Turkish Journal of Agricultural Engineering Research

https://dergipark.org.tr/en/pub/turkager
https://doi.org/10.46592/turkager.1116725

Turk J Agr Eng Res
(TURKAGER)

ISSN: 2717-8420
2022, 3(2), 380-396

Review Article

Comparative Study of the Developed Peanut Shelling Machines

Olufemi Adeyemi ADETOLA[a*] ID, Opeyemi Emmanuel AKINNIYI[a] ID, Emmanuel Ayodeji OLUKUNLE[a] ID

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

(*): Corresponding author. oaadetola@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 type 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 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.

REVIEW ARTICLE

Received: 14.05.2022
Accepted: 01.07.2022

Keywords:

- Ground nut,
- Shelling machine,
- Shelling efficiency,
- Moisture content,
- Operational parameters,
- Performance evaluation

To cite: Adetola OA, Akinniyi OE and Olukunle EA (2022). Comparative Study of the Developed Peanut Shelling Machines. *Turkish Journal of Agricultural Engineering Research (TURKAGER), 3(2), 380-396.* https://doi.org/10.46592/turkager.1116725

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 *Isagua* 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.

$$Shelling\ efficiency\ (\%) = \left(\frac{Q_s}{Q_t}\right) \times \frac{100}{1} \quad (1)$$

$$Mechanical\ damage\ (\%) = \left(\frac{Q_d}{Q_u+Q_d}\right) \times \frac{100}{1} \quad (2)$$

$$Material\ efficiency\ (\%) = \left(\frac{Q_u}{Q_u+Q_d}\right) \times \frac{100}{1} \quad (3)$$

$$Throughput\ capacity\ (\frac{kg}{h}) = \left(\frac{Q_s}{T_m}\right) \times \frac{100}{1} \quad (4)$$

Where Q_s 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.

$$Cleaning\ efficiency\ (\%) = \frac{Wd}{W_{wp}}\ x\ \frac{100}{1} \quad (5)$$

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).

$$V_t = \sqrt{\frac{2mg}{\rho A C_d}} \quad (6)$$

Where, V_t is the terminal velocity (m s^{-1}), m is the mass of falling grain (kg), g is the accelation due to gravity, ρ 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).

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.

Type of concave sieve	Shelling capacity ($kg\ h^{-1}$)	Shelling efficiency (%)	Percentage breakage (%)
Wire mesh	86	83-89	3.7-6.7
Slotted grate	60	82-84	8.4-12.6

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).

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 Ugwuoke *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.

Figure 4. Groundnut sheller by Raghtate and Handa (2014).

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).

Figure 5. Prototype Groundnut sheller by Madi (2017).

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}.].

Figure 6. Groundnut sheller by Hoque and Hossain (2018).

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}.].

Figure 7. Groundnut sheller by Darshan *et al.* (2018).

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.

S/N	Names of authors on groundnut sheller	The contribution was made to the improvement of the groundnut shelling machine.
1	Darshan *et al.* (2018)	Performance evaluation of motorized groundnut sheller.
2	Atiku *et al.* (2004)	Performance evaluation of Bambara groundnut sheller
3	Maduako *et al.* (2006)	Testing of an engine-powered groundnut shelling machine
4	Oluwole *et al.* (2007)	Development and performance evaluation of impact Bambara groundnut sheller
5	Abubakar and Abdulkadir (2012)	Design and evaluation of a motorized and manually operated groundnut shelling machine
6	Ossom *et al.* (2020)	Modification and performance testing of a Bambara groundnut sheller
7	Alonge *et al.* (2017)	Design modification and performance testing of a Bambara groundnut sheller

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

S/N	Names of authors	Power Output (hp)	Shelling capacity	Shelling efficiency (%)	Mechanical damage (%)	Cleaning efficiency (%)
1	Gamal *et al.* (2009)			80		79.5
2	Okegbile *et al.* (2014)	1	400 kg h^{-1}.	78	17.25	
3	Ugwuoke *et al.* (2014)	1	400 kg h^{-1}.	95.25	17.25	91.67
4	Alonge *et al.* (2017)		75000 seeds h^{-1}.	83.2	17.4	
5	Ejiko *et al.* (2015)	1		84	14	
6	Muhammed and Isiaka *et al.* (2019)		233.81 kg h^{-1}.	98.32	4.33	50.63

Table 4. Global contributions on groundnut shelling machine.

