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REVIEW ARTICLE

Review of the Performance of Developed Cassava Primary Processing Technologies

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ABSTRACT

This study aimed to review the performance of developed cassava processing technologies to generate information for future intervention on improvement. Additionally, this work figures out the strengths, limitations, performance results, material selection, machine parameters, future areas of concentration, and other statuses related to developed cassava processing machines. This particular study describes a detailed review of the literature concerning developed cassava processing machine machines. The methodology used in this study was a secondary data collection approach that involves the review of journal and conference paper articles from past authors, internet sources and materials, newspapers and magazines and so on. Several types of cassava processing equipment have been developed globally; however, some are not cost-effective for use in small-scale operations but rather for large industries; others have poor efficiency, low throughput capacity, high percentage of loss, and food contamination due to mild steel's propensity to rust over time and subsequently degrade processed products' quality. Mechanizing cassava processing will greatly enhance its processing rate, quality, and quantity of products and make them more easily accessible to consumers in the market. Processing is necessary for several reasons: it reduces or removes the potentially dangerous cyanogenic glucosides found in raw cassava, serves as a preservation tool, yields goods with different qualities, and gives cassava consumers more options for their diets. The processing of cassava tubers for commercial or consumption applications employs numerous procedures such as grating, peeling, boiling, slicing, drying, fermenting, steaming, soaking, roasting, and grinding. From the review investigation, it was observed that the maximum grating capacity, efficiency, and loss for developed graters were recorded as 500 kg h-1, 97%, and 8.44% but the minimum grating capacity, efficiency, and loss were noted as 60 kg h-1, 91.56% and 2.5%. The maximum peeling capacity, efficiency, and flesh loss for developed peelers were obtained as 306 kg h-1, 95%, and 5.09% whereas the minimum peeling capacity, efficiency, and loss were obtained as 60 kg h-1, 70.45%, and 4.3% respectively. The speed range for the developed grating machines was 650 rpm to 1500 rpm, the peeling machines were 120 rpm to 450 rpm, and the slicing machines mostly ran in the 300 rpm to 500 rpm range. Since there is a growing global demand for processed goods, it is imperative to use the most effective performing technology when processing. From the review, it was found that most of the cassava processing machines still need further redesign and improvement to achieve the desired performance results. The study states that since no cassava processing machine has yet been developed that can achieve the intended result with 100% efficiency and 0% loss, precision technology should be taken into consideration for future developments.

Keywords: Capacity, Efficiency, Loss, Graters, Peelers, Slicer

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1. INTRODUCTION

Cassava (Manihot esculenta Crantz) is a perennial woody shrub with an edible root, which grows in tropical and subtropical areas of the world. Cassava is the fourth most important crop for farmers in the tropics and subtropics after rice, wheat, and maize (1). The year-round sustainable availability of food, income generation, resource base conservation, and food security are all significantly aided by cassava. It is one of the important root crops that feeds a sizable section of the global population. Over 500 million people get their fundamental nutrition from cassava, a major staple food in poor countries (2).

Approximately 63.3% of the 304 million metric tons of cassava produced globally in 2019 came from Africa (3). In 2018, the world's total production of cassava root was roughly 278 million tons, with Nigeria accounting for 21% of this total production. The Democratic Republic of the Congo, Thailand, Brazil, and Indonesia were also essential cassava growers. According to FAO forecasts, sub-Saharan Africa will produce 62% of the world's cassava by 2025 (4). Nigeria is the world's top producer of cassava, producing almost twice as much as others. Forecasts indicate that domestic cassava consumption will increase from 45.68 million tons in 2020 to 47.34 million tons in 2021, a 1.67 million-ton increase. It is projected that the initial stock will increase from 4.68 million tons in 2020 to 8.15 million tons in 2021, a growth of about 3.47 million tons. Moreover, cultivation of it has expanded throughout the humid tropics and subtropics, with the belief that it was first domesticated in South America (5). Around 76% of the world's cassava plantings, or over 26 million hectares, were in Africa in 2017 (6).

In Ethiopia, cassava typically grows across almost all of the parts of the country. However, the majority of the nation's production is concentrated in the southwest, west, and south. The average yearly land coverage and productivity in Ethiopia are 195,055 hectares and 501,278.5 tons, respectively. This suggests that the average productivity of cassava in the nation is not more than 25 tons per hectare (7), which is excessively low compared to the yield attained by other tropical countries like Nigeria, which is 35 tons per hectare per year (8). Cassava was introduced to Ethiopia in the 1960s, and the plant is now being planted throughout the nation as a means of addressing food insecurity (9). However, the distribution by area is not as noticeable. In the southern region of the nation, it was produced for a longer period to cover the key times of household food insecurity. These days, it is being encouraged in Ethiopia's northern regions, where there is a food shortage (9). Ethiopia, unlike other African nations, does not yet have unique processing techniques, storage capabilities, or consumption patterns (10).

