Comparative Study of the Developed Peanut Shelling Machines

Olufemi Adeyemi ADETOLA*, Opeyemi Emmanuel AKINNIYI*, Emmanuel Ayodeji OLUKUNLE*

*Department of Agricultural and Environmental Engineering, School of Engineering and Engineering Technology, Federal University of Technology Akure, Ondo State, NIGERIA

(*)& Corresponding author: oadetola@futa.edu.ng

ABSTRACT

The comparative study in the development of peanut shelling machines is presented. Peanut shelling constitutes a significant part of peanut processing. Researchers had developed different types of peanut shelling machines, addressing the problem of shelling groundnut. Some authors modified past machines to improve efficiency and get the best possible output. This study presents the trends of these shelling machines, performance evaluation, merits, and demerits. A look at the factors affecting the performance of the shelling operation is also considered. These factors include the groundnut size, moisture content, shelling speed, sieve, concave clearance. These factors were observed based on the operational parameters, including the shelling and cleaning efficiencies, mechanical damage, and throughput capacity. The operating speed of the machines ranged from 150–300 rpm; the range of the shelling efficiency, cleaning efficiency and terminal velocity were 78-98.32%, 50.63-91.67% and 7.7-12.9 m·s\(^{-1}\) respectively, while the mechanical damage ranged between 5.3-17.4%; the variation in the performance evaluation parameters is caused by the moisture content, variety, concave clearance, shelling speed, shelling blades, type of concave sieve. It was revealed that as the shelling speed increases, the mechanical damage and shelling efficiency increase whereas as the moisture content increases (5-15% wet base), the shelling efficiency decreases, and the mechanical damage and the terminal velocity increases respectively. These factors, in different ways, influence the revenue generated by farmers.

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➢ Shelling machine,
➢ Shelling efficiency,
➢ Moisture content,
➢ Operational parameters,
➢ Performance evaluation


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INTRODUCTION

Groundnut (*Arachis hypogaea* L.), also known as peanut or earthnut, is the most common crop for oil production in the world (Bhalavignesh *et al.*, 2019). It is grown on about 19 million hectares of land across the earth, one-third landmass, and principally for its edible oil content and protein-rich seeds (Lawal *et al.*, 2015). Groundnut is an important oil-related crop that is ranked the sixth in the universe. For humans, groundnut is a valuable source of edible oil (43-55%) and protein (25-28%) as well as feed for livestock (Darshan *et al.*, 2018). Groundnut can be traced to the Latin American Brazilians (Ejiko *et al.*, 2015). History shows that Peru was where groundnut was first cultivated (Karthik *et al.*, 2018). West Africa is the leader in the production of peanuts among developing countries. Delhagen *et al.* (2003) identified 14 countries in West Africa involved in peanut production and estimated that growth has increased by over 53% in the last 25 years. This shows us the volume and interest of countries in groundnut trading and production.

Groundnut (peanut) has moved to be cultivated in over 100 countries globally (Ravindra *et al.*, 2008), with developing countries contributing about 94% of the worldwide production (Ugwuoke *et al.*, 2014). Groundnut is prevalent in Nigeria who is a significant producer of groundnut in Africa. In 2008, amongst countries such as the Gambia, Togo, and Ghana, Nigeria accounted for 51% of groundnut production in the West African region and 31% in Africa, making her the most prominent producer (Ajeigbe *et al.*, 2015). This popularity can be seen in the different names given to it by various ethnic groups, such as *Epa* in southwestern Nigeria and *Isagwa* in South-Eastern Nigeria. In northern Nigeria, we can see the groundnut pyramids far back as the 1950s to 1960s.

The use of groundnut cannot be overemphasized as it cuts across many industries. It ranges from consumptive usage to industrial usages. This is because of the nutritional values of groundnut, and it can serve as addictive for several industrial products. Before the groundnut is being processed for usages, it undergoes some pre-processes to ensure the best possible output. These include cleaning harvested groundnuts, removing dirt and plan debris, and drying groundnut to control the moisture content influence on processing. Some common uses of groundnut include groundnut oil and groundnut (peanut) butter.

