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Research Paper

Engineering

Design Modification and Performance Evaluation of a Melon *(Citrullus lanatus)* Depodding Machine

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ABSTRACT

Design modifications were carried out on an existing melon (Citrullus lanatus) depodding machine. The existing machine can adequately depod melon but it had no mechanism for separating seeds and the pulp to obtain clean seeds. The modifications made include; the incorporation of water showering system, which represents the mechanism of seeds removal from depodded pulp; the incorporation of a reciprocating sieve (cleaning system), which removes unwanted material from clean seeds; and the addition of seed guard system, which influences the flow of seeds directly into the reciprocating sieve (cleaner). The performance evaluation of the machine was carried out on three different melon treatments i.e. freshly sliced pods, fresh and unsliced pods, and fermented pods. The performance evaluation of the machine was conducted under five different pulley speeds i.e. 229 rpm, 187 rpm, 163 rpm, 150 rpm and 122 rpm, in a 5 x 3 factorial experiment which was replicated 3 times. Results of the performance evaluation of the modified machine indicated significant improvement over the existing one. There was reduction in clean seeds output with reduced speed of the machine for the sliced, unsliced and fermented pods respectively. The maximum overall efficiencies on the basis of the considered operating speeds of the machine are 89.2, 77.4 and 93.4% for the sliced, unsliced and fermented pods, respectively. The difference in overall machine efficiency at speeds of 229, 150 and 122 rpm is significant at P = 0.05 but not significant at speeds 187 and 163 rpm. The highest depodding efficiency (98% at 229 rpm speed) was observed while the machine worked on fermented pods. Seed discharge efficiency on the basis of the considered operating speed varies linearly with machine speed and was highest (91.3%) on fermented pods at speed of 229 rpm, while the highest mean discharge efficiency on sliced pod was 85.0% at speed 229 rpm.

KEYWORDS: Melon; depod, design modification, performance, efficiency

1. INTRODUCTION

Melon (*Citrullus lanatus)*, grown for its seed, has probably been domesticated in the southern Sahel zone or in regions surrounding the Kalahari desert. It is especially important in West Africa. The seeds are increasingly used for their oil in semi-arid regions and also the use of the oil in the cosmetic and pharmaceutical industry is increasing. There are also prospects for use of the seeds in the improvement of infant nutrition in view of their high protein and fat content. The introduction of new melon cultivars into traditional cropping systems combined with appropriate cultural practices will improve the suppression of weeds and soil erosion and will reduce the production costs. Research is needed on the development of improved agronomic practices and labour-saving equipment for seed extraction and shelling.

World production of melon seed in 2002 was reported as 576,000 tons from 608,000 ha. Production in Nigeria amounted to 347,000 tons from 361,000 ha, Cameroon produced 57,000 tons, Sudan 46,000 tons, DR Congo 40,000 tons, Central African Republic 23,000 tons and Chad 20,000 tons. Outside Africa, China is important with a production of 25,000 tons. An estimated 5000–7000 tons is traded from Nigeria to other West African countries. Sudan (where production for seed is important especially in Kordofan) exports about 27,000 tons, mainly to Arab countries; however, quantities fluctuate strongly from year to year. Unrecorded trade of pulp and oil from the seed to African communities in North America and Europe occurs. For the Kalahari region international trade has recently started, but is still on a small scale.

Melon is popular in Nigeria because of the edible seeds which have varied uses in preparation of local soup or stew and snacks. The main cultivars found in Nigeria are *Bara, Serewe* and *Sofin*. *Bara* also known as *Papa* has large brown seed with thick black edges thickened towards the apex, about 16 x 9.6 mm and is common in the northern and western part of Nigeria. The 100 seed weight is about 14g, while *Serewe* seed are smooth, light brown, with a light whitish edge that is not thickened about 15 x 9mm in dimension. They are mainly found in eastern Nigeria. Analysis made on melon seed Ajilola *et al.* (1990) indicated that melon seed contains about 50% oil by weight, 37.4% of protein 2.6%fibre, 3.6% ash and 6.4% moisture. Out of the oil content of the seed, 50% are saturated fatty acids, which are stearic and palmitic acids. The presence of unsaturated fatty acids, makes melon nutritionally desirable and suggest a possible hypocholesterolic effect (lowering of blood cholesterol). Research has shown that the consumption of melon seed and its product reduce the chance of developing *terra arterial* or heart diseases Ajilola *et al*. (1990). Melon has amino acid profile that compare favourably with that of soybeans and even white of eggs Oyenuga and Faluga (1975). Also USDA Nutrient database shows that melon is a rich source of sodium (Na), Iron (Fe), Manganese (Mn), Cupper (Cu), Zinc (Zn) and fat. The nutritional value for melon per 100g are: carbohydrate – 7.6 g, dietary fibre – 0.4 g, fat -0.2 g, protein – 0.6 g and vitamin C – 8 mg Gorski (1985).

