa seed to maximise the utilization of the kernel and shell. Moreover, kernel damage is a factor arising from mechanized processing of moringaseed which must be put into consideration to reduce losses (Fadele and Aremu, 2016). Sitkei (1986) reported that mechanization has unwelcome implications such as mechanical damage during processing, whereby the quality of agricultural material is reduced or eventually become valueless.Process optimization is useful in minimizing undesirable characteristics or properties in processed

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agricultural materials. This technique could as well be applied in maximizing parameters such as shelling efficiency. Process optimization is a statistical method which involves combination of several variables with the purpose of obtaining the best output. Optimization of most unit operation in food processing is often achieved by application of Response Surface Methodology (RSM). Response Surface Methodology is a collection of mathematical and statistical techniques that are useful for modeling and analyzing situations in which a response of interest is influenced by several variables, and the objective is to optimize this response (Montgomery and Runger, 2002). Kumar et al. (2016) studied the optimization of sal seed decorticator to improve its performance; Rashid et al. (2011) also optimized the transesterification of *Moringa oleifera* seed oil using response surface methodoloy to obtain the optimum condition for the process. Figueiredo et al. (2014) analyzed the performance of sunflower seed dehuller to improve whole kernel out-turn using Response Surface Methodology (RSM). Figueiredo et al. (2013) also optimized the dulling ability of a dehulling system for safflower applying RSM. Fakayode and Ajav (2016) studied the optimization of mechanical expression of moringa oil from moringa seed. The seeds were manually shelled before the extraction process. Moreover, seed size is a factor that influences shelling process. Most researchers have worked on effects of variation in sizes of agricultural materials on decortications and shelling processes. Seed sizes are normally categorized into three viz. small, medium and large. It was reported that the sizes of the seed depend mainly on the thickness of the shell for most seed (Ogunsina and Bamgboye, 2012; Gupta and Das, 1999; Akubuo and Eje, 2002; Ogunsina and Bamgboye, 2014). The kernel sizes are not closely related to the external size of the nut. Irregularities in nuts or seed sizes can be dealt with by prior size grading, but it may be difficult to establish a workable machine setting for each size grade that will allow an acceptable balance to be achieved between the production of broken and whole kernels (Pinson et al., 1991). Fadele and Aremu (2016) developed a moringa seed shelling machine which was evaluated usingungraded moringa seed. However, it was necessary to optimize the performance of the moringa seed shelling machine to reduce kernel damage and improve the shelling efficiency based on seed sizes. Therefore, this research presents optimal combination of the seed condition (moisture content), operating conditions (viz. cylinder-concave clearance, feed rate and cylinder speed) and design parameter (cylinder bar inclination) in the shelling process of moringa seed using small, medium and large sizes of moringa seed.

2. Materials and methods

2.1. Sample preparation

Some moringa seeds were purchased in Ibadan from Association of Moringa Farmers (AMF). The seeds were cleaned manually to get rid of foreign materials such as stone, pods, leaves and so on. The initial moisture content of moringa seed was found to be 10.75% (w.b.) using ASABE (2008) standard for oil bearing seeds. Moreover, the seeds were graded into three size grades, small, medium and large seed sizes using screens as shown in Fig. 1. The length, breadth and thickness of the graded moringa seeds were measured using a digital vernier caliper (Mitutoyo Precision Instrument, reading to 0.01 mm). The Geometric Mean Diameter (GMD), Arithmetic Mean Diameter (AMD) and sphericity of the graded moringa seeds was determined applying Eqs. (1)–(3) respectively. The GMD, AMD and sphericity of small, medium and large grades of moringa seeds were 9.64 ± 0.66 mm, 11.05 ± 0.59 mm and 12.23 ± 0.59 mm; 9.69 ± 0.65 mm, 11.10 ± 0.59 mm and 12.33 ± 0.57 mm; 0.88 ± 0.05, 0.90 ± 0.05 and 0.86 ± 0.07 respectively as shown in Table 1. The mean values of the length, breadth, thickness of small, medium and large grades of moringa seeds were 10.92 ± 0.80 mm, 8.88 ± 0.71 mm and 9.27 ± 0.85 mm; 12.30 ± 0.78 mm, 10.25 ± 0.79 mm and 10.73 ± 0.79; 14.30 ± 1.22 mm, 10.88 ± 0.81 mm and 11.81 ± 0.86 mm while the kernel and shell percentages were 74.73% and 25.27%; 76.58% and 23.42%; 71.31% and 28.69% respectively as presented in Table 1. Samples of each grade were moistened using a calculated quantity of water to condition them to the desired moisture content using Eq. (4). The seeds were sealed in some polythene bags and left for three hours so as to enhance moisture stability and uniform distribution of moisture within the seeds (Sharma et al., 2013; Aremu and Fadele, 2010).

Fig. 1. Moringa seed grading.

Table 1
Some Physical Properties of Various Grades of Moringa Seeds.

Sizes and Shapes		Observations	Min	Max	Mean	SD
Small	Length (mm)	100	8.68	12.78	10.9219	0.79511
	Breadth (mm)	100	7.30	10.70	8.8824	0.71123
	Thickness (mm)	100	7.37	10.95	9.2742	0.84557
	Sphericity	100	.77	1.02	0.8847	0.05029
	Geometric Mean Diameter	100	8.04	11.04	9.6440	0.65836
	Arithmetic Mean Diameter	100	8.08	11.05	9.6928	0.65025
	Percentage of Kernel in Seed (%)	10	66.67	80.0	74.73	4.49
	Percentage of Shell in Seed (%)	10	20.0	33.33	25.27	4.49
Medium	Length (mm)	100	10.23	14.95	12.3040	0.77617
	Breadth (mm)	100	8.49	11.92	10.2524	0.79350
	Thickness (mm)	100	9.00	13.48	10.7349	0.79002
	Sphericity	100	.79	1.02	0.8998	0.04697
	Geometric Mean Diameter	100	9.77	12.79	11.0509	0.59218
	Arithmetic Mean Diameter	100	9.78	12.87	11.0971	0.58628
	Percentage of Kernel in seed (%)	10	70	80.56	76.58	3.14
	Percentage of Shell in seed (%)	10	19.44	30.0	23.42	3.14
Large	Length (mm)	100	11.35	17.69	14.3081	1.21786
	Breadth (mm)	100	8.54	13.46	10.8814	0.80695
	Thickness (mm)	100	9.52	13.82	11.8102	0.86163
	Sphericity	100	.66	1.02	0.8594	0.06616
	Geometric Mean Diameter	100	11.01	13.80	12.2279	0.58528
	Arithmetic Mean Diameter	100	11.04	13.88	12.3332	0.57396
	Percentage of Kernel in seed (%)	10	60.53	76.92	71.31	4.53
	Percentage of Shell in seed (%)	10	23.08	39.47	28.69	4.53

$$GMD = (abc)^{1/3} \tag{1}$$