S/N	Names of authors	The contribution made on the improvement of the groundnut shelling machine
1	Kittichai (1984)	Development and test of a power-operated groundnut
2	Gore *et al.* (1990)	Development of power-operated groundnut sheller.
3	El-Sayed (1999)	A simple prototype of conical sheller
4	Singh (1993)	Development of a unique groundnut decorticator
5	Abou El-kheir and Shoukr (1993)	Modelling of the action of mechanical shelling of peanut for different materials of beater drum.
6	Younis and Abdel-Mawla (1997)	Development of peanut sheller.
7	Anantachar *et al.* (1997)	Development and performance evaluation of pedal operated decorticator
8	Helmy (2001)	Evaluation of a reciprocating peanut sheller
9	Nyaanga *et al.* (2003)	Development and evaluation of a portable hand operated groundnut sheller
10	Nyaanga *et al.* (2007)	Development and testing of a portable hand-operated groundnut sheller.
12	Rostami *et al.* (2009)	Design, development and evaluation of a groundnut sheller
13	Hoque *et al.* (2011)	Design and development of manual groundnut sheller
14	Gitau *et al.* (2003)	Optimizing the performance of a manually operated groundnut (Arachis hypogaea) decorticator
15	Helmy *et al.* (2013)	Modification and evaluation of a reciprocating machine for shelling peanut
16	Raghtate and Handa (2014)	Design and fabrication of groundnut sheller machine
17	Arjun *et al.* (2015)	Design and fabrication of groundnut decorticator
18	Wangette *et al.* (2015)	Influence of groundnut and machine characteristics on motorized sheller performance.
19	Mungase *et al.* (2015)	Peanut sheller using screw conveyor
20	Walke *et al.* (2015)	Design and fabrication of groundnut sheller machine
21	Madi (2017)	Manufacture and evaluation of a simple prototype of peanut sheller.
22	Bhalavignesh *et al.* (2019)	Modelling and fabrication of groundnut separating machine

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.

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

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 term 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

Abou El-kheir MM and Shoukr AZ (1993). Modelling of the action of mechanical shelling of peanut for different materials of beater drum. *Misr Journal of Agricultural Engineering. 10(1): 123–135.*

Abubakar M and Abdulkadir BH (2012). Design and evaluation of a motorised and manually operated groundnut shelling machine. *International Journal of Emerging Trends in Engineering and Development, 4(2): 673–682.*

Adedeji OS and Ajuebor FN (2002). Performance evaluation of motorized groundnut sheller. *Journal of Agricultural Engineering, 39(2): 53–56.*

Ajeigbe H, Waliyar F, Echekwu C, Ayuba K, Motagi B, Eniayeju D and Inuwa A (2015). A farmer's guide to groundnut production in Nigeria.

Akcali ID, Ince A and Guzel E (2006). Selected physical properties of groundnuts. *International Journal of Food Properties, 9(1): 25-37.*

Alonge AF, Ossom IS and Bassey EJ (2017). Design modification and performance testing of a Bambara groundnut sheller. *Chemical Engineering Transactions, 58: 367-372. https*://doi.org/10.3303/CET1758062.

Anantachar M, Maurya NL and Navaravani NB (1997). Development and performance evaluation of pedal operated decorticator. *Journal of Agricultural Sciences, 10(4): 1078-1081.*

Arjun V, Tejas T and Kekan RH (2015). Design and fabrication of groundnut decorticator. International Journal of Mechanical and Industrial Technology, [Internet]. 2021 [cited 2021 June 25]. Available from www.researchpublish.com

Armitage D and Wontner-Smith T (2008). Grain moisture-guidelines for measurement. HGCA-Funded Project, Caledonia House 223 Petronville Road London NI9HY. 2008.

Atiku A, Aviara N and Haque M (2004). Performance evaluation of a Bambara groundnut sheller. *Agricultural Engineering International, the CIGR journal of Scientific Research and Development, 6: 1–18.*

Aydin C (2007). Some engineering properties of peanut and kernel, *Journal of Food Engineering, 79(3): 810-816,* https://doi.org/10.1016/j.jfoodeng.2006.02.045.