The oil extracted from the melon seeds can be used in the manufacture of margarine, shortening and cooking oils, while the residual cake is a useful source of protein for livestock feed. Melon seed is also used for producing melon snack known as *Robo*. Melon seeds may account for up to 80% of dietary protein and may be the only source of protein for some group where it is used to substitute meat or fish Aidoo (1986).

Processing of melon include fermentation, coring, washing, drying, cleaning, shelling and oil extraction (Figure 1).The process of breaking melon pods to remove seeds is known as melon depodding. In Nigeria, the traditional technologies are still employed in the processing of melon. These include manual depodding of melon fruit and decaying of fruits in a heap. These techniques are not only energy sapping and time consuming, they yield low quality products, while the rotten pods contribute to environmental pollution Aviara and Hague (2002).

Taking a careful look at the usefulness of melon seeds, there is a need for efficient means of processing it. Research into melon processing is highly relevant to the developing countries because melon seed contribute nutritious diet in the tropical and subtropical countries. One of the stages in melon processing is the removal of seeds from pods known as depodding. With the expansion of the alternative processing options for melon seeds, it will improve the quality of its product. Fur-

thermore, market will be created and farmers would be offered a good price for their products with a consequent sustainable production.

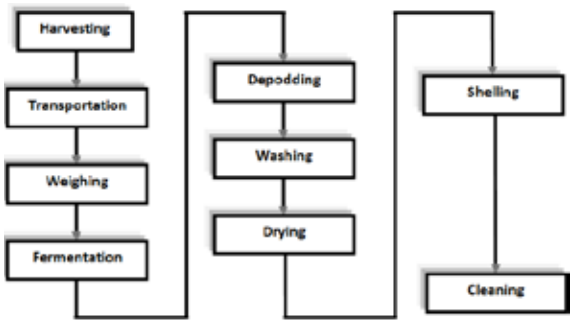


Figure 1: Process chart for melon processing.

Despite the large productivity and nutritional potentials of melon, there has been a hindrance to the use of melon for a large–scale production of oil and protein source. This is as a result of the inability to process melon to meet the capacity required for industrial use over a specified period of time. In order to address the problem associated with melon processing, Odigboh (1979) designed and constructed a melon shelling machine using the centrifugal impact method. Likewise, Fadamoro (1999) designed and constructed another machine based on the principle of friction between a rotating disc and a stationary disc positioned to be parallel to the rotating disc. Oloko and Agbetoye (2006) also designed and constructed a melon depodding machine using the principle of impact forces. However, the efficiency obtained by each of these machines designed was a little above 30%. The equipment used in processing melon has been generally designed without taking into cognizance the physical properties of melon which includes size, mass, bulk density, sphericity, porosity, coefficient of static frictional and angle of repose and resultant systems leads to reduction in working efficiency and increased product losses (Manuwa and Afuye, 2004). Investigations have been carried out to determine the engineering properties of melon seeds such as axial dimension, geometric and arithmetic mean diameter, surface area, bulk density and static coefficient of friction of melon seeds in order to develop appropriate equipment that will alleviate laborious nature experience in processing the crop.

A coring machine was designed and used to remove the seed bearing pulp of the fruit core to accelerate decomposition of the mesocarp and endocarp (Akubuo and Odigboh, 1999). A guna seed extractor have been designed and developed Aviara *et al.* (2009). The machine utilizes the principle of impact forces from braker arms and macerators. It is made up of five units, namely the feed hopper, seed extraction unit, cleaning unit, power system and tool frame. The machine can extract two varieties of guna crop namely *Citrullus colocynthis* and *Citrullus lanatus* in the moisture ranges of 87.2% - 92.5% (wb) and 85.1% 89.7% (wb) respectively, obtained by varying the fruit storage duration. The maximum efficiency of the machine is 94.15%.