The local names for cassava in Ethiopia include Mogo, Furno Tree, Mita Boye, and Yenchet Boye (11). The majority of cassava farms and homesteads are enclosed by fences. In the southern and southwestern regions of Ethiopia, farmers blend cassava flour with other grains including maize, teff, and wheat to create a composite flour for baking.

Cassava is grown by small-scale farmers primarily as a subsistence crop, selling the excess for profit. It requires little labor and grows well in poor soils. Plantation crops like sweet potatoes, maize, groundnuts, and other legumes are typically interplant with cassava. A starchy tuberculate crop belonging to the Euphorbiaceae family is cassava (12). Mature tubers can be harvested nine to twelve months after planting, with diameters of five to ten centimeters and lengths of fifteen to thirty centimeters (13).

The root contains significant amounts of calcium, phosphorus, and iron and a comparatively high vitamin C content (14). Cassava's chemical composition is primarily composed of water (60%) and starch, with smaller amounts of protein, fiber, minerals, vitamins, and the toxic compound HCN (15). However, the protein content is minuscule, ranging from 1% to 3%. Fresh cassava roots have the highest starch yield per unit area of any crop known, with a starch content of approximately 30%. There are wide variations in the nutritional content of cassava roots. Apart from its culinary applications, cassava possesses remarkable versatility as its derivatives and starch can be utilized to produce an extensive array of products such as monosodium glutamate, medications, sweeteners, adhesives, plywood, fabrics, and paper. Alcohol is produced from cassava peels and leaves, and animals are fed on them (15).

According to Steve (2007), cassava is an agricultural crop that can be left in the ground for up to two years before harvest. In developing nations like Ethiopia, where malnutrition and calorie deficit are pervasive, its tuberous roots are an invaluable source of inexpensive calories, making it one of the most significant starchy foods (16,17). In contrast to cereal crops, cassava yields more, is better for the environment, and adds cheap energy to the diet.

1.1. Cassava tuber processing

Cassava roots are processed into a variety of products using different techniques after harvesting. This involves some different unit operations, such as grating, peeling, fermenting, drying, and other procedures. Because the cassava tuber's shape and slice size are irregular, manually performing the aforementioned cassava processing unit operations is very challenging. However, since the tubers are stored underground, farmers would rather wait to harvest them until they are necessary before processing them, which means they could remain in the ground for up to two years or longer.

By mechanizing the cassava processing, the products' quantity, quality, and processing rate will all be significantly increased, as well as their marketability (18). But to successfully carry out unit operations like grating, drying, milling, pressing, screening, frying, and extrusion, mechanization is required for the commercialization of cassava production (19). Therefore, for a large portion of the population to safely use cassava as a healthy diet, proper processing is essential. Subsequent processing stages, such as peeling, slicing, grating, and others, significantly reduce and remove hydrogen cyanide. The majority of these tasks are still performed by hand, and because of their low output, they are typically labor-intensive, difficult, time-consuming, and unsuitable for large-scale processing (20,21).

1.2. Purpose of processing

After harvesting, cassava roots should only be preserved without preservatives for about 48 hours because they easily deteriorate (22). Another important reason why processing cassava is necessary is that its high moisture content makes it poorly storable in its raw state. Processing the tubers as soon as possible after harvest is essential to halting the degradation process and converting them into storable food stock. Cassava first goes through a two- to three-day period of physiological deterioration after harvest. Since the earlier stage of deterioration would have produced the perfect environment for microbial infestation, microbial deterioration then starts. Because the product deteriorates so quickly after harvest, it must be processed as soon as possible. Steps in the cassava processing process that decrease its size include peeling, grating, dehydrating, milling, and sieving (23). Processing is necessary for various purposes. Firstly, it gets rid of or lessens the potentially dangerous cyanogenic glucosides that are found in raw cassava. Secondly, it serves as a preservation tool. Third, processing yields products with diverse qualities, giving consumers of cassava more options for their diets.

1.3. Cassava processing steps

For cassava processing, cassava washing and peeling is a necessary step (24). However, depending on the needs of the final product, different cassava processing machines are needed. Three methods are used to process cassava for food: fermentation, drying, and cooking. The fermentation of grated cassava roots for 72 hours was the most effective of the three processing methods in bringing the HCN levels down to a safe level (10 ppm, WHO) for ingestion by humans. A few important steps in turning cassava into mash include peeling, grating, dewatering or fermenting, sifting, and roasting or frying (24). as shown below in Figure 1.