Over the years, manual groundnut shelling has been the livelihood of many groundnut growers. This is commonly accomplished by matching groundnuts or beating a bag of groundnuts with sticks. This is a time-consuming and tedious operation. It is inefficient since it results in significant groundnut losses. Machines, on the other hand, are required for mechanical shelling but because of their size and cost, these machines are still not widely used. Impact action, stripping, rubbing, or a combination of these methods are used to remove kernels from groundnut pods. The most common method of shelling is to break the pods and release the kernel by pressing the groundnut between the index finger and thumb (Ugwuoke *et al.*, 2014).

There are various methods of groundnut shelling, ranging from the traditional to the most recent ones. The methods of groundnut shelling are classified as follows by Ejiko *et al.* (2015). This is the manual application of energy by the groundnut shelling personnel. This includes the beating of groundnuts in bags, pressing the pods out with
your hands, and manually operating a shelling machine by rotating the wheels with the hand. This method is time-consuming and is often inefficient.

From its nutritious content to its diverse applications, processed groundnut is necessary for human consumption. This necessitates making the best use of harvested groundnut, which is not always the case with traditional approaches. Traditional methods typically result in significant waste due to breakage while pounding, difficulties sorting and cleaning, and other factors. This results in lower earnings for groundnut farmers or owners, which may deter farmers from trading in groundnut. Also, because groundnut processing firms would want to break even by selling the products at prices that meet their budgets, this makes groundnut output expensive.

Only if a significant portion of the total groundnut shelled is converted for consumption in a fair amount of time will optimal utilisation be attainable. Many groundnut shelling machines developed by researchers and authors have solved this problem; some are reliable, have high shelling efficiency but are expensive, while others are less expensive but less efficient in shelling and cleaning (Kittichai, 1984; Gore et al., 1990; El-Sayed, 1999; Singh, 1993; Okegbile et al., 2014; Ugwuoke et al., 2014; Ejiko et al., 2015; Alonge et al., 2017; Muhammed and Isiaka et al., 2019; Madi, 2017; Bhalavignesh et al., 2019). This is the problem that this project will investigate, with the goal of developing a dependable and economical groundnut shelling machine. There are many groundnuts shelling machines all around the world. The development of a new groundnut shelling machine will necessitate the study of previous designs. If a better groundnut sheller is imagined, constructed, and developed, it will need to consider shelling efficiency, production costs, power consumption, maintenance costs, and so on. Engineers can use the data offered in this study to design better groundnut shelling machines by looking at the trends of the machines that have been built by researchers over time.

**COMPARATIVE STUDY OF PEANUT SHELLING MACHINES**

Comparative study of peanut shelling machines was carried out. This involved obtaining information from the developed peanut shelling machines from different researchers. The factors affecting the performance of the shelling operation were considered: mainly the crop factors and the machine-based variables. The crops factors considered include the moisture content and variety of the groundnut. The machine-based factors evaluated include concave clearance, shelling speed, shelling blades, and sieve size. The machine parameters reviewed include the shelling efficiency, cleaning efficiency, terminal velocity, mechanical damage, and throughput capacity. The contribution of the authors, merits, and demerits of the shelling machines were reviewed with the view to provide information for engineers to develop a better peanut shelling machine.

**Factors affecting performance of groundnut shelling machines**

**Shelling efficiency, Mechanical damage, Material efficiency, Throughput capacity, Cleaning efficiency and Terminal velocity of a groundnut (peanut)**

Groundnut shelling is a fundamental part of groundnut processing. Butts et al. (2009) estimated that groundnut shelling accounts up to 38% of post-harvest costs. These large
per cents give reasons for optimal performance for any groundnut shelling technique, in this case, machines. Groundnut shelling machines are influenced by three factors, according to Abubakar and Abdulkadir (2012). Crop factors and machine-based variables are the two factors covered here. The effect of these factors' characteristics on some observable dependent parameters is used to evaluate the performance of these machines. Shelling efficiency, cleaning efficiency, throughput, and mechanical damage are all common parameters. Darshan et al. (2018) recommends using equations 1 to 4 to estimate these parameters.