The melon depodding machine earlier mentioned (Oloko and Agbetoye, 2006) which utilize the principle of impact forces adequately depodded two of the main cultivars of melon found in Nigeria which are *Bara and Serewe.* A melon washing machine had earlier been developed (Oloko *et al*. (2002) to reduce drudgery involved in the traditional method of washing melon after fermentation and depodding. The design and construction of manually and motorized operated melon shelling machine using impact was reported to meet the domestic, commercial and industrial requirement of melon for food processing (Adekunle *et al.,* 2008). The machine is made up of three sections namely: The hopper, the shelling chamber which consists of the shelling disc and the shaft, and the gear system. The machine was made from locally sourced materials and it can be used in both urban and rural areas even where there is no power supply. The working principle of the machine was based on the principle of energy absorbed by a seed as a result of impact (collision) between the seed and a stationery wall which did cause the cracking and removal of the seed coat. The machine can be used to shell *Bara and Serewe* properly. The shelling efficiency of the machine is above 68%.

The difficulties inherent in the removal of seeds from pod has made it to constitute a bottleneck to the large–scale production and processing of the crop. A melon depodding machine which was previously designed and constructed (Oloko and Agbetoye, 2008) operated on the principle of impact forces from spikes on a rotating drum. It removes the seeds from the fermented pods and discharges pulp and seeds together. The seeds have to be removed and washed manually from the pulp which is tedious and time consuming. To solve this problem, there is a need to modify the existing melon depodding machine to enhance proper and effective removal of seeds from the fermented pods.

The specific objectives of the research were to;

i. test the existing melon depodding machine and identify its deficiencies;
ii. carry out design modifications on the machine components to improve its performance;
iii. fabricate and assemble the modified components of the machine; and
iv. evaluate the performance of the machine in depodding freshly sliced, fresh and unsliced, and fermented pods.

2. MATERIALS AND METHODS

2.1 Design Modifications

To improve the performance, design modifications were carried out on the existing melon depodding machine, specifically to ensure that both the seed extraction and cleaning are done by the machine. The modifications made include the design, fabrication and installation of a reciprocating sieve (seed-wash), where seeds from machine outlets are washed clean of other materials especially, the pulp. Another modification was the introduction of water flow system into the machine cylinder, which helps to wash-off seeds from the broken pod and pulp, and also to wash seeds into the reciprocating sieve. The last modification was the construction of 'seed-guard', which assisted the seed flow process from the cylinder chamber where pods are crushed before moving to the machine outlet.

In the design of these additional components, the following factors were taken into consideration:

i. the construction materials were adequate in strength and suitability so as to withstand the forces acting in the various component parts of the machine; and
ii. materials were sourced locally in order to minimize the cost of the construction.

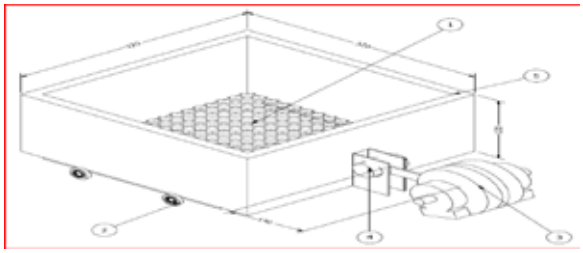
2.1.1 Reciprocating sieve

A simple definition of sieving is the separation of fine materials from unwanted materials by means of perforated vessels or mesh. It is a process very prominent in processing both cereals/grains such as maize, guinea corn, millet and root tubers such as cassava into local diet and beverages such as pap and burukutu (Inyang and Dabot, 2007). Sieves are effective, provided they are made to vibrate (Fellows and Hampton, 1992). The throughput of a sieve is dependent upon a number of factors, chiefly the nature and amplitude of the shaking; the methods used to prevent sticking of the sieve; the tension and physical nature of the sieve material (Earle, 1983).

