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Performance Evaluation of a Locally Fabricated Roasted Groundnut Dehuller.

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Abstract: A locally fabricated roasted groundnut dehulling machine was evaluated for performance under three different speeds of 30, 40 and 50 rpm, and three crop moisture contents of 8%, 9% and 10% using three common varieties of groundnuts (Runner, Red Valencia and Kampala). The components of the dehuller include the hopper, a specially designed dehulling chamber, sprout orchute/outlet, frame and an electric motor-driven belt-pulley drive power transmission mechanism. The test results showed that the dehuller's operating speed and the roasted groundnut moisture content have significant effect on the mechanical damage and the dehulling efficiency. The efficiency of the dehuller decreased with increase in speed. It attained the highest efficiency of 92.1% at 9% moisture content and at an operating speed of 30 rpm, while the mechanical damage was minimal(1.86%) in the runner groundnut variety. All the materials used for fabrication were sourced locally. The dehuller has a capacity of 5.3 kg/h of roasted groundnut seeds. It is affordable, costing about four hundred and two thousand, two hundred Naira (N402,200 equivalent to US$335.17 at the rate of N1,200 to US$1) to produce, simple to operate, suitable for domestic uses and is also recommended for both small and medium scale roasted groundnut processors. The study provided useful information on the effective and efficient optimum conditions required for roasted groundnut dehulling. Further studies are suggested for further investigation by adopting the techniques used in this study for dehulling other similar crops.

Keywords: Dehuller**,** groundnut, roasting, performance evaluation, breakages, speed, moisture content

I. Introduction

Groundnut belongs to the family *Leguminosae,* subfamily *Papilionoidae*, tribe *Aeschnomeneae,* sub-tribe *Stylosanthinae*, genus *Arachis* and species *hypogaea* (Isleib *et al*., 1994).It is grown on 26.4 million hectares worldwide with a total production of 36.1 million metric tons, and an average yield of 1.4 metric tons/ha (FAO, 2013). According to FAO (2015) and Vara Prasad *et al.* (2009), groundnut is grown in nearly 100 countries with China, India, U.S.A, Indonesia, Nigeria, Myanmar and Sudan as major producers. Groundnut can thrive very well in all the States of Nigeria. Only 6 million hectares or 55,500 km^2 (5.1%) of the arable land are used for cultivating groundnut. With this little cultivated portion, Nigeria is ranked 1st in Africa and 3rd in the world after China and India in the production of groundnut with around 4.49 million metric tons (FAO, 2021).

Peanut or groundnut is one of the major oilseed crops of the tropics and subtropics, although it is also cultivated in the warm areas of the temperate regions. It is a valuable source of edible oil (43-55%) and protein (25-28%) for human beings, and of fodder for livestock (Ebunilo*et al*., 2016). About two thirds of world production is crushed for oil and the remaining one third is consumed as food(Ajeigbe*et al.,* 2015). The dry roasted groundnut is useful in preparation of peanut butter, confectionary or bakery products. After roasting, the testa is removed and the dried cotyledons are consumed. Roasting reduces moisture content and develops a pleasant taste which makes the product more acceptable for consumption. However, excess heating during roasting results in low nutritive quality of protein. In Nigeria, the processing of groundnut into various products is mostly done by women either for home consumption or for commercial purposes. Large quantities of groundnuts are lost annually due to lack of storage facilities and simple mode of processing. In order to improve its storability and value, various ways of processing the seeds have been adopted among which is the roasting (Alao *et al.,* 2020; Kabri *et al.,* 2006; Agboola *et al*., 2023; Lawson *et al*., 2023)) and removal of husk or rind from the roasted groundnuts (Gana *et al*., 2011; Ayelegun and Ajewole, 2015; Adekola *et al.,* 2018)

Dehulling is the removal of the outer skin from the groundnut seeds with mild pressure. This is a process employed to get rid of the outer pericarp and testa (hull) of most cereal grains, grain legumes, nuts and oilseeds using mechanical means. The removal of

