RESEARCH AND DEVELOPMENT OF CASHEW NUT SHELLING MACHINES IN NIGERIA: A REVIEW

https://doi.org/10.63749/agrimech.5.1.1005u

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ABSTRACT

Cashew nut shelling is known to be the most challenging activity in the nut processing line due to inherent hardness of its shell, fragile kernel, presence of caustic phenolic resin-hazardous substance and inconsistent morphological characteristics of the nuts. To address this, machines have been developed but presently, there is scarcity of information on the state of research on home-grown cashew nut shellers in Nigeria. This study is revealing and suggestive whether the present state is worth sustaining or demanding for improvement of research and development in this area to foster efficiency, product quality and capacity of the cashew kernel industry. Therefore, the state of cashew nut shelling machines in Nigeria was examined through thorough literature review. Recommendations for further development of efficient and appropriate cashew nut shelling machines were suggested after observing some inefficiencies associated with home-grown designs and developed machines. Most of them are characterized by lack of process optimization, inadequate performance evaluation, low capacity rating, and product quality. Challenges ranging from scarcity of review information in this area to inadequate research and lack of investment in the industry were identified to be responsible for this trend.

Keywords: Cashew nut, Nigeria, Research, Review, Shelling Machine.

1. INTRODUCTION

Cashew (*Anacardium occidentale* L.) is a tropical nut tree crop which is a good source of food, income, industrial raw materials and foreign exchange for many countries of Africa, Asia and Latin America. Cultivation and processing activities in cashew provides employment and income generation for women and smallholder farmers in Nigeria (Topper *et al.,* 2001).

In Nigeria, commercial cultivation of cashew is now more than 60 years old and the current cashew trading and exports worth 24 billion naira ($160 million) with over one million people employed in the industry (Adeigbe *et al*., 2015). Nigeria is the third largest producer of cashew nut in Africa and the sixth in the world with a capacity of 240,000 tonnes annually and yield ranging from 300 – 800 kg/ha (NEPC, 2023). Products derived from the nuts of the crop include the world's highly delighted Kernel Nut (KN), Kernel Oil (KO), Cashew Nut Shell Liquid (CNSL), and from the apple of the crop: juice, jam and alcohol among others are derived (Adeigbe *et al.,* 2015).

Cashew kernel is first among the world nut snacks because of its nutritional advantages: it has high amount of protein, soluble sugar and rich in polyunsaturated fatty acid that lowers blood cholesterol (Adeigbe *et al.,* 2016). It is globally consumed for its desirable nutritional and sensory attributes, being a good source of proteins (20%), carbohydrates (23%), and fats (45%) (Das *et al.,* 2014; Dantas and Costa, 2022). Cashew kernel is widely consumed as roasted, fried, salted or sugared snacks and used as raw material for confectionery, bakery products as well as a food ingredient (Alamnie, 2022). Studies revealed that cashew consumption is linked

to lower blood cholesterol levels, cancer and gallstone prevention, improved brain function, and a reduced risk of cardiovascular diseases (Das *et al.,* 2025; Gonçalves *et al.,* 2023; Ros *et al.*, 2010; Jenab *et al.*, 2004).

Shelling is the removal of the shell (epicarp, mesocarp and endocarp) of cashew nut to birth cashew kernel (Borah *et al.,* 2023). Shelling process emerges as a complex activity occasioned by the irregular shape and size variations of the nuts, the presence of Cashew Nut Shell Liquid (CNSL), inherent hardness of the nut (Kilanko *et al*., 2018; Sanchez *et al*., 2024) and fragile nature of the kernel. Therefore, cashew nut shelling machines operational effects directly affects and have significant impact on its final product quality, acceptability and market value at the international market (Sanchez *et al*., 2024). Although cashew nut shelling machines has been developed in Nigeria but it working quality has always been an issue of concern yearning for minimal kernel damage percentage to enhance improved cashew kernel quality. So, several researchers within the country have further conducted studies on the development of cashew nut shelling machines.