Figure 1. Major steps involved in processing cassava

1.4. Cassava processing unit operations

The processing techniques employed in cassava unit operations include grating, peeling, boiling, slicing, drying, fermenting, steaming, soaking, pounding, roasting, pressing, and grinding (24). According to (24), the unit activities used to prepare cassava include grating, slicing, peeling, drying, and sieving. Farmers of cassava applied methods such as fermentation, sun-drying, and boiling to eliminate the nutritional components found in ants. Conventionally processed cassava yields a multitude of intermediate and final products that are generally shelf-stable and suitable for a wide range of food applications.

1.5. Processing methods

The processing process is typically carried out by hand or using power-operated equipment of different types and models, which are more frequently used in the cassava processing method. Since the tubers were invented and put into production, many methods for shredding cassava tubers have been tried and tested. They include both mechanical and manual methods. There are advantages and disadvantages to every (25).

1.6. Manual method

In this conventional method of processing cassava, the peeled tubers are manually rubbed against a mild steel surface that has been roughened and is mounted on a wooden or metal frame. Hand processing is labor-intensive, time-consuming, and often results in finger injuries for the operator. It may also eventually lead to the development of back pain because of the constant bending of the backbone. Furthermore, products produced through manual cassava processing vary in quality. The quality can differ even when the same person uses the machine (26). Hand processing results in non-uniform particle sizes and large losses because the person is unable to hold onto tiny bits of cassava during the rubbing process. The traditional ways of processing tools for cassava include mortar, pestle, grinding stone, and millstone.

Figure 2. Perforated metal plate grater.

Figure 3. Mortar type grater

1.7. Mechanical method

To meet market demand and standards for cassava mash or powder, efficient mechanized processing technologies utilizing drums or discs are required to produce a sufficient quantity of the product. Machines for processing cassava are required for large-scale operations. Many machine parts in mechanically driven technologies come into direct contact with cassava tubers, leading to the production of fresh, high-quality end product.

2. METHODOLOGY

The investigation of the effectiveness of developed cassava primary processing technologies was conducted on cassava graters, slicers, chippers, peelers, and choppers. The performance of the developed grater, slicer, peeler, and chopper was reviewed at different operating speeds and feed rates for cassava tuber or test materials in terms of key performance indicators or throughput capacity, efficiency, percentage of loss, time, and other performance parameters. Based on their impact on cassava processing, the primary cassava processing technologies (graters, slicers, chippers, peelers, sifters, and choppers) were chosen for review. The method employed during review was conducting the effectiveness result or tests of the technology's capabilities under different conditions and parameters. The methodology used in this study was a secondary data collection approach that involves the review of journal and conference paper articles from past authors, internet sources and materials, newspapers and magazines and so on. Hence, this research reported that to achieve the call for a good design that assures the effectiveness and quality of the processed products.

2.1. Mechanical cassava graters

2.1.1. Dual-operational mode machine

The design by (28), in his design of a dual-operational mode machine, which could be operated by hand or electrically, aimed to enhance the design of a wooden grater with a 60% effective performance. Electrical and manual operating efficiencies were 92.4% and 91.4%, respectively. The majority of his design was constructed of mild steel which causes food contamination and low durability due to wrong selections of materials.

Figure 4. Dual-operation cassava grater.

2.1.2. Modified NCAM motorized grater

The modified NCAM motorized cassava grating machine is composed of a 50mm x 50mm angle iron frame, a cylindrical perforated galvanized sheet for the grating drum, and a trapezoidal-shaped hopper made of 2mm thick stainless steel sheet materials. The modified grater has a grating efficiency of 84%, a grating capacity of 2.0 tons per day, a mechanical loss of 10.9%, and a quality performance efficiency of 92.23%. However, the outcome showed that using this machine was not advised due to the machine loss.

Figure 5. Modified NCAM grater

2.1.3. Electric motor driven cassava grater

It can be powered by a single phase 6.5 hp electric motor. Cassava processing nowadays includes using an electric or engine motor for cassava processing. This is home use small scale cassava grating machine. It could grate about 158.9kg/hr. The efficiency of this machine was found to be 82.7%, which was medium for grating cassava, it needs further improvement. This grater has a low capacity to grate fresh tubers depending on the rotary drum's diameter, speed, and number of perforations per unit area of the drum surface.