The reciprocating action of the sieve is transmitted from an elliptical shaped cam which is connected to a shaft from a pulley driven by 1.50 kW, 1420 rpm electric motor (Figure 2). Rollers were attached below the shaking compartment to ensure that the oscillatory motion is transmitted smoothly on the sieve housing compartment to reduce vibration and noise as shown in Figure 2

2.1.2 Water Showering System

The pictorial view of the machine showing the water showering system and the sieve is shown in Figures 3 to 5. The system consists of a 0.75 kW water pump, which by suction transmits water from a reservoir to five outlets through piping systems. Four of the water outlets were located directly on the cylinder, while the remaining one was located in a position inside of the hopper. The dispense mechanism was designed such that water sprays in form of showers on all sides of the inner part of the cylinder through the outlets, in such a manner that enables all seeds to be washed-off the broken pods. The washing action of water pushes removed seeds into the reciprocating sieve where final cleaning and separation occurred.



Legend:

S/No	Part Description
1	Mesh
2	Roller
3	Cam
4	Support
5	Sieving Compartment

Figure 2: Isometric view of reciprocating sieve.

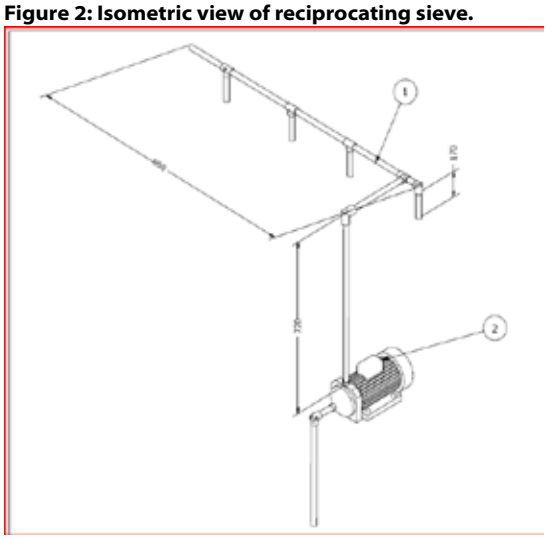


Figure 3: Water showering system



Figure 4: Reciprocating sieve separating and washing seeds off unwanted materials.



Figure 5: Pictorial view of the machine showing the water showering system

Table 1: Correlations statistics of clean melon seeds obtained from machine at varying speeds

		SP1	SP2	SP3	SP4	SP5
SP1	Pearson Correlation	1	.782*	.856**	.925**	.892**
	Sig. (2-tailed)		.013	.003	.000	.001
	N	9	9	9	9	9
SP2	Pearson Correlation	.782*	1	.780*	.889**	.614
	Sig. (2-tailed)	.013		.013	.001	.079
	N	9	9	9	9	9
SP3	Pearson Correlation	.856**	.780*	1	.894**	.795*
	Sig. (2-tailed)	.003	.013		.001	.011
	N	9	9	9	9	9
SP4	Pearson Correlation	.925**	.889**	.894**	1	.799**
	Sig. (2-tailed)	.000	.001	.001		.010
	N	9	9	9	9	9
SP5	Pearson Correlation	.892**	.614	.795*	.799**	1
	Sig. (2-tailed)	.001	.079	.011	.010	
	N	9	9	9	9	9
*. Correlation is significant at the 0.05 level (2-tailed).						
**. Correlation is significant at the 0.01 level (2-tailed).						

4.3 Machine Overall Efficiency (Eo)

The mean maximum and minimum overall efficiencies of the machine are 89.2 and 33.4, 77.4 and 32.6, and 93.4 and 42.6 for the sliced, unsliced and fermented pods respectively (Figure 9). The difference in mean overall efficiencies of the machine on sliced, unsliced and fermented are significant at P = 0.01. Pearson correlation coefficient of overall machine efficiencies showed high correlation coefficient r = 0.89 between sliced and unsliced pods, r = 0.85 between sliced and fermented pod and r = 0.80 between unsliced and fermented pods at P = 0.05>. Also, the difference in overall efficiency of machine at speeds 229, 150 rpm and 122 rpm are significant at P = 0.05 but not significant at speeds 187 and 163 rpm.