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grains from their stalk, pod or cub can be achieved either by stripping, impact action and rubbing or any combination of these methods. The most popular method of dehulling which is still widely used in Nigeria is the method of pressing the roasted seeds between the thumb and the finger to remove the skin and release the seed. This method has low efficiency, it is time consuming, and has high demand of energy. In addition, the output per-man hour is as low as 1-2.5 kg of groundnut. Some works have been carried out on the design of roasted groundnut dehulling machine (Gana*et al.*, 2011; Ikechukwu *et al*., 2014; Ayelegun and Ajewole, 2015; Oladimeji and Lawson, 2019) with little success.There is need to achieve greater efficiency and minimize breakages and seed losses during the process of dehulling. The performance evaluation of a roasted groundnut seed dehulling machine designed and fabricated in the department of Agricultural and Environmental Engineering, Federal University of Technology Akure, Ondo state, Nigeria was carried out to assess the effects of groundnut moisture content and variety, and machine speed on dehulling efficiency, mechanical damage and seed losses andto ascertain the optimum operating parameters of the dehuller.

II. Materials and Method

The roasted groundnut dehulling machine was designed and fabricated at the Department of Agricultural and Environmental Engineering Workshop, Federal University of Technology, Akure, Ondo State, Nigeria in 2022.

2.1Design Considerations

The following factors were taken into consideration in the design and production of the machine:

i. Low cost of production totaling four hundred and two thousand, two hundred Naira (N402,200) which is about US$335.17 (at the rate of N1,200 to US$1).
ii. Physical properties of groundnut seed(sizes and mass) (Table 1)
iii. Ease of operation
iv. Properties of fabrication materials (Table 2)
v. Reduction of drudgery
vi. Aesthetics
vii. Safety
viii. Ease of maintenance

Table 1: Groundnut sizes and weight as a function of the varietal differences

Variety	Length (mm)	Breadth (mm)	Thickness (mm)	Mass (g)	Volume (mm^3)
Red Valencia	16.74[a]	8.75[a]	9.24[a]	0.667[a]	0.701[a]
Runner type	12.15[c]	7.82[b]	8.50[b]	0.483[c]	0.517[b]
Kampala	14.02[b]	8.65[a]	8.78[b]	0.598[b]	0.658[a]

Numbers within columns, with different letters in superscripts are significantly different from one another at P<0.05

2.3 Description and Operation of the Roasted Groundnut Dehuller

The roasted groundnut dehulling machine (Figures 1 and 2 and Plate 1) consists of the following components:

i. *Hopper:* This is a rectangular pyramid shaped hopper positioned at the top side of the machine. The hopper serves as input channel for groundnut to be dehulled.The volume, V (mm^3) was obtained as follows:

$$V = \frac{1}{3}h\,[A1 + A2 + \sqrt{A1.A2}\,] \quad (1)$$

Where A1 is area of larger base, (mm^2), A2 is area of smaller base (mm^2) and h is the height of the pyramid (mm).

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ii. *The Frame:* The frame is made of 40 x 40 x 3 (mm) mild steel angle with length and width of 615 and 460 mm respectively. The rectangular mild steel angle frame is firmly joined together by welding. Cross-sectional area of frame member is calculated using:

$$\text{Area} = 2t[L + B - 2t] \quad (2)$$

Where A is the length and B is the breadth and t is the thickness of frame in mm. Analysis showed that they satisfied the strength and rigidity requirement.

iii. *The Dehulling Chamber:* This is the core part of the machine because the dehulling of the roasted groundnut takes place in this unit. The volume of the cylindrical dehulling chamber was calculated by using equation;

$$\text{Volume of chamber} = \pi r^2 h \quad (3)$$

Where r is the radius of the circular base and h is the height of the cylinder

iv. *Sprout or Chute outlet:* This is where the roasted groundnut seeds and the chaff from the dehulling chamber are collected.The area (mm^2)is calculated using:

Area = L x B

Where L is the length in mm and B is the breadth in mm.

v. *Power Transmission System:*This was made up of a Vee-belt and pulley drive mechanism driven by a 3.8 kW (5 hP), 1420 rpm, single-phase electric motor.

The diameter of driven pulley, d_2 is given by the formula given in equation 4 (Khurmi and Gupta, 2005);

$$d_2 = \frac{n1d1}{n2} \quad (4)$$

Where d_1 is diameter of motor pulley in mm, n_1 is rotational speed of motor pulley in rpm and n_2 is the rotational speed of driven pulley in rpm.