Aydin C and Ozcan M (2002). Some physico-mechanic properties of terebinth (*Pictacia terebinthus* L.) fruits. *Journal of Food Engineering, 53, 97-101.*

Balami AA, Adgidzi D, Kenneth CA and Lamuwa G (2012). Performance evaluation of a dehusking and shelling machine for castor fruits and seeds. *Journal of Engineering, 2(10): 44-48.*

Bhalavignesh R, Arjunan L, Arunkumarrao BS, Arun G and Vinayagam Mohanavel SP (2019). Modelling and fabrication of groundnut separating machine. *International Research Journal of Automotive Technology, 2(5): 1-7.*

Bobobee E (2002). No more Fingertip Shelling: The TEK groundnut Cracker to the Rescue. *International Journal of Small-scale Food Processing, 30: 12-15.*

Butts CL, Sorensen RB, Nuti RC, Lamb MC and Faircloth WH (2009). Performance of Equipment for In-field Shelling of Groundnut for Biodiesel Production. *American Society of Agricultural and Biological Engineers, 52(5): 1461-1469.*

Darshan GCP, Venkatagiri HA and Govindarej AJ (2018). Automatic groundnut decorticator. *Open Access International Journal of Science and Engineering, 3(7): 16-21.*

Delhagen W, Hussam S, Mohdramli R and Alexander Y (2003). A Low-cost groundnut sheller for use in developing nations. Final Application for IDEAS. 2003.

Ejiko S, Adu J and Osayomi P (2015). Design and Fabrication of groundnut shelling machine. GRIN Verlag, Munich. [Internet]. 2021 [cited 2021 May 20]. Available from https://www.grin.com/document/306848.

El-Sayed AS (1999). A simple prototype of a conical sheller of peanut seeds. *Misr Journal of Agricultural Engineering, 9(2): 149-159.*

El-Sayed AS, Yahaya R, Wacker P, and Kutzbach HD (2001). Characteristic attributes of the peanut (Arachis hypogaea L.) for its separation. *International Agrophysics, 15, 225-230.*

Gamal E, Radwan S, ElAmir M and ElGamal R (2009). Investigating the effects of moisture content on some properties of groundnut by the aid of digital image analysis. *Food and Bio products Processing, 87: 273-281.*

Gitau AN, Mboya P, Njoroge BK and Mburu M (2003). Optimizing the performance of a manually operated groundnut (*Arachis hypogaea*) Decorticator. *Open Journal of Optimization, 2(1): 26-32.*

Gore KL, Gupta CP and Singh G (1990). Development of power-operated groundnut sheller. *Agricultural Mechanization in Asia, Africa and Latin America, 21(3): 38-44.*

Helmy MA (2001). Evaluation of a reciprocating peanut sheller. *Agricultural Mechanization in Asia, Africa and Latin America. 32(4): 24-27.*

Helmy MA, Abdallah SE, Mitrroi A and Basiouny MA (2013). Modification and performance evaluation of a reciprocating machine for shelling peanut. *Agricultural Mechanization in Asia, Africa and Latin America, 44(3): 18-24.*

Helmy MA, Mitrroi A, Abdallah SE and Basioury MA (2007). Modification and evaluation of a reciprocating machine for shelling groundnut. *Misr Journal of Agricultural Engineering, 24(2): 283-298.*

Hoque M, Hossain M and Hossain M (2018). Design and development of a power groundnut sheller. *Bangladesh Journal of Agricultural Research. 43(4): 631-645.* https://doi.org/10.3329/bjar.v43i4.39162.

Hoque MA, Hossain MA, Wahab MA, Amin MN and Hassan MS (2011). Design and development of manual groundnut sheller. *Annual Research Report of Farm Machinery and Postharvest Process Engineering Division, BARI, Gazipur. p. 13-17.*

Kamboj P, Singh A, Kumar M and Din S (2012). Design and development of small-scale pea depoding machine by using CAD software. *Agricultural Engineering International: CIGR Journal, 14(2): 40-48.*

Karthik G, Balashankar D, Rambabu G, Nagabhushanam B, Akhil L and Naidu A (2018). Design and fabrication of groundnut pods and shell stripper. *International Journal of Engineering Trends and Technology, 58(2): 60-64.*

Kittichai T (1984). *Development and test of a power-operated groundnut sheller.* M. Eng. Thesis No. AE-84-11, Asian Institute of Technology, Bangkok.

Kural H and Carman K (1997). Aerodynamic properties of seed crops. In National symposium on mechanisation in agriculture pp. 615-623, Tokat, Turkey.