\[ \text{Shelling efficiency (\%)} = \left( \frac{Q_u}{Q_t} \right) \times \frac{100}{1} \]  

\[ \text{Mechanical damage (\%)} = \left( \frac{Q_d}{Q_u+Q_d} \right) \times \frac{100}{1} \]  

\[ \text{Material efficiency (\%)} = \left( \frac{Q_u}{Q_u+Q_d} \right) \times \frac{100}{1} \]  

\[ \text{Throughput capacity \left( \frac{kg}{h} \right)} = \left( \frac{Q_u}{T_m} \right) \times \frac{100}{1} \]  

Where \( Q_u \) is the total weight of shelled groundnut, \( Q_t \) is the total weight of groundnut, \( Q_d \) is the total weight of damaged groundnut, \( Q_u \) is the total weight of undamaged groundnut, and \( T_m \) is the time to shell the groundnuts.

Cleaning efficiency involves the separation of the dehulled seeds from the pod/chaff. Alonge et al. (2017) recommends using equation 5 to estimate the cleaning efficiency.

\[ \text{Cleaning efficiency (\%)} = \left( \frac{W_d}{W_{wp}} \right) \times \frac{100}{1} \]  

Where \( W_d \) is the weight of dirt included in kernels and \( W_{wp} \) is weight of total dirt from shelled groundnut.

Terminal velocity is the greatest velocity that grains can achieve as they fall through air. It takes place when the downward force of gravity acting on the grains is equal to the drag force plus buoyancy (NASA, 2021).

\[ V_t = \sqrt{\frac{2mg}{\rho AC_d}} \]  

Where, \( V_t \) is the terminal velocity (m s\(^{-1}\)), \( m \) is the mass of falling grain (kg), \( g \) is the accelelation due to gravity, \( \rho \) is the mass density of particle (kgs\(^2\) m\(^{-4}\)), \( A \) is the Projected area of particle in perpendicular direction of motion (m\(^2\)), and \( C_d \) is the overall drag coefficient, \( g \) is the acceleration due to gravity (m s\(^{-2}\)).

The terminal velocity for several types of pods
The terminal velocity for several types of pods varied from 7.7 to 12.9 m s\(^{-1}\). Therefore, when creating devices for the separation of peanut parts, these variables could be taken into account. The air stream's velocity cannot be greater than 7.7 m s\(^{-1}\) in order to remove lighter material from the peanut pods (El-Sayed et al., 2001). For peanuts, the
terminal velocity increased from 7.25 to 7.93 m s\(^{-1}\) as the moisture content rose from 4.85 to 32.00 percent d.b. The terminal velocity was seen to rise linearly with increasing moisture content (Aydin, 2007). The findings are comparable to those made known by Kural and Carman (1997), however Aydin and Ozcan (2002) found that the values were lower than those for terebinth fruits. Due to the increased mass of a single peanut per unit frontal area exposed to the air stream, the terminal velocity increases as moisture content increases.

**Crop factors**

Mould growth, mite infestations, and sprouting can all be caused by excessively moist cereals and oilseeds, according to Armitage and Wontner-Smith (2008). On the other hand, over-drying grain before or during storage can cause splitting and cracking, as well as poor quality and energy waste. As a result, the moisture content is an important factor to consider (Rai et al., 2005). For all groundnut cultivars investigated, Gitau et al. (2003) reported that shelling efficiency rose as moisture content dropped. This is in line with the findings of Atiku et al. (2004), who discovered that when moisture content rises, shelling efficiency falls, and seed damage rises. Gamal et al. (2009) discovered that raising the moisture content causes the axial dimensions of the kernel to increase. According to Nyaanga et al. (2007), shelling efficiency reduces as moisture content rises. This is because the pods become friable after being imparted, allowing them to bend rather than fracture. Only a fraction of the peanut is shelled as a result. Researchers such as Adedeji and Ajuebor (2002) proposed a moisture content of 10-15% wet base to achieve the optimum shelling results. Nyaanga et al. (2007) and Akcali et al. (2006) suggested 5% wet base and 13% wet base respectively. Gitau et al. (2003) later proposed a 5% wet base.