Figure 6. Electric motor driven cassava grater

2.1.4. NASENI mobile cassava grater

The grater's components include the main frame, hopper, wheeled tire, grating drum, shoot, pulley, and 6.6 horsepower mover. It can handle loads of 300 – 500 kilograms per hour. It can use water to cool the prime mover. It measures 1840 inches in length, 1000 inches in width, and 1600 inches in height. In comparison to others machines, this one had a higher loading capacity for processing cassava.

2.1.5. ARCADEM grater

It can power an electric motor that matches its 5.2 horsepower gasoline or diesel engine power drive. The machine can produce 300 kilograms per hour and has the following measurements in millimeters: 1090 height, 1000 length, and 460 widths. Additionally, it features a stainless steel grating drum, but the hopper and chute are constructed from painted mild steel which leads to direct contamination of processed product.

2.1.6. Starron's cassava grater

Its output capacity is comparatively low at 150 kg h^{-1}, and it uses 1 liter of fuel per hour. A machine's overall dimensions are 44 x 36 x 24 inches (28).

2.1.7. The Jahn's grater

The Jahn grater consists of a rotating drum and replaceable saw-blade-like flat blades with serrations. The individual blades are made of mild steel with a thickness of approximately 1 mm and are available in lengths of 10, 20, and 30 cm. They are 2 cm broad, with a tooth on each long side. The teeth may have tips that are 2 or 3 mm deep and 1.5 to 2.5 mm apart. However, it is better to fabricate the blade from stainless steel rather than mild steel to maintain food quality.

2.1.8. Niji Lukas's electrical grater

This has a 300 kg h^{-1} capacity and is solely electrically powered. It runs on a 5-horsepower, 1400 rpm, 3-phase motor. It measures 30 by 30 by 42 inches and costs US$1347.80, which makes it a fairly expensive item for end users.

2.1.9. The International Institute of Tropical Agriculture (IITA)

The IITA Model designed by Y.W. Jeong is made of mild steel. To make the drum, the metal is cut to a circumference preferred by the manufacturer and then rolled with a rolling machine to form a cylindrical drum. It had food contamination problems due to materials selection.

2.1.10. Power-driven cassava grater and chipper

Temam, developed a combined cassava grater and chipper that was poorly efficient. It could grate 114.94

kg of cassava per hour with a fuel consumption of 325 ml, and chip 30.3 kg of cassava per hour with a fuel consumption of 150 ml (29). It was made up of the chipping and grating units as well as the power motor that was positioned in the middle of the two machines and could be shared based on the task at hand. This machine performed very poorly when it came to chipping and grating the cassava tuber.

Figure 7. Cassava grater and chipper.

Figure 8. Diesel engine-operated cassava grater

2.1.11. Diesel engine-operated cassava grater

The cassava grater was developed by Erchafo, this machine can process up to 471 kilograms of material per hour at a speed of 1400 rpm and a feeding rate of 5 kilograms per minute. On the other hand, it can process up to 273 kilograms of material per hour at a speed of 1100 rpm and a feeding rate of 5 kilograms per minute (30). At a feeding rate of 15 kilograms per minute and a speed of 1400 rpm, the highest grating efficiency of 97% was recorded; at a feeding rate of 5 kilograms per minute and a speed of 1100 rpm, the lowest grating efficiency was recorded. At a feeding rate of 15 kilograms per minute and a speed of 1400 rpm, the lowest percentage of mechanical loss 2.5% was recorded, while the highest percentage18% was recorded at a speed of 1100 rpm and a feeding rate of 5 kilograms per minute. The machine's fuel consumption was determined to be 1.8 L h^{-1}. The performance results revealed that the farmers who grow cassava were highly encouraged to use this machine. Also the material selected for fabricated this machine was free from corrosion because it fabricated from stainless steel and aluminum.

2.1.12. Motor-operated cassava grater

Esteves et al., stated in their investigation on cassava grating machines that utilizing inexpensive and easily accessible materials from the area, the motor-operated cassava grater was created for use in domestic processing (31). This 1.5-horsepower electric motor powered the cassava grater. Peeled cassava tubers were grated at three different average grating drum rotational speeds: 1424.3 rpm, 1148.3 rpm, and 857.4 rpm. Capacity, efficiency, loss, and fineness modulus were used to assess the grating drum's performance. Based on the test parameters, the average drum speed was found to be 1424.3 rpm, with an average capacity of 283.26 kg h^{-1}, a grating efficiency of 91.56%, and an 8.44% loss. According to the review, the material choice for fabrication was incorrect, the machine was still recommended for users based on its results.