The length of the belt was calculated from the measured driver and driven pulley diameters and also the centre distance between the driver and driven pulleyusing equation 5 (Khurmi and Gupta, 2005);.

$$L = 2C + \frac{\pi}{2}(d1 + d2) + \frac{(d1-d2)^2}{(4C)^2} \quad (5)$$

Where L is belt length in mm, and C is the centre distance between the driver and driven pulleys in mm.

Power requirement, P (kW) is given byBurr and Cheatham (2002);

$$P = (T_1 - T_2)V \quad (6)$$

Where T_1 and T_2 are the tensions in the tight and slack sides of the belt, and V is the linear velocity of the belt in m/s

The roasted groundnut to be dehulled is fed into the hopper, then it moves to the dehulling chamber where the upper and lower dehulling plates act on it by abrasive action to peel the roasted groundnuts. As the groundnut seeds are dehulled, they come out through the chute outlet where the already dehulled groundnuts are collected with the coats. The coats are then blown out manually.

Table 2: Table of materials selectionfor components of the dehuller

Machine Component	**Criteria forSelection**	**SuitableMaterial**	**MaterialSelected**	**Reason forSelection**
Dehulling chamber	High strength,rigidity and resistance to wear	Stainless steel	Stainless steel	Availability, workability durability and food grade.

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Spout/outlet	High strength, resistance to wear and rigidity	Wood, galvanized steel, stainless steel, mild steel	Stainless steel	Availability,work ability andresistance to corrosion
Belt drive	High strength	Rubber	Rubber	Workability and availability
Machine frame	High strength,rigidity and medium carbon	Wood, galvanized sheet, mild steel, stainlessSteel,angle iron	Galvanize steel	Availability workability and durability
Dehulling surface	Provide the required adhesive force needed to dehull roasted groundnut	Towel, rug, sand paper	Rug	Availability workability and cheap
Electric motor	It should be able to supply the required speed	Cast iron	Cast iron	readily available
Pulley	Adequate strength and rigidity	Cast iron, plywood	Plywood	Readily available, light, workability and cheap
Hopper	High strength rigidity and resistance to wear	Stainless steel, galvanized steel, mild steel	Stainless steel	workability readily available and resistance to corrosion