However, the home-grown machines have recorded little success and are characterized by low whole kernel out turn efficiency, product quality and capacity in comparative terms with the similar technologies developed in China and India (Ogunsina and Bamgboye, 2013), hence, the need for reference point, further research and innovative breakthroughs. This paper reviews Nigeria home grown cashew nut shelling machines with the aim of understanding the state of research, providing a reference point to spur further indigenous research work on cashew nut shelling for better efficiency, capacity and competiveness.

2. PRESENT STATE OF RESEARCH ON CASHEW NUT SHELLING MACHINES DEVELOPMENT

2.1 Account of Cashew Nut Shelling Machines Development in Nigeria

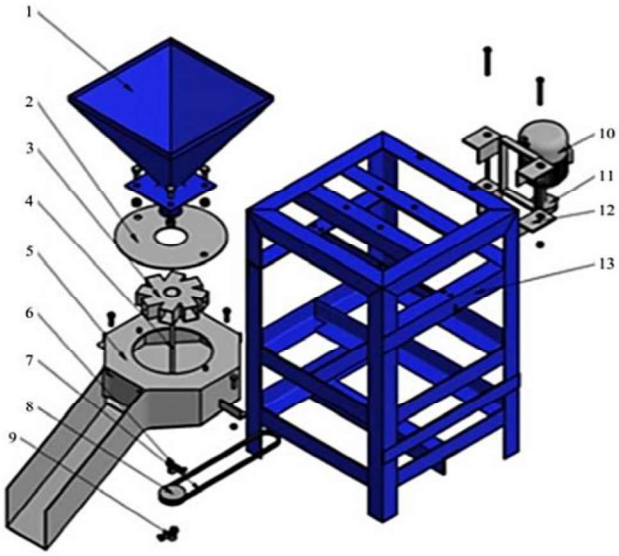
Indigenous researchers such as Kilanko *et al*. (2018), Osunde and Oladeru (2006), Ojolo and Ogunsina (2007), Ropo *et al.* (2022), Ajav (1996) and Ojolo *et al.* (2010) have done concerted efforts in the area of development of cashew nut shelling machines to better the capacity, efficiency and product quality of Nigerian cashew processing industry. Kilanko *et al*. (2018) developed a centrifugal cashew nut sheller for improving the whole kernel recovery. The design consists of a hopper, shelling chamber (centrifugal impeller), shaft and an electric motor. 79%, and 73.7% shelling efficiency (SE) and whole kernel recovery (WKR) were obtained respectively, as well as 65.4% WKR and 96.8% SE as the maximum predicted optimal values at 3110 rpm and 9.06% wb (Figure 1); Osunde and Oladeru (2006) developed a cashew nut shelling machine that consists of a frame, press lever, upper and lower blade holder, and blades. It resulted to 80%, 66.7% and 0.52 kg//h shelling efficiency, whole kernel recovery and machine capacity; Ojolo and Ogunsina (2007) developed a cashew nut cracking device. The box-like machine consists of a hinged and spring-loaded mild steel cracking lid with grooves to hold a cast aluminum feeding tray machined to hold 25 nuts at a time. It resulted to 66.66% whole kernel recovery and 18.3 kg/h machine (Figure 2); Ropo *et al.* (2022) developed cashew nut processing machine which consists of a heating chamber, shelling unit (impeller) and frame. Eighty (80) percent whole kernel recovery (WKR) was reported as the performance of the machine (Figure 3); and Ajav, (1996) developed a cashew-nut cracker for peasant farmers. The design was a pedal operated cashew nut cutting knives. The outcome of the work was 75.7% shelling efficiency.

The analysis of the reviewed works was done based on the fact that grading of nuts before shelling and nuts cutting approach improves shelling efficiency, WKR, and lowers kernel

breakage percentage; efficient separation enhances product quality; high level of WKR promotes product acceptability; process optimization enhances efficiency at minimal cost; proper determination of machines promotes adoption and capacity. This is in line with the current international best practices on cashew nut shelling (Sanchez *et al*., 2024, Kilanko *et al*., 2018, GIZ/ComCashew., 2019). Technology missing gaps were found to be 100%, 100%, 83.3%, 50% and 83.3% absence of nut graders, nut cutters, separation units, shelling process optimization, relevant performance indices, and lower WKR {below the standard acceptable value (87.5%)}, respectively.