Multiple comparisons of means of overall efficiency of machine at speed 229 rpm showed that the mean difference between the machine efficiency of depodding sliced and unsliced pods are not significantly (0.127) at P = 0.05. The mean difference at speed 229 rpm between efficiencies at depodding sliced and fermented pods, and between unsliced and fermented pods are significant at P = 0.01. No significant different was observed in **Eo** among all pod treatments at operating speed 187rpm and 163rpm. The difference in E**o** of machine between unsliced and fermented pods is significant at P = 0.05 at speeds 150 and 122 rpm.

Generally, the machine was found to be more efficient in the depodding of fermented pod at all operating speeds when compared with the depodding of sliced and unsliced pods. Fermented pods were easily broken down under the impact of the machine anger spikes within the depodding chamber. The overall efficiency of the machine while working on fermented pods was least at speed 122 rpm and highest at machine speed of 229 rpm.

4.4 Depodding Efficiency, E_d

The machine depodding efficiency under varying speeds was found to be in the order 229 rpm>187 rpm>163 rpm>150 rpm>122 rpm. The mean depodding efficiencies of the machine while it worked on sliced pods were 92.6%, 80.8%, 71.9%, 71.6% and 60.1% at speeds 229, 187, 163, 150 and 122 rpm, respectively (Figure 10). The machine depodding efficiency on unsliced pods were lowest at all operating speeds considered with values 83.8%, 78.7%, 62.8%, 60.2% and 53.4% under speeds 229, 187, 163, 150 and 122 rpm, respectively. The highest depodding efficiency was observed while the machine worked on fermented pods. The depodding efficiency ranged from 98.8% at speed 229 rpm to 79.1% at speed 122 rpm. Lowest depodding efficiency observed under speed 122 rpm must have been caused by the reduced impact force of machine spikes on pods while the machine operates. Significant proportion of the unsliced and sliced melon pods escaped without being broken at speed 122 rpm.

Analysis of variance of the depodding efficiencies of machine on sliced,

unsliced and fermented pods shows that the difference is highly significant at the p = 0.05. Tukey's HSD analysis of the depodding efficiencies showed that the mean difference of the depodding efficiencies of sliced pods of machine between speeds 229 and 187 rpm, speeds 187 and 163 rpm, speeds 187 and 150 rpm are not significant at P = 0.05. The difference in the depodding efficiencies of machine on sliced pods between speeds 229 and 163 rpm, 229 and 150 rpm, 229 and 122, 187 and 122 rpm are significant at P = 0.05. The above observations implies that the depodding efficiency of machine was best influenced by the speeds 229 and 187 rpm while working the machine on sliced pods at lower speeds i.e. 163, 150 and 122 rpm may significantly lower the machine depodding efficiency.

The unsliced pods were much more affected at lower speeds in terms of depodding efficiency. The difference in mean efficiency of machine between 229 rpm and 187 rpm, 229 and 163 rpm, 187 and 163 rpm, 187 and 150 rpm, and between 163 and 122rpm are not significant at P = 0.05. The mean difference in depodding efficiency between 229 and 150 rpm, 229 and 122 rpm, and 187 and 122 rpm are significant at P = 0.05.

Conversely, fermented pods were best depodded and the depodding efficiency of machine was well enhanced by the fermentation of pods before being fed into machine. Significant difference in depodding efficiency was recorded between speed 229 and 122 rpm and between 187 and 122 rpm at P = 0.05.

3.5 Seeds Discharge Efficiency

Seed discharge efficiency was highest (91.3%) on fermented pods at speed of 229 rpm, while the highest mean discharge efficiency on sliced pod was 85.0% at speed 229 rpm. Though, there were reductions in the seed discharge efficiency of machine with reduced speed of machine in the order 229 rpm>187 rpm>163 rpm>150 rpm>122 rpm, the least efficiency was observed at speed 122 rpm in fermented pods. The efficiency of seed discharge at speed 122 rpm were 51% and 45.1% under sliced and unsliced pods respectively. The plot of seed discharge efficiency against machine operating speeds is shown in Figure 10. The correlation coefficient between seed discharge efficiency and machine operating speed was high for the three pod treatments with values of 0.99, 0.97 and 0.94 for the sliced, unsliced and fermented pods respectively.