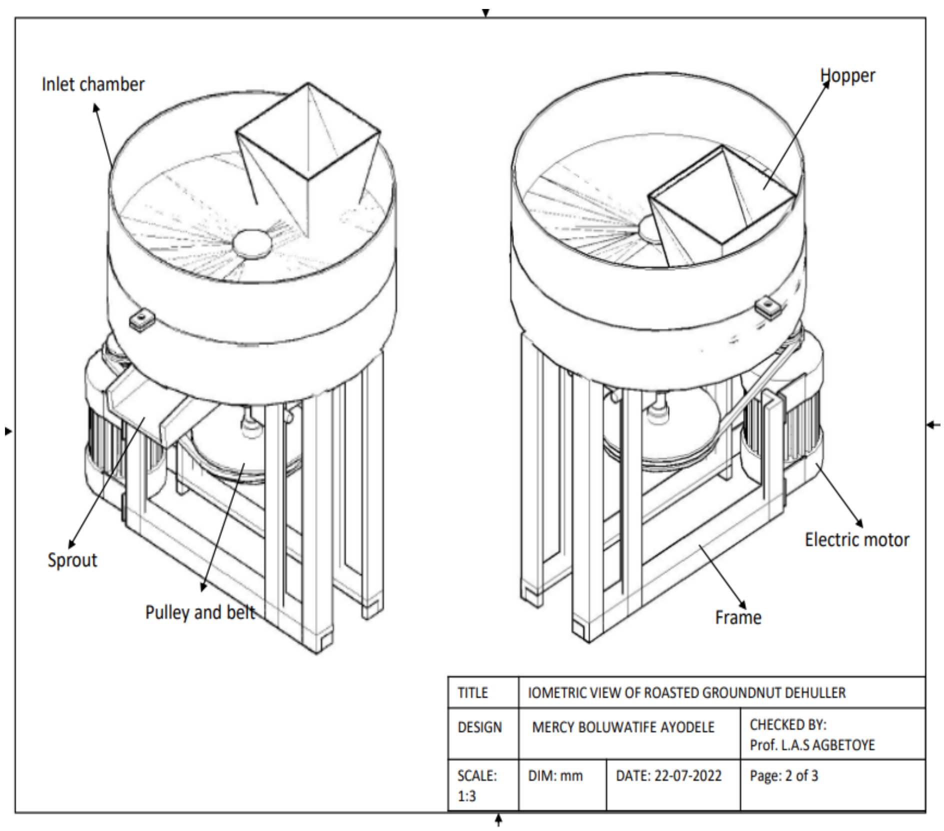

Figure 1: Isometric view of the groundnut dehuller

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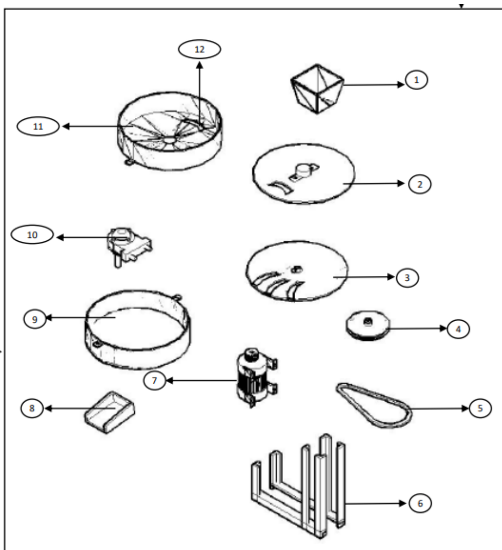

S/N	Description	Qty	Dimension (mm)
1	Hopper	1	270x270x200
2	Dehulling first plate (rug surface)	1	Ө500
3	Dehulling second plate (rug surface)	1	Ө500
4	Pulley	2	Ө200
5	Belt	1	
6	Frame	1	615x460
7	Electric motor	1	
8	Sprout	1	200x90
9	Dehulling chamber	1	910x610x460
10	Gear box	1	Ө510
11	Inlet chamber	1	Crank Mechanism
12	Roasted groundnut inlet	1	R60

TITLE	EXPLODED VIEW OF ROASTED GROUNDNUT DEHULLER		
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Figure 2: Exploded view of the groundnut dehuller

Plate 1: Fabricated roasted groundnut dehulling machine

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1.3 Performance Tests

Before starting the experiment, the required three varieties of shelled groundnut seeds were procured from the market, dried to the required moisture content and roasted at 60^0C to their respective moisture contents using the roasting machine available in the department (Agboola *et al.*, 2023). The moisture content in the initial and roasted groundnut seeds was checked using a speedy moisture meter. The machine speeds were varied by changing the diameter of the machine driven pulley. For each treatment, 0.215kg of the samples was measured using the weighing balance for the test and was replicated three times.

The following were the variables used in evaluating the performance of the machine. They include:

i. *Speed*: Three different speeds were used in evaluating the performance of the machine, 30 rpm,40 rpm and 50 rpm (Adekola *et al*., 2018).

ii. *Crop moisture content*: Moisture content of 8%, 9% and 10% were used in the performance evaluation of the roasted groundnut dehulling machine (Oladimeji and Lawson, 2019).

iii. *Variety*: Three different varieties of groundnuts were used in the process of the performance evaluation namely; Red valencia, runner and kampala groundnuts.

The following parameters were determined and used to evaluate the machine;

i. Dehulling efficiency: This determines how efficiently the machine dehulls the roasted groundnut. It is calculated using equation 1 (Ayodele, 2023);

$$E_{d\,(\%)} = \frac{Mi}{Md}\ X\ 100 \qquad (7)$$

Where: E_d is dehulling efficiency, M_i is mass of roasted groundnut before dehulling (kg) and M_d is mass of completely dehulled groundnut (kg)

ii. Mechanical damage: This determines the extent of damage on the roasted groundnut as a result of machine use e.g the extent at which the groundnut breaks, splits or grinds. It was expressed as shown in equation 2 (Ayodele, 2023);

$$Me_d\ (\%) = \frac{Ms}{Mi}\ X\ 100 \qquad (8)$$

Where: Me_d is mechanical damage (%), M_i is mass of roasted groundnut before dehulling (kg), and M_s is mass of splitted groundnut (kg)

iii. Losses, %: This determines the amount of roasted groundnut that is lost as a result of machine use. It was expressed as shown in equation 3 (Ayodele, 2023);

$$SL = \frac{\mathrm{Mi-Mf}}{\boldsymbol{Mf}} \qquad (9)$$

Where: SL = Seed losses (%), M_i is mass of roasted groundnut before dehulling(kg), and M_f is mass of roasted groundnut after dehulling (kg).