Figure 9. Motor operated cassava grater

2.1.13. Portable cassava chopping machine

Figure 10 depicts a portable cassava-chopping machine that was developed by (32) and has three different sieve sizes (sizes 1, 2, and 3) as well as type A and type B chopping blades. The machine chops the tubers using shear strength produced by the blades' rotary motions. Based on the results obtained, the machine's performance has significantly improved after theoretical evaluation. The machine's capacity to generate various chopped sizes somewhat lowers production costs. The evaluation's results demonstrate the machine's 814–1227.4 kg h^{-1} capacity, over 95% efficiency, and low flesh loss. From an operational standpoint, this machine is deemed suitable and adaptable to small and medium-sized cassava tuber processors due to its ease of use, portability, performance outcomes, and ease of maintenance.

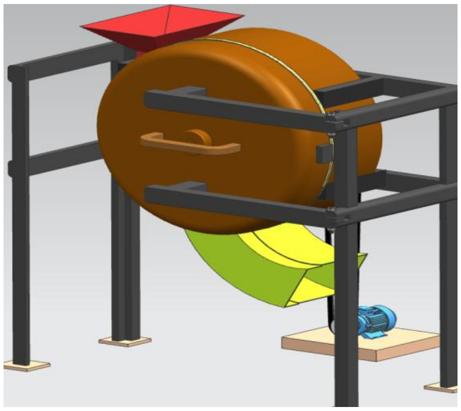

Figure 10. Portable cassava chopping machine

2.2. Mechanical cassava slicers/chippers

2.2.1. Reciprocating type cassava slicing machine

This cassava reciprocating slicer machine was developed by (33), utilizing mild steel materials not food-graded. The slicing process is inefficient; it is stressful, labor-intensive, and time-consuming. The machine uses little power but requires a lot of labor. The electric motor that powers the cassava reciprocating slicing machine has a rating of 0.75 kW (1 horsepower) and runs at 99 rpm. The machine increases cassava chip production in low mass, which suggests low profit. The machine has an overall efficiency of 91.05% and a capacity of 22 kg h^{-1} for both boiled and unboiled cassava root. The average slicing time for boiled cassava root is 0.005 h, and for unboiled root it is 0.00455 h. When tested, the developed cassava root slicing machine did not perform up to par even though it was fed a full mass of preconditioned cassava root at a constant operating speed of 99 rpm.

Figure 11. Reciprocating type cassava slicing machine

2.2.2. Motor-driven cassava slicer

The cassava slicing machine developed by, Wangkuanklang et al. (34) runs with a 3-horsepower single-phase electrical motor attached to a milled steel frame with a shaft that powers a circular slicer disc. This prototype's performance was assessed using metrics like machine capacity, slicing damage, and slicing efficiency. With a slicing disc speed of 60 rpm and a feed rate of 10 kg min^{-1}, the developed cassava slicing machine showed a slicing capacity of 198 kg h^{-1}, slicing efficiency of 87.6%, and damaged slices at 13.89%. The results showed that speed had a significant effect on damage, efficiency, and slicing capacity. By addressing postharvest issues, the development of this cassava-slicing machine is a critical step towards increasing cassava production.

Figure 12. Electrical motor driven cassava slicer.

2.2.3. Cassava slicer machine (small scale)

The machine was developed by Aji et al. (35) for small-scale activities, as depicted in Figure 13. To help cassava tubers move by gravity to the chipping unit, an elevated hopper is provided. A galvanized steel sheet was used to cut a chipping disc, and a gap was made across the sheet metal to allow cassava to be chopped as soon as the tuber reached it. A chipping cover was included, which aids in directing the cassava chips through a discharge chute and keeps them from being carried away by the centrifugal force acting on the cutting disc. To prevent any kind of accident during operation, a power transmission unit comprising a 0.5-watt electric motor, belt, and pulleys was provided at a section of the machine. Chips of different shapes and sizes were produced by the machine. At 5.3 kg min^{-1} on average and 6.0 kg min^{-1} at its maximum, it has an efficiency of 95.6%. Its recommended use for small-scale cassava processing was its only drawback.

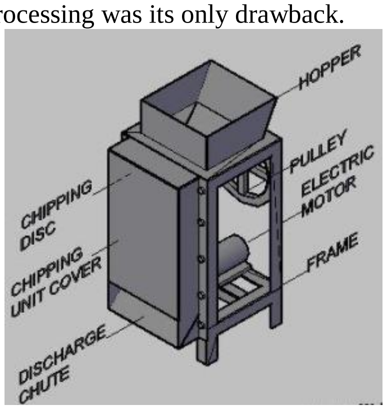

Figure 13. Small-scale level cassava slicer

2.2.4. Dual-operated cassava chipper

The cassava chipper was developed by (36), it could be used by both manual and motorized operators, and it could be customized to fit the needs of cottage-level local processors. The primary focus of this study was to examine how the diameter and length of the cassava tuber affect the amount of cutting force needed to perform an efficient chipping operation. It was noted from the review that as the tuber's length and diameter increased, so did the average cutting force. For this machine, a single phase 1 horsepower electric motor was needed. This motor can power the machine up to about 225 kg of work per hour, which is equivalent to the amount of labor that would be needed. The average chip size that was obtained was 30 mm, indicating that a larger slice thickness required a longer drying time for processed cassava.