Lawal I, Ali MA, Abubakar M and Muhammad A (2015). An overview of groundnut oil extraction technologies. proceedings of second international interdisciplinary conference on global initiatives for integrated development (Chukwuemeka Odumegwu University, Igbariam Campus Nigeria) Sept. 2-5.

Madi MA (2017). Manufacture and evaluation of a simple prototype of peanut sheller. *Misr Journal of Agricultural Engineering. 34. 751-766.*

Maduako JN, Saidu M, Matthias P and Vanke I (2006). Testing of an engine-powered groundnut shelling machine. *Journal of Agricultural Engineering and Technology, 14, 29-37.*

Muhammed AI and Isiaka M (2019). Modification of locally developed groundnut sheller. *Bayero Journal of Engineering and Technology, 14(2): 169 -182.*

Mungase PG, Lokhande AD, Mashalkar ST and Soman SA. (2016). Peanut sheller using screw conveyor. *International Journal of Current Engineering and Technology. 4, 321-323.*

NASA Glenn Research Center (2021). Terminal velocity Retrieved June 27, 2022. https://www.grc.nasa.gov/WWW/K-12/airplane/termv.html

Nyaanga DM, Chemeli MC and Wambua RM (2007). Development and testing of a portable hand-operated groundnut sheller. *Egerton Journal, 7(5): 117-130.*

Nyaanga DM, Chemeli MC, Kimani PK, Kirui WK and Musimba SK (2003). Development and evaluation of a portable hand-operated groundnut sheller. Paper presented at the KSAE Inter. Conf. on 27-28 November 2003.

Okegbile OJ, Hassan AB, Mohammed A and Obajulu O (2014). Design of a combined Groundnut Roaster and Oil Expeller Machine. *International journal of science and Engineering Investigations, 3(26): 26-30.*

Oluwole FA, Abdulrahim AT and Olalere RK (2007). Evaluation of some centrifugal impaction devices for shelling Bambara groundnut, Agricultural Engineering, IX, 1-14.

Ossom IS, Alonge AF, Umani KC and Bassey EJ (2020). A mathematical model for predicting the winnowing efficiency of Bambara groundnut sheller. *European Journal of Engineering Research and Science, 5(2): 225–228.*

Raghtate AS and Handa CC (2014). Design and fabrication of groundnut sheller machine. International *Journal for Innovative Research in Science and Technology, 1(7): 38–45.*

Rai AK, Kottayi S and Murty SN (2005). A low-cost field usable portable grain moisture meter with direct display of moisture (%). *African Journal of Science and Technology, Science and Engineering Series, 6(1): 97–104.*

Ravindra A, Rohit G, Saurav A and Khare GN (2008). A review on design and fabrication of groundnut shelling and separating machine. *International Research Journal of Engineering and Technology, 4(10): 1403-1406.*

Rostami MA, Azadshahraki F and Najafinezhad H (2009). Design, development and evaluation of a groundnut sheller. *Agricultural Mechanization in Asia, Africa and Latin America, 40(2): 47-49.*

Shoko AZ and Mushiri, T (2015). Design of an automated powered peanut shelling. [Internet]. 2021 [cited 2021 June 20]. Available from http://dx.doi.org/10.4108/eai.20-6-2017.2270755.

Siebenmorgan TJ, Jia C, Qin G and Schluterman D (2006). Evaluation of selected rice laboratory shelling equipment. *American Society of Agricultural and Biological Engineers, 22(3): 427-430.*

Singh G (1993). Development of a unique groundnut decorticator. *Agricultural Mechanization in Asia, Africa and Latin America 24(1): 55-64.*

Ugwuoke IC, Okegbile OJ and Ikechukwu IB (2014). Design and fabrication of groundnut shelling and separating machine. *International Journal of Engineering Science Invention, 3(4): 60-66.*

Walke T, Gadge P, Gohate G and Banpurkar R (2017). Design & fabrication of groundnut sheller machine. *International Research Journal of Engineering and Technology, 4(3): 1606–1610.*

Wangette IS, Nyaanga DM and Njue MR (2015). Influence of groundnut and machine characteristics on motorised sheller performance. *American Journal of Agriculture and Forestry. 3(5): 178-191.*

Younis SM, Abdel-Mawla HA and Farag HA (1997). Development of peanut sheller. *Misr Journal of Agricultural Engineering. 14(1): 106-117.*