2.2 Research on Cashew Nut Material Characteristics

Study outcomes on engineering properties of biomaterial are fundamental for the design of appropriate processing (shelling, de-hulling, separation etc.) and handling machines (ASABE, 2005; Bart-Plange *et al*., 2012; Sanchez *et al*., 2024).



PART LIST

1. Hopper
2. Cover
3. Impeller
4. Shaft
5. Shelling bin
6. Bearing 1
7. V-belt
8. Grooved pulley 1
9. Bearing 2
10. Electric motor
11. Grooved pulley 2
12. Electric motor hanger
13. Machine frame

Figure 1. Exploded view showing structural components of a centrifugal cashew nut shelling machine by Kilanko *et al*. (2018)

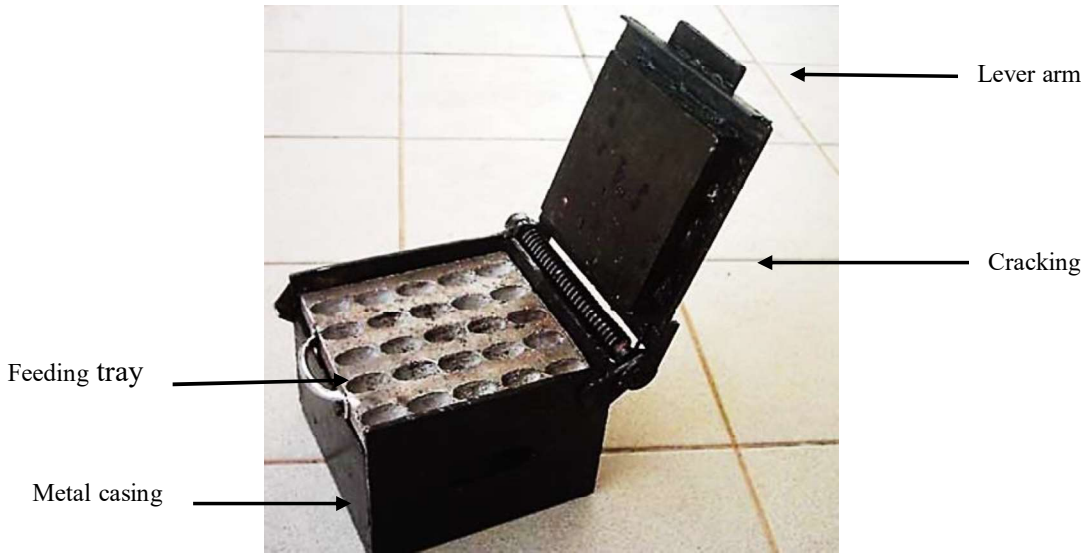
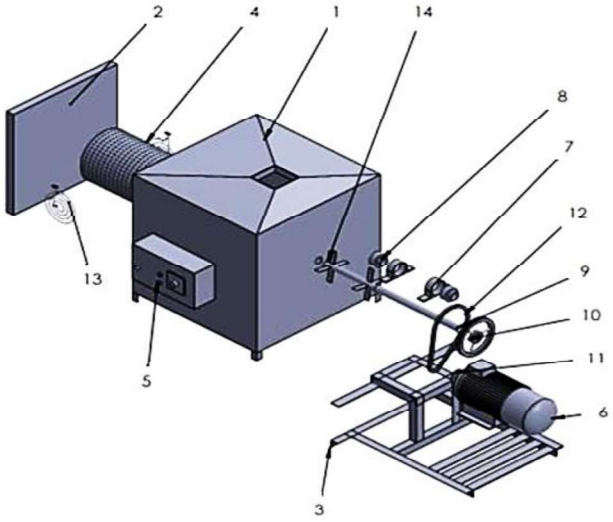


Figure 2. Cashew Nut Cracking Device by Osunde and Oladeru (2006);



PART LIST

1. Chamber
2. Cover
3. Frame
4. Fenestrated cylinder
5. Control panel
6. Electric motor
7. Bearing support
8. Bearing
9. Shaft
10. Pulley
11. Motor shaft
12. Belt
13. Heating element

Figure 3. Cashew nut processing machine by Ropo *et al.* (2022)

Studies on engineering properties of cashew nut by Nigerian scholars are scarce. Researchers in Brazil, China, and India etc. have done a lot in this area to provide a reference for the design and development of efficient cashew nut shelling machines.