III. Results and Discussion

3.1 Effect of Speed on Dehulling Efficiency

Figure 3 shows the effect of dehulling speed on dehulling efficiency of the machine. It was observed that the speed is inversely proportional to dehulling efficiency. An increase in speed results in a reduction in the dehulling efficiency. Highest dehulling efficiency of 92% was recorded at the lowest speed (30 rpm) while the lowest efficiency of 73% was recorded at the highest speed (50 rpm) in all moisture contents (8, 9 and 10%) evaluated respectively. Low operation speed leads to an increase in dehulling efficiency indicating that roasted groundnut dehulling operation is an operation that requires low speed. This conforms to the findings of Adekola *et al*. (2018) that low operational speed gives better results in roasted groundnut dehulling. The increase is speed leads to a reduction in dehulling efficiency for all varieties of groundnut. Runner groundnut had the highest efficiency because of the easy to peel testa. Red valencia had the lowest dehulling efficiency because of the tough testa. Statistical analysis indicated significant effect of speed on the dehulling efficiency of groundnut at $P<0.05$ in the three varieties evaluated.

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3.2 Effect of Speed on Mechanical Damage

Figure 4 shows the mechanical damage of the roasted groundnut dehuller at different machine speed, moisture and with different varieties of groundnut. According to the figure, the mechanical damage ranges from 1.86 to 8.84%. The maximum value (8.84 %) of the mechanical damage was recorded at a machine speed of 50 rpm. The minimum value (1.86%) of the mechanical damage was recorded at a machine speed of 30 rpm. This figure also shows that as the machine speed increases from 30 to 50 rpm, the mechanical damage of the groundnut increases. This is because as the machine speed increases, there is an increase in the number of splitted and broken groundnuts. This is lower than the values obtained by Ayelegun and Ajewole (2015) and Adekola *et al.* (2018). Statistical analysis of the data showed that the dehulling speed had significant effect on the mechanical damage of the groundnut seeds at P<0.05 in all the varieties evaluated.

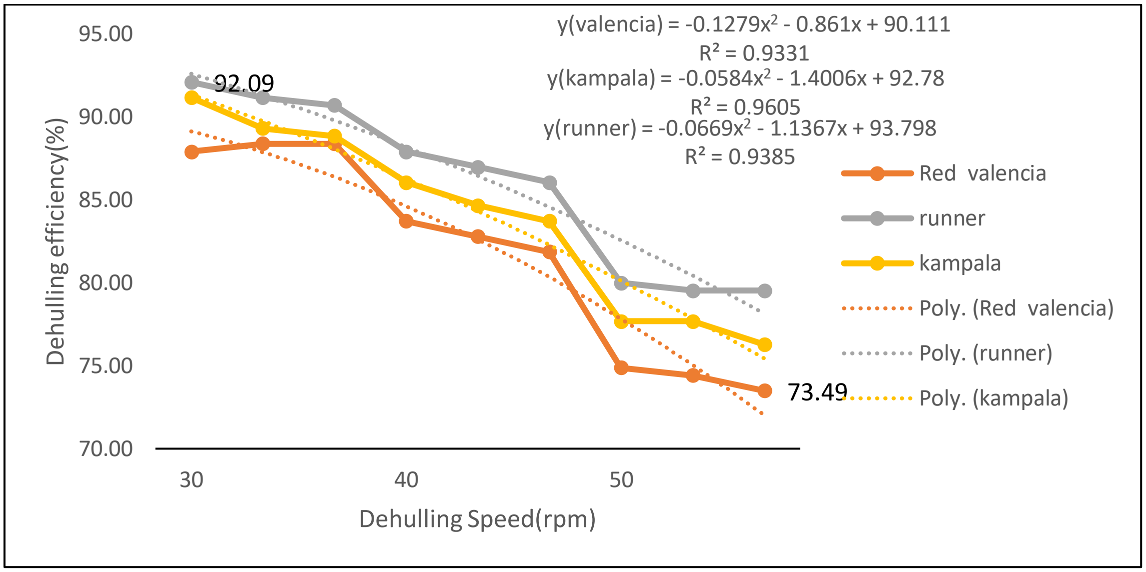

Figure 3: Effect of machine speed on dehulling efficiency for three varieties of groundnuts