**Variety**

Shoko and Mushiri (2015) classified groundnut into four varieties: Runner, Virginia, Spanish, and Valencia, as presented in Figure 1. Each groundnut has its unique properties such as the number of kernels, colour, etc. Several researchers have investigated the physical properties of various groundnut cultivars. Gitau et al. (2003) conducted one of these investigations at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Kenya. Akcali et al. (2006) conducted another study on groundnut cultivars developed by the Turkish government. They calculated the size of groundnuts by taking the average of the axial measurements, which include the minor, intermediate, and major diameters of the kernel. Results from the study showed that there was higher shelling efficiency for larger varieties.

![Figure 1. Varieties of groundnut (Shoko and Mushiri, 2015).](image-url)
Machine based factors

Concave clearance

Shelling efficiency and mechanical damage rise as concave clearance decreases, according to researchers. Although many researchers agreed, their concave clearance numbers for the best result were different. In Thailand, clearance between 7 mm and 15 mm was used for different groundnut varieties local to Thailand. It was observed that less damage and decreased shelling efficiency were obtained with a larger clearance. This conclusion was similar to that of Nyaanga et al. (2007), who found that increasing the concave clearance from 20 mm to 30 mm boosted the machine's shelling efficiency from 73.6 percent to 79.8% and raising the clearance to 40 mm reduced it to 73.2 percent. Shelling efficiency declined as clearance increased, and damage decreased significantly as clearance grew from 8 to 12 mm and gradually as clearance rose from 12 to 20 mm, according to Rostami et al. (2009). Bobobee (2002) proposes a concave clearance of 16-18 mm when working on a variable speed motor running at 180-220 rpm.

Shelling speed

Shelling efficiency rose to a maximum with increased speed, but reduced with increased speed, according to Nyaanga et al. (2007). Rostami et al. (2009) came to the same conclusion, indicating that speed increased shelling efficiency but had no effect on peanut damage. When employing a variable speed motor, Bobobee (2002) discovered that speeds of 180-200 rpm generate an output range of 240-250 kg h⁻¹ with a breakage rate of 10 – 14 percent in a pneumatic drum sheller. Further research into the ideal shelling speeds for castor oil fruits indicated that 240 rpm is the best. In their trials, Adedeji and Ajuebor (2002) and Balami et al. (2012) obtained the best groundnut shelling performance at 260 pm and 150 kg h⁻¹ feed rate. In-field groundnut shelling tests were conducted by Butts et al. (2009) using a cylinder revolving between 160 and 300 pm.

Shelling blades

Gitau et al. (2003) discovered that steel rod blade shellers outperformed wooden blade shellers in terms of shelling efficiency. Groundnut pods are shelled when they pass between the shelling blades' space and the concave sieve. One of the factors that influence shelling performance is the material of the blade; others include the design of the blade and the number of blades. Helmy et al. (2007) found that the shelling efficiency of a rubber-covered drum was lower than that of a steel or hardwood drum in an experiment. At speeds of 1.83 m s⁻¹ and 4.58 m s⁻¹, Helmy et al. (2007) discovered that increasing the number of blades from four to eight improved shelling efficiency. When rubbing peas, Kamboj et al. (2012) used L-shaped blades to generate maximal shelling motion. As a result, compared to shearing and impact, there was very little damage. Kernels with hard pods or coatings, such as Bambara nuts, are utilized in the shelling process, as are centrifugal impellers or rollers rotating in opposite directions (Siebenmorgan et al., 2006).

Sieves

The sieve size for groundnut shelling machines is determined by the type of groundnut and, more specifically, the size of the groundnuts to be shelled. The slotted grate sieve
and the wire mesh sieve are the two most frequent types of sieves. Helmy et al. (2007) found that the wire mesh sieve outperformed the slotted grate sieve in their study. Table 1 shows this information.