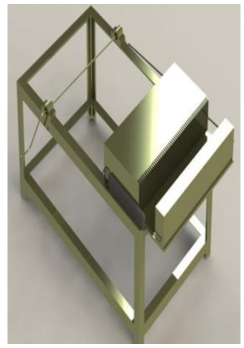

Figure 14. Dual-operated cassava chipper

2.2.5. Manual fed cassava chipper

This manual-fed cassava root chipper for household cassava processors as shown in Figure 15 was developed by (37), it's comprised of an enclosed hopper in the shape of a cuboid, with a feeding chute by the side. A guide by the sides provides the feeding chute. To facilitate efficient chipping, the feeding chute is designed to allow tuber movement horizontally against the chipping blade's vertical rotation. The cassava tuber is manually fed into the chipping chamber, where it is radially chipped by a revolving stainless chipping blade. Through the shaft, pulley, and v-belt connections, the 5.5 horsepower gasoline engine powers the blade. It is collected in a bag, tray, or open basin after the chipped cassava exits the chipping chamber through the outlet chute. An iron frame with angular shapes holds the components together. The desirability factor determined the optimal moisture content of 65.27% and the ideal thickness of 0.618 at 450 rpm for the cassava chips, which ranged from 0.56 to 0.96 cm at the four ranges of moisture content, speeds, and constant feed rate of 89±26.6 kg h^{-1}. The machine's throughput capacities ranged from 49 to 118 kg h^{-1}, with an optimum value of 118 kg h^{-1} at a speed of 600 rpm and 68% moisture content. The average chipping efficiency ranged from 60 to 90% with an optimum value of 79.57% at 533 rpm and a moisture content of 68%. From a review of this paper, the performance results found for this slicer were satisfactory but its usage was scoped at the household level only.

Figure 15. Manual fed cassava chipper

2.2.6. Electric motor cum manually operated chipper

This machine was developed by Awulu et al. (38), the chipper is composed of a frame, driving hand pulley, chipping units, and hopper made of mild steel that has been galvanized. The hopper has a curved shape and measures 640 x 750 x 3 mm. It is inclined at a 45-degree angle to facilitate the easy sliding of the tubers into the chute and clipping knife. A 160 mm diameter pulley powers the machine. The 670 x 700 x 400 mm angle iron that makes up the frame is securely welded together for strength. When operating manually, the handle that is fastened to the shaft's left side is utilized. The machine was tested at speeds between 300 and 400 rpm. To evaluate the electrical motor operation, the mass of well-chipped cassava ranges from 1.27 to 1.73 kg, or 63.5 to 86.5% of the mass loaded in the hopper. At 300 rpm, the efficiency was at its maximum of 86.7%, while at 400 rpm, it was at its lowest of 68%. At a speed of 350 rpm, the lowest mass of 1.42 kg was obtained, while the highest mass of welled chipped was obtained at a speed of 300 rpm. The performance results of this machine showed that an improvement must be needed for the chipper.

Figure 16. Electric motor cum manually operated chipper

2.3. Mechanical cassava peeler

2.3.1. Electrical motor-operated cassava Peeler

The cassava peeler machine developed by Hassan, rotates a 30 mm diameter shaft that is firmly fixed to the cylindrical peeling drum that is mounted on the frame composed of 40 hollow square sections (39). The motor is a 1 horsepower single-phase electrical motor. The machine's performance was assessed using metrics like throughput capacity, percentage flesh loss, and peeling efficiency. This peeler was tested at peeling drum speeds of 30 and 60 rpm and drum fill levels of 10, 15, and 20% while the operation was held for 7 minutes. When the drum was filled to 20% and rotated at 60 rpm, the developed cassava peeling machine had a peeling efficiency of 82.83%, a percentage of flesh loss of 4.03%, and a throughput put capacity of 120 kg h^{-1}. Because of its modest output, the local cassava producers may be able to use this safe cassava peeling machine.