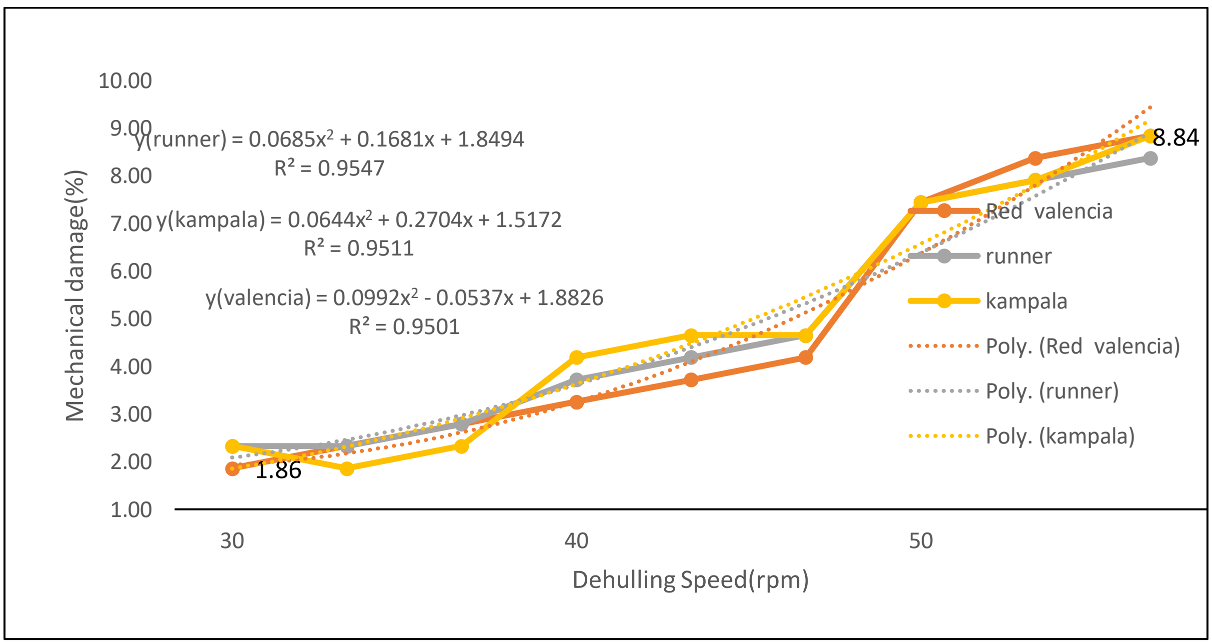

Figure 4:Effect of machine speed vonmechanical damage for three varieties of groundnuts

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3.3 Effect of Speed on Seed Losses(%)

Figure 5 shows the percentage seed losses of the roasted groundnut dehuller at different machine speed, moisture and with different varieties of groundnut. According to the figure, the seed losses range from 0.47 to 6.51%. The maximum value (6.51%) of the seed losses was recorded at a machine speed of 50 rpm. The minimum value (0.47%) of the mechanical damage was recorded at a machine speed of 30 rpm. This figure also shows that as the machine speed increases from 30 to 50 rpm, the seed losses of the groundnut also increases. This is because as the speed increases, there is an increase in the number of groundnut that flies out through the inlet. The statistical analysis of data indicated that there is no significant effect between speed and percentage seed losses at $P<0.05$. Similar results were obtained by