Table 1. Comparison of the wire mesh and slotted grate sieve.

<table>
<thead>
<tr>
<th>Type of concave sieve</th>
<th>Shelling capacity (kg h⁻¹)</th>
<th>Shelling efficiency (%)</th>
<th>Percentage breakage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire mesh</td>
<td>86</td>
<td>83.89</td>
<td>3.7-6.7</td>
</tr>
<tr>
<td>Slotted grate</td>
<td>60</td>
<td>82.84</td>
<td>8.4-12.6</td>
</tr>
</tbody>
</table>

Source: Helmy et al., 2007.

Trends in the development of groundnut shelling machines

The mechanized shelling machine is shown in Figure 1. This is the use of mechanical and electrically operated devices such as gasoline engines and electric motors. These devices are responsible for the operation of the machine as they supply the power required for shelling, either by converting mechanical energy from the gasoline engine or the electrical energy from the electric motor. This method consumes less time for shelling if compared to the manual methods considering the same tons of groundnut. Shelling mechanisms in the mechanized method involve reciprocating and rotary (Walke et al., 2017).

Figure 2. Mechanized shelling (Walke et al., 2017).

Over the years, there have been development of different groundnut shelling machines and decorticators by different group of engineers, intending to solve groundnut shelling-related problems. Kittachai (1984) developed the first recorded ground shelling machine which was called the power–operated groundnut sheller. This machine had a capacity of 210.5 kg h⁻¹ with it shelling efficiency and mechanical damage as 98% and 5.3% respectively. The machine capacity is lower than that of Muhammed and Isiaka et al. (2019) [233.81 kg h⁻¹], Ugwuoke et al. (2014) [400 kg h⁻¹] and Okegbile et al. (2014) [400 kg h⁻¹]. The shelling efficiency is higher than that of Okegbile et al. (2014) [78%], Gamal et al. (2009) [80%], Ejiko et al. (2015) [84%], Ugwuoke et al. (2014) [95.25] however it is similar to that of Muhammed and Isiaka et al. (2019) [98.32%]. The mechanical damage is lower than that of Ejiko et al. (2015) [14%], Okegbile et al. (2014) and Ugwuoke et al. (2014) [17.25%], Alonge et al. (2017) [17.4%] but higher than that of Muhammed and Isiaka et al. (2019) [4.33%]. The variation in the shelling efficiency and
mechanical damage might be due to different concave clearance used by the various researchers because it has been reported by researchers that decrease in concave clearance led to increase in shelling efficiency and mechanical damage.

The machine served as the reference point for many other groundnut shelling machines developed afterwards. New machines are being developed globally and locally for improvement in shelling machines: shelling efficiency and mechanical damage for the best possible output.

Atiku et al. (2004) produced a Bambara groundnut sheller that operates by a rotational mechanism. Figure 3 shows a typical groundnut shelling machine in action. They considered how the moisture content of the groundnut affected the pace of shelling. They discovered that as the moisture level in the air rises, the efficiency of shelling diminishes.

![Figure 3. Groundnut sheller by Atiku et al. (2004).](image)