3.6 Machine Performance with Respect to Existing Melon Depodding Machine

The modified melon depodding machine is obviously a significant improvement on the existing machine considering the machine performance. The incorporation of showering, sieve and seed guard systems into the modified machine has reduced the drudgery involved in the process of removing melon seeds from pods. Also, seeds loss associated with the operation of the existing machine reduced with the inclusion of a mechanism (seed guard) that directs seeds flow system appropriately in the machine. In terms of overall machine performance efficiency on depodding fermented pods, the existing machine could only attain a marginal efficiency of 50.3% at a speed of 200 rpm, while the overall efficiency of the modified machine was significantly high (93.4%) even at a slightly higher speed of 229 rpm. Ultimately farmers' interest in melon production on a large scale basis will be enhanced through this technological breakthrough.

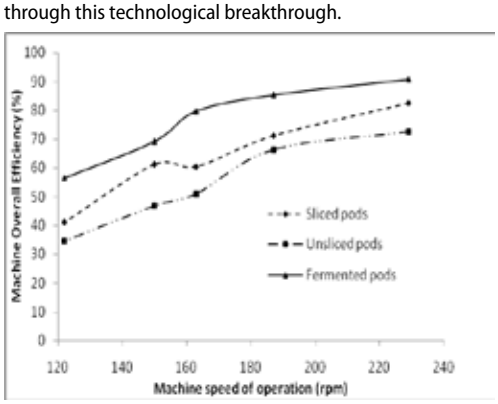


Figure 9: Machine overall efficiency at varying speeds on sliced, unsliced and fermented pods

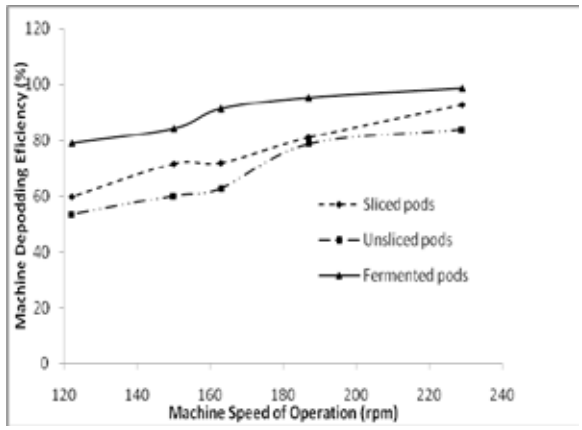


Figure 10: Machine depodding discharge efficiency at varying speeds on sliced, unsliced and fermented pods

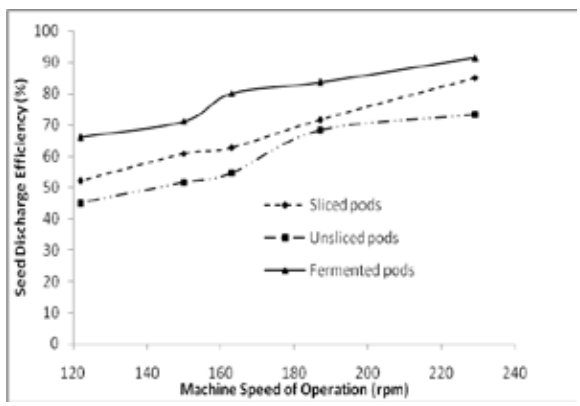


Figure 11: Machine seed discharge efficiency at varying speeds on sliced, unsliced and fermented pods

4. CONCLUSIONS

An existing melon depodding machine was modified and tested for performance at the workshop of the Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria. The modifications made on the existing machine include incorporation of: (i) reciprocating sieve that separates non-seed materials from discharged melon seeds, (ii) water showering system that wash-off seeds from the pulp and (iii) cylinder guide that prevents clean seeds from escape due to impact of machine spikes on pods. Seed discharge and depodding rates varied linearly with the machine speed of operation. Machine performance efficiency was enhanced when pods were fermented. Though, the efficiency of depodding sliced pods was equally enhanced at higher speeds, seeds extraction from pods were not significantly high when compared with the efficiency of depodding fermented pod.

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