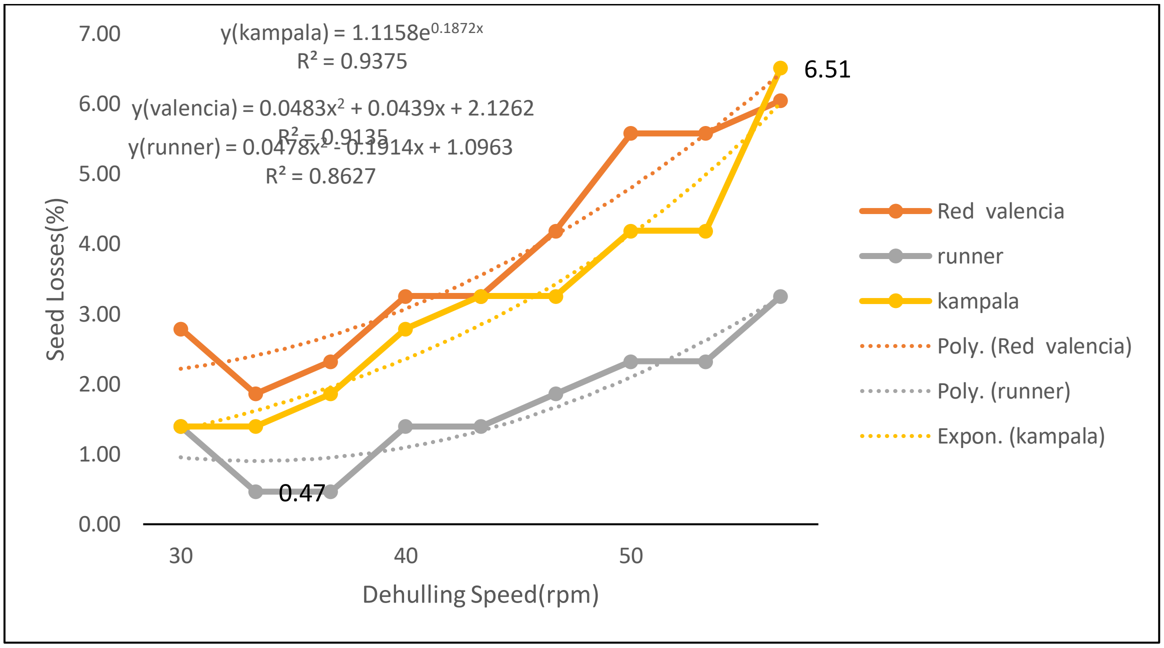

Figure 5: Effect of machine speed on seed losses for three varieties of groundnuts.

3.4 Effect of Seed Moisture Content on Dehulling Efficiency

It was observed (Figure 6) that the machine had the best efficiency of 92% at 9% moisture content which is the medium moisture and 30 rpm. In (Figure 7) the machine had the lowest efficiency of 73% at 8% moisture content which is the lowest moisture and 50 rpm This conforms to Oladimeji and Lawson(2019) that reported a similar case after obtaining the highest dehulling efficiency (80%) at 12% moisture content (w.b) from a range of moisture contents. The works of Gana *et al.* (2011), Ayelegun and Ajewole (2015) and Adekola *et al.* (2018) also showed similar trend. Hence, the medium moisture content is best for roasted groundnut dehulling.The moisture content of 8% was too dry hence leading to the breakage and grinding of the groundnut. The moisture content of 10% was still a bit wet so there was an increase in the number of un-dehulled groundnuts. The medium moisture content of 9% worked perfectly and dehulled efficiently.

IV. Conclusions

The results of the study gave high dehulling efficiency when used to dehull roasted groundnuts. Based on the machine evaluation, it was observed that the dehulling efficiency reduces with increase in dehulling speed. .It was also observed that as the machine speed increases above 30 rpm, the dehulling efficiency decreases and the mechanical damage increases. The best conditions derived from this study for dehulling roasted groundnut using the locally fabricated machine are: machine speed of 30 rpm and moisture content of 9% to yield a dehulling efficiency of 92.09 %, mechanical damage at a reduced value of 1.86 % and a seed loss of 0.47%. The machine will therefore eliminate the constraints in manual processing and also provide improved quality product thereby improving timeliness and reducing the drudgery associated with groundnut processing at domestic and commercial levels.