2.3.2. Cassava peeling machine powered by 1hp

This cassava root peeling machine was driven by a 1 horsepower electric motor that had a built-in gearbox that served as a speed reducer. The gearbox had two shafts that ran in and out of it, arranged horizontally and vertically. The mechanical energy was transferred from the electric motor and gearbox to the peeling chamber (drum), which was outfitted with abrasive surfaces and perforated sheets to peel cassava roots. To enable the waste peel or flake discharge, the peeling drum (perforated sheet) was assembled with a 5 mm gap between each piece. Despite having a low-performance output and an average throughput capacity of 105.10 kg h-1, this machine demonstrated an impressive average efficiency rate of 87%. This result implies that the performance result recorded was low.

Figure 17. Cassava peeler powered by 1hp

2.3.3. Pedal Peeling Machine

The cassava peeler a pedal-driven was presented in Figure 18, this machine consists of a 20 kg capacity cylindrical drum made of bars of wire brushes that are attached to the pedal via a chain. Before being loaded into the drum, the tubers are cleaned; the machine should be pedaled slowly to minimize damage and improve the effectiveness of peeling; the tubers are peeled as they rotate over the wire brushes in the drum (the door must be locked first) despite requiring pedaling, it can peel more cassava tubers in a given amount of time than manual peeling. Its capacity is 60-100 kg h^{-1} (as opposed to 20-35 kg h^{-1} when peeling by hand), and its average peeling efficiency is 95%. It also has an average flesh loss percentage of 5% (as opposed to 25% when peeling by hand). For peeling cassava, this peeler machine featured medium performance indicators.

Figure 18. Pedal Peeling Machine

2.3.4. Hand-fed cassava peeling machine

Hassan, designed and fabricated a hand-fed cassava peeling machine (Figure 19) that uses an abrasive surface as its peeling tool (40). It consists of a cylindrically-rolled metal that has spikes achieved by punching holes outwardly; the abrasive rolled metal is connected to a shaft eccentrically, which is then connected to a motor which drives the machine during its operations. The performance of the machine was evaluated, of which 58.5-77.5% and 240-300 kg/hr were recorded to be the average peeling efficiency and throughput capacity ranges respectively. The developed an automated cassava peeling machine by (40) that is based on the principle of a continuous tuber feeding system. The peeling unit is equipped with two peeling tools: a conveyor with a fixed brush and a peeling brush that rotates in opposite directions. The tubers that are dropped into the unit turn and peel as a result of the opposing motions' forward linear velocity and shear stress. The outcomes demonstrated that at 3000 rpm brush speed and 150 rpm conveyor speed, the maximum peeling efficiency of 88.50% was recorded, and at 500 rpm brush speed and 150 rpm conveyor speed, the minimum peeling efficiency of 83.80%. This suggests that, in contrast to conveyor speed, which is inversely correlated with peeling efficiency, brush speed is directly related to peeling efficiency.

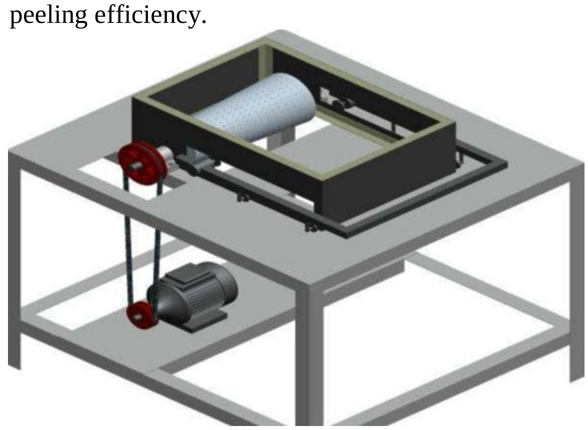

Figure 19. Hand-fed cassava peeling machine

2.3.5. Cassava Peeler and Grater

Rikzx, embarked on designing and fabricating a combined cassava peeling and grating machine (41), (Figure 20). Cassava tubers are being fed into a rectangular container, peeling unit, which has three peeler blades (like a long slanting strip which horizontal and parallel to each other) at the bottom. The peeler blades, fixed on a cylindrical metal, are connected to a rotating shaft, and they peel off the tubers as they come in contact with them. Flat strip blades are employed in the peeling unit to prevent or minimize tuber loss; whiles peeling, water pumps from a tank and sprinkles on the tuber to wash it. Peeled cassava moves to the grating chamber for further processing. The hand-fed double and the single gang cassava peelers were developed by utilizing a brush-auger arrangement that affects the tuber's rotary motion. The auger rotates at a rate opposite to the brushes, from 120 to 450 rpm, causing the tuber to experience both rotary and linear motion. The peeling chamber contains abrasive brushes that rotate at 500 to 1500 rpm. In addition, trimming and cutting were thought to be the machine's most efficient functions. A spring-loaded guide was included to account for the variations in tuber size and shape. These devices can peel and have an 8 tons per day throughput capacity. The device has been enhanced to eliminate manual feeding up to a daily capacity of 10 tons. Based on its design, the self-feed single and double gang is an enhancement of the hand-feed type, utilizing the same design and operating concepts.