Raghtate and Handa (2014) performed and extensive research on the output of the shelling machine they developed. During first testing, they recorded a shelling capacity of 81.2% and mechanical damage of 20.03%. The shelling efficiency and mechanical damage obtained in this experiment is similar to the ones obtained by Okegbile et al. (2014) and Alonge et al. (2017). During their research, they decided to adjust the parameters such as feed rate, shelling speed, fan speed and used different moisture content. This led to different results as they recorded a shelling efficiency as high as 98.86% and cleaning efficiency as high as 99.17%. The variation in the value of cleaning obtained by different researchers might be due to the variation of the terminal velocity used by various authors because the terminal velocity plays a significant in the cleaning efficiency of a shelling machine. The shelling and cleaning efficiencies are in accordance with the ones reported by Ugwuko et al. (2014). In another case, they recorded a mechanical damage as low as 1.1%. They tested the machine (Figure 4) on roasted groundnut and recorded a shelling efficiency of 66%. Their experiment revealed that the output of a machine can be improved by varying some parameters.
Madi (2017) developed a prototype groundnut shelling machine to carry out evaluation at varying parameters of shelling speed, feed rate, and blower speed. The machine has a rubber shelling drum with a rough surface for shelling which was different from many other groundnut shellers having metallic shelling drums. When performing the evaluation, the shelling speed and blower speed ranged from 150 – 300 rpm and 4.9 – 8.8 m s⁻¹, respectively, with a feed rate of 170 kg h⁻¹, 210 kg h⁻¹, and 250 kg h⁻¹. The machine's output revealed that when the shelling speed increases, cleaning efficiency diminishes but shelling efficiency rises. This machine, shown in Figure 5, has a cleaning efficiency ranging between 94.8% to 98% for shelling speeds of 300 rpm and 150 rpm, respectively. Helmy et al. (2007) found that the wire mesh sieve outperformed the slotted grate sieve in their study. Ugwuoke et al. (2014) reported similar result but higher than that of Gamal et al. (2009) and Muhammed and Isiaka et al. (2019).

Hoque and Hossain (2018) designed a power groundnut sheller, as presented in Figure 6. The shelling capacities of the groundnut sheller were 110 and 115 kg h⁻¹ for two varieties of groundnut used, namely, Dhaka-1 and BARI Badam-8. The machine capacity is lower than that of Muhammed and Isiaka et al. (2019) [233.81 kg h⁻¹], Ugwuoke et al. (2014) [400 kg h⁻¹] and Okegbile et al. (2014) [400 kg h⁻¹].
The shelling efficiency on the former and latter were 86.6% and 88.82%, respectively, at 11.5% moisture content wet base (wb). This is in accordance with the value obtained by Ejiko et al. (2015) and higher than that of Okegbile et al. (2014) [78%], Gamal et al. (2009) [80%], but lower than that of the values obtained by Ugwuoke et al. (2014) [95.25] and Muhammed and Isiaka et al. (2019) [98.32%]. Gitau et al. (2003) reported that factors such as material of the blade, the design of the blade and the number of blades influence the shelling performance of a peanut shelling machine. The kernel damage was 2% to 7.5% moisture content wet base (wb). According to the authors, using this machine can reduce shelling costs by 76% compared with manual methods. Based on their recommendation, the power groundnut sheller should be used at the farm and small industry levels.

Another of these machines was Darshan et al. (2018), which developed a low-cost groundnut shelling machine with a blower separation technique, as shown in Figure 7. They aimed to design and fabricate an affordable and portable that will shell as much groundnut as possible in the shortest possible time. Their performance evaluation of the shelling machine revealed its shelling efficiency as 95%, the mechanical damage is 0.088%, throughput capacity is 22.98 kg h⁻¹, and material efficiency of 91.15%. These results were obtained after five tests were carried out on the machine, with the average results considered. The shelling efficiency is in accordance with the values obtained by Ugwuoke et al. (2014) [95.25] and Muhammed and Isiaka et al. (2019) [98.32%] and higher than that of Ejiko et al. (2015) [84%], Okegbile et al. (2014) [78%] and Gamal et al. (2009) [80%]. Akcali et al. (2006) reported that larger varieties of peanut gave a higher shelling efficiency. Therefore, variation in the shelling efficiency reported by various researchers might be due to different varieties of peanut used in performing evaluation for their developed shelling machines. The mechanical damage is lower than of the values obtained by Ejiko et al. (2015) [14%], Okegbile et al. (2014) and Ugwuoke et al. (2014) [17.25%], Alonge et al. (2017) [17.4%] but higher than that of Muhammed and Isiaka et al. (2019) [4.33%]. The throughput capacity is lower than that of Muhammed and Isiaka et al. (2019) [233.81 kg h⁻¹], Ugwuoke et al. (2014) [400 kg h⁻¹.] and Okegbile et al. (2014) [400 kg h⁻¹.].
Some contributions to the development of groundnut sheller by Nigerian researchers are presented in Tables 2 and 3. Global contributions are presented in Table 4.