Sudaryanto *et al.* (2022) studied engineering properties of cashew nut in context of designing post-harvest handling and processing machinery. The study focused on physical, mechanical and colour properties of cashew nuts (n = 100) at a moisture content of 7.63% (dry basis) which were derived from Central Java, Indonesia. The main characteristics of the study included the length, width, thickness, mass, volume, and density. The derived properties considered include geometric diameter, arithmetic diameter, surface area, frontal surface area, transverse area, shape index, sphericity, bulk density, and porosity. The mechanical properties studied include static friction, static and dynamic angle of repose, and compressive load (in four orientations).

Stepwise regression analysis of the study showed that volume of nut had the most substantial relationship with the mass ($R^2 = 0.949$), the bulk density had the highest correlation with the mass ($R^2 = 0.968$), and the porosity showed a high correlation with the true density and mass ($R^2 = 0.997$). The highest friction, static angle of repose, and dynamic angle of repose occurred on the surface of plywood, and the lowest was on the stainless-steel surface. Also, Sanchez *et al.* (2024) conducted a study on physical, morphological, and mechanical properties of raw and steamed cashew nuts (*Anacardium occidentale* L.). The study presented a comprehensive characterization of raw and steamed cashew nuts from Puerto Carreño, Colombia, with focus on morphological, physical, and mechanical properties. The findings of the study indicated significant differences in morphological and mechanical properties between raw and steamed cashew nuts. Similarly, Bart-Plange *et al.* (2012) studied some physical and mechanical properties of cashew nut and kernel grown in Ghana. The average length, thickness, width, equivalent diameter, sphericity and volume for cashew nuts obtained in the study were 41.15 mm, 23.92 mm, 32.76 mm, 31.89 mm, 77.37% and 312.54 mm^3, respectively and that for the kernels were 33.16 mm, 15.87 mm, 17.91 mm, 21.23 mm, 64.02% and 101.47 mm^3, respectively. The bulk density of cashew nut and kernel decreased linearly from 625.62 to 592.68 kgm^{-3} and 559.60 to 505.06 kgm^{-3}, respectively. However, true density, surface area, and porosity increased linearly from 1100.16 to 1209 kgm^{-3}, 2754.68 to 2918.18 mm^2, and 43.19 to 51.02%, respectively for the nuts while for the kernels the properties increased from 946.23 to 991.29 kgm^{-3}, 1189.98 to 1309.02 mm^2, and 40.86 to 49.05%, respectively. The maximum compressive load, maximum displacement, stress, strain, and young's modulus obtained increased linearly from 0.445 to 0.574 kN, 7.760 to 8.008 mm, 2.225 to 2.872 MPa, 0.777 to 0.801 mm/mm and 4.666 to 9.853 MPa, respectively for the kernel and increased from 0.146 to 0.213 kN, 3.006 to 4.105mm, 0.214 to 1.214 MPa, 0.355 to 0.472 mm/mm, and 2.446 to 6.416 MPa, respectively for the nuts. The relationship between compressive stress properties studied and moisture content were found to be significant at 0.05.