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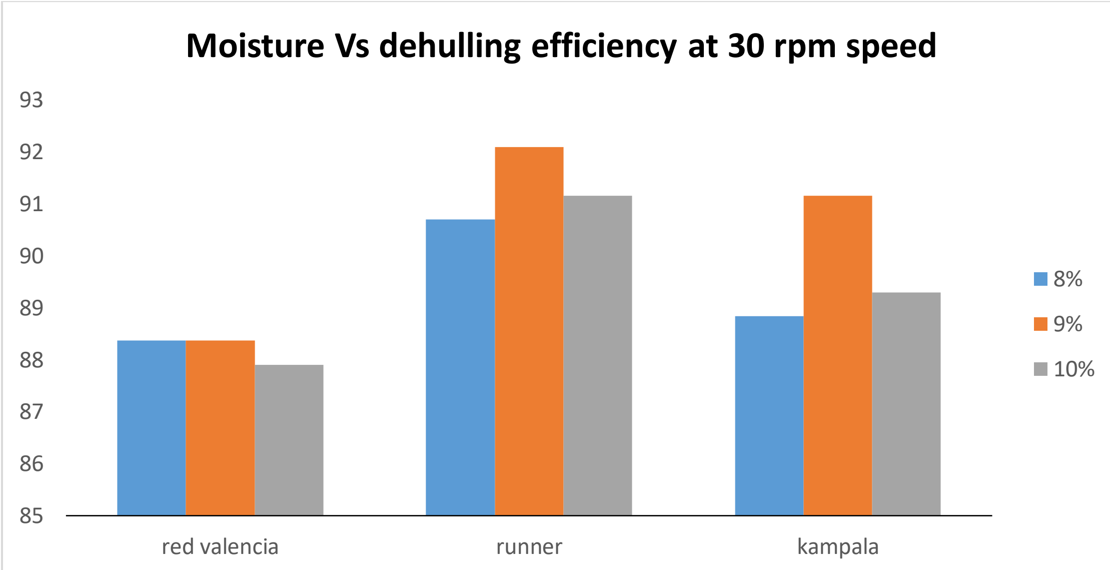

Figure 6: Effect of seed moisture content on dehulling efficiency at 30 rpm for three varieties of groundnuts

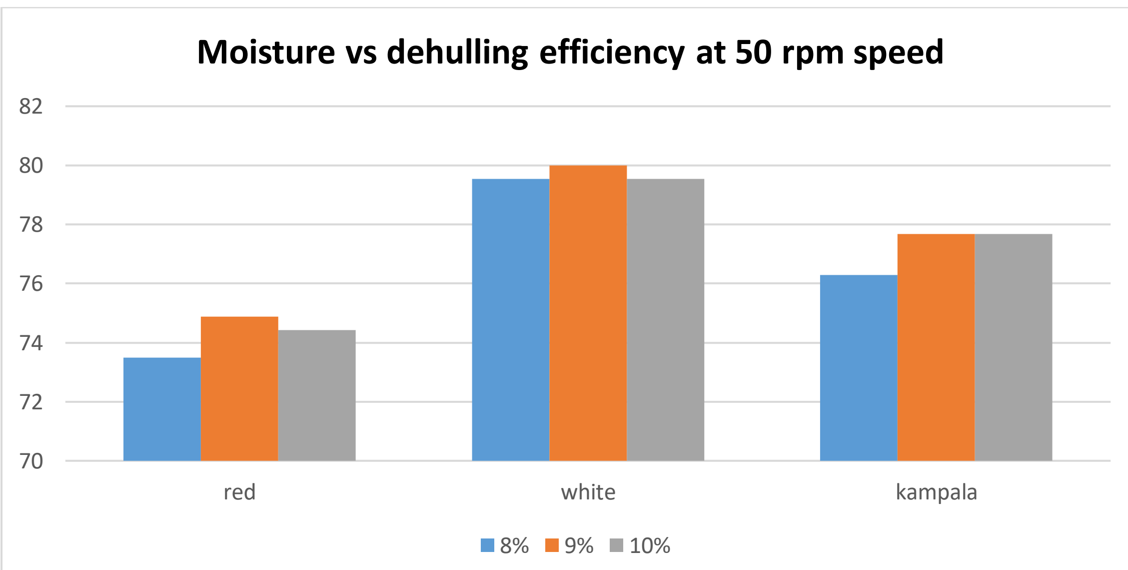

Figure 7: Effect of seed moisture content on dehulling efficiency at 50 rpm for three varieties of groundnuts

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