Table 2. Nigerian contributions on groundnut shelling machine.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Names of authors on groundnut sheller</th>
<th>The contribution was made to the improvement of the groundnut shelling machine.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Atiku et al. (2004)</td>
<td>Performance evaluation of Bambara groundnut sheller</td>
</tr>
<tr>
<td>5</td>
<td>Abubakar and Abdulkadir (2012)</td>
<td>Design and evaluation of a motorized and manually operated groundnut shelling machine</td>
</tr>
<tr>
<td>6</td>
<td>Ossom et al. (2020)</td>
<td>Modification and performance testing of a Bambara groundnut sheller</td>
</tr>
<tr>
<td>7</td>
<td>Alonge et al. (2017)</td>
<td>Design modification and performance testing of a Bambara groundnut sheller</td>
</tr>
</tbody>
</table>

Table 3. Output of some groundnut shelling machines developed by Nigerian researchers.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Names of authors</th>
<th>Power Output (hp)</th>
<th>Shelling capacity</th>
<th>Shelling efficiency (%)</th>
<th>Mechanical damage (%)</th>
<th>Cleaning efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gamal et al. (2009)</td>
<td></td>
<td></td>
<td>80</td>
<td>79.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Okegbile et al. (2014)</td>
<td>1</td>
<td>400 kg h⁻¹</td>
<td>78</td>
<td>17.25</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ugwuoke et al. (2014)</td>
<td>1</td>
<td>400 kg h⁻¹</td>
<td>95.25</td>
<td>17.25</td>
<td>91.67</td>
</tr>
<tr>
<td>4</td>
<td>Alonge et al. (2017)</td>
<td></td>
<td></td>
<td>75000 seeds h⁻¹</td>
<td>83.2</td>
<td>17.4</td>
</tr>
<tr>
<td>5</td>
<td>Ejiko et al. (2015)</td>
<td>1</td>
<td></td>
<td>84</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Muhammed and Isiaka et al. (2019)</td>
<td></td>
<td>233.81 kg h⁻¹</td>
<td>98.32</td>
<td>4.33</td>
<td>50.63</td>
</tr>
</tbody>
</table>
### Table 4. Global contributions on groundnut shelling machine.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Names of authors</th>
<th>The contribution made on the improvement of the groundnut shelling machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kittichai (1984)</td>
<td>Development and test of a power-operated groundnut</td>
</tr>
<tr>
<td>2</td>
<td>Gore et al. (1990)</td>
<td>Development of power-operated groundnut sheller.</td>
</tr>
<tr>
<td>4</td>
<td>Singh (1993)</td>
<td>Development of a unique groundnut decorticator</td>
</tr>
<tr>
<td>7</td>
<td>Anantachar et al. (1997)</td>
<td>Development and performance evaluation of pedal operated decorticator</td>
</tr>
<tr>
<td>14</td>
<td>Gitau et al. (2003)</td>
<td>Optimizing the performance of a manually operated groundnut (Arachis hypogaea) decorticator</td>
</tr>
<tr>
<td>15</td>
<td>Helmy et al. (2013)</td>
<td>Modification and evaluation of a reciprocating machine for shelling peanut</td>
</tr>
<tr>
<td>16</td>
<td>Raghtate and Handa (2014)</td>
<td>Design and fabrication of groundnut sheller machine</td>
</tr>
<tr>
<td>17</td>
<td>Arjun et al. (2015)</td>
<td>Design and fabrication of groundnut decorticator</td>
</tr>
<tr>
<td>20</td>
<td>Walke et al. (2015)</td>
<td>Design and fabrication of groundnut sheller machine</td>
</tr>
<tr>
<td>22</td>
<td>Bhalavignesh et al. (2019)</td>
<td>Modelling and fabrication of groundnut separating machine.</td>
</tr>
</tbody>
</table>