2.3 Research on Cashew Nut Shelling Process

The shelling process encompasses drying, moisture adjustment, thermal treatment, cooling, grading, shelling, kernel scooping, oven drying, thermal shocking/humidifying, peeling of test, kernel size grading, and kernel packaging (GIZ/ComCashew, 2019; Dakuyo *et al.,* 2022; Sanchez *et al.,* 2024). Robust research works on the process is key to achieving efficient and appropriate development of efficient and appropriate shelling machines but much is yet to be done in the nation. Ogunsina, and Bamgboye (2014) investigated pre-shelling parameters and conditions that influence the whole kernel out-turn of steam-boiled cashew nuts

2.4 Research on Cashew Nut Shelling Principles

Shelling principle of cashew nut refers to the techniques applied to safely remove the edible kernel from its hard shell. Applied centrifugal forces and application of pair of knives are the two principles commonly used (Kilanko *et al*., 2018). Kilanko *et al*. (2018) and Ropo *et al.* (2022) employed the use of centrifugal forces to shell cashew nuts while Osunde and Oladeru (2006), and Ojolo and Ogunsina (2007) used pair of knives to cut and shell cashew nuts. Kabir and Fedele (2018) reported that the principle of operation of a sheller usually involves application of impact force with partial shear force depending on the hardness of the shell of the seed. Kilanko *et al.* (2018) reported that centrifugal impeller shelling mechanism for cashew nut has lower whole kernel recovery percentage but on the other hand has high throughput capacity.

2.5 Research on Cashew Nut Shelling Machines

This involves studies on the effect of application different fabrication materials, mechanism type, and machine factors on the performance of shelling machines. Common materials include light density polymers, steels, and alloys. Shelling mechanism types include knives configuration and arrangement, and impeller mechanisms. Machine factors and techniques include operating speed, feeding rate, clearance space and feeding rate as well as process optimization. The shelling process optimization process which is essential for achieving product quality at minimal cost was studied by Kilanko *et al*. (2018) among all the reviewed works.

3 CHALLENGES FACING CASHEW NUT SHELLING MACHINES DEVELOPMENT IN NIGERIA

Cashew nut shelling machine development in Nigeria is faced with the following challenges:

i. Inadequate integration of agronomy of cashew and processing machines development

Adequate integration has the capacity to enhance the development of varieties of cashew nuts that are most suitable for shelling. But the linkage between cashew Agronomist and Engineers is week. Also, the degree of standardization of cashew varieties and equipment is low resulting different varieties and shelling equipment types with an uneven effect on cashew kernels.

ii. Inadequate systematic research on the shelling process

There is inadequate research on the process that encompasses cashew nuts pre-shelling treatments (drying, moisture adjustment, steaming), shelling treatment (structural machine type, parameters), and post shelling treatment (separation, peeling, grading, color sorting, humidification, packaging). Strengthened research in this area can improve cashew kernel quality and quantity.

iii. Weak innovative research on shelling principles and machines

There is poor innovative research on automation and intelligence in the area of cashew shelling in the country. Process optimization is also very low as well as availability machines for separating the kernels from the shells.

iv. Lack of appropriate and efficient shelling machines

There is lack of modern shelling machines for cashew nut in the country. This inhibits large scale shelling of cashew nuts. Consequently, hand tools are predominantly used by farmers and processors.

v. Limited Access to finance

Framers and processor lack access to funds to enable them procure and apply modern cashew nut shelling facilities for higher efficiency, product quality and capacity.

4 RECOMMENDATION

The followings recommendations are suggested to promote the development of appropriate and efficient cashew shelling machines in Nigeria:

i. They should be adequate integration of cashew agronomist and research engineers for development of most suitable varieties for shelling in Nigeria.
ii. Systematic research on the shelling process should be strengthened.
iii. Innovative research on shelling principles of machines should be encouraged.
iv. Appropriate and efficient home-grown shelling machines should be identified and promoted.

v. Research and application of new materials and intelligent means of shelling should be explored and strengthened.
vi. Government and private investors should intensify funding of research and development of appropriate and efficient cashew nut shelling machines.

5 CONCLUSION

Cashew is extensively cultivated and the nuts massively produced in Nigeria. The state of research on cashew nut shelling machines development in Nigeria has been reviewed and found to be lower than her contemporaries as it is faced with challenges encompassing weak linkage between cashew agronomist and research engineers in the business of machines development, lack of systematic research on the shelling process, innovative research on shelling principles of machines, efficient home-grown shelling machines and limited access to funds. The enumerated recommendations would address the challenges through public-private partnership to revolutionize home-grown cashew shelling machines development for sustainable economic development of Nigeria.

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