The data obtained from the research revealed the following merits and demerits of some machines developed by Nigerians is presented in Table 5.
Table 5. Merits and demerits of some groundnut shelling machines developed by Nigerians.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Name of authors</th>
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<tbody>
<tr>
<td>1</td>
<td>Okegbile et al. (2014)</td>
<td>Moderate shelling efficiency and shelling capacity</td>
<td>Do not have a cleaning compartment and high damage of kernel.</td>
</tr>
<tr>
<td>2</td>
<td>Alonge et al. (2017)</td>
<td>Moderate shelling efficiency and shelling capacity</td>
<td>High damage of kernel.</td>
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<tr>
<td>3</td>
<td>Muhammed and Isiaka et al. (2019)</td>
<td>High shelling efficiency and low damages caused to kernel</td>
<td>Cleaning efficiency is low, machine is not compact.</td>
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<tr>
<td>4</td>
<td>Ugwuoke et al. (2014)</td>
<td>High shelling efficiency and High cleaning efficiency</td>
<td>High damage of kernel</td>
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<tr>
<td>5</td>
<td>Ejiko et al. (2015)</td>
<td>Moderate shelling efficiency</td>
<td>Cleaning is done manually and high damage of kernel</td>
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</table>

**CONCLUSION**

The trends in the development of groundnut shellers had been presented. It was observed that these groundnut shelling machines improved on the previous ones developed in terms of shelling efficiency, mechanical damage, cleaning efficiency, etc. This shows that for any machine to be developed, there is a need to observe the trends of the existing machine used for the same purpose. This will help the engineer understand what problem needs to be solved and what improvement needs to be made. Based on the review carried out, the following conclusions are made:

i. Groundnut shelling machines have been in development for over 35 years with drastic improvement occurring in each decade.

ii. The shelling of groundnut is affected by factors such as variety of groundnut, size of groundnut, moisture content, shelling techniques, shelling speed, etc.

iii. The power requirement for most machines observed is 1 hp. This was effective in operating the shelling machine.

iv. The cleaning efficiency of many of the machines for bought–out components such as blower was more effective than the locally developed ones.

v. Most machines used bought–out component (blower) compared to the locally developed fans for the cleaning compartments.

vi. Most of the shelling machines used metal for the shelling drum.

**RECOMMENDATIONS**

The goal of groundnut shelling machines at inception was not only to shell groundnut in a considerable period, but also to maintain optimum productivity. This will require researchers and engineers to take into consideration several factors that can improve or decline the productivity of the shelling machines during design and development process. The following under–listed are recommendations for future research and development:

1. There should be a universal model for measuring the performance evaluation of the machine. This will help engineers and researchers in identifying areas that need improvements.
2. The physical properties of the groundnut such as moisture content should be taken into considerations during the machine designs as it directly affects the machine efficiency.

3. Researchers should include specification such as the type or variety of groundnut that was used for experiment for easy comparison of machine outputs.

4. The use of other materials such as rubber for shelling drum is encouraged in further research. This will help in monitoring power consumption, shelling efficiency and mechanical damage.

5. Other means of power generation such as solar power is encouraged in future designs to help develop self–propelling shelling machines that can serve in remote area lacking access to electricity and fuel.

6. Research into automated groundnut shelling machines will make the process more effective with little or no human supervision.

7. Further research for the use of the groundnut chaffs can be instituted, thereby establishing sustainability and consequently promote circular economy in the country.

DECLARATION OF COMPETING INTEREST

The authors state that no conflict of interest exists.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

This review was carried out among all the three authors in collaboration. The research was planned by the three authors Olufemi Adeyemi Adetola, Opeyemi Emmanuel Akinniyi, and Emmanuel Ayodeji Olukunle.

Olufemi Adeyemi Adetola wrote the protocol and managed the searches for literature. Read, corrected the first draft of the manuscript, read and accepted the final manuscript.

Opeyemi Emmanuel Akinniyi supervised the study's analyses, managed the searches for literature, read and accepted the final manuscript.

Opeyemi Emmanuel Akinniyi wrote the first draft of the manuscript, read and accepted the final manuscript.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

REFERENCES