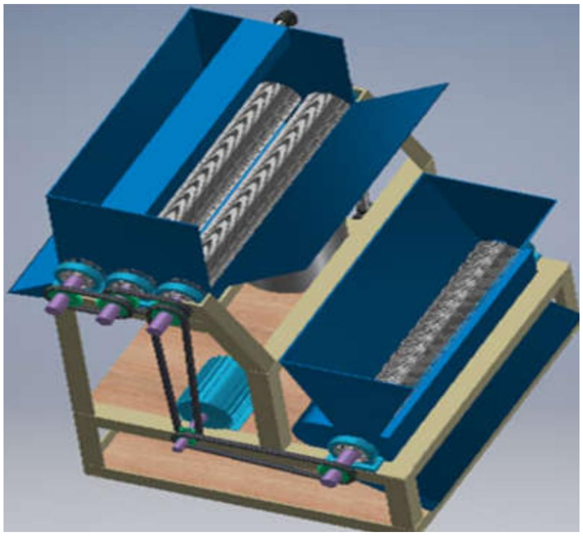

Figure 20. Cassava Peeler and Grater

2.3.6. Abrasive peeling machine

Figure 21 shows the peeler used in this experiment, with the following components: frame, peeling unit, water bath with heating system, motor and frequency converter. It has overall dimensions of 1500 × 500 × 1000 mm and employs five rotating abrasive brush rollers as the peeling mechanism. The peeler was evaluated at five rotational speeds (550, 700, 850, 1000, and 1150 rpm) and five peeling times (1, 2, 3, 4, and 5 min). The most efficient process conditions of 1000 rpm speed, 3.4 min peeling time, 59 °C thawing temperature, and 90 s incubation time produced a peeling efficiency of 99.5 % and flesh loss of 19 % after freeze-thawing. The developed and constructed a batch cassava peeler machine by (42). that does not peel tubers of all sizes and operates on an abrasive mechanism. The apparatus features a revolving inner drum with an 8.5 kg batch capacity and a stationary abrasive drum. The machine's peeling efficiency and flesh losses were measured at 394 rpm and 364 rpm, respectively, when it was tested with cassava that was 200 mm in length and 90 mm in diameter. After the peeling drum's capacity was decreased to 5.1 kg, the average peeling efficiency and flesh losses were found to be 70.45% and 5.09%, correspondingly, for tubers with diameters of 200 mm and lengths of 70 mm. Improvements are necessary because the machine's average peeling efficiency was found to be too low based on its performance outcomes.

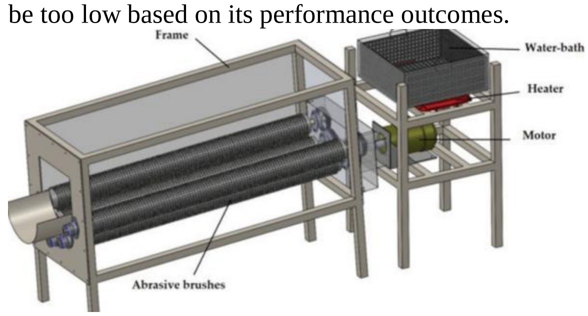

Figure 21. Abrasive peeling machine

The speed at which the machines operated had a significant influence on the performance of the cassava graters, peelers, slicers, and chippers. The tuber's moisture content, irregular shape, non-uniform cortex thickness, and insufficient technical design data affect the performance parameters. To achieve the intended results, proper automation and mechanization are required. Since there is a growing global demand for processed goods, using the most effective performing technology when processing is imperative. The study states that since no cassava processing machine has yet been developed that can achieve the intended result with 100% efficiency and 0% loss, the precision technology should be taken into consideration for future developments. Depending on the review, grating and peeling are the main research and development activities on cassava processing, however, some work is done on others.

3. DISCUSSION

Based on the study, various types of cassava grating machines have been developed as regards the performance evaluation of Cassava graters, not much work has been done beyond testing for the capacity, efficiency and loss of the graters. The majority of the developed graters have low capacity and efficiency and are driven by a 5 hp diesel engine. Several types of cassava processing equipment have been developed globally; however, some are not cost-effective for use in small-scale operations but rather for large industries; others have poor efficiency, low throughput capacity, high percentage of loss, and food contamination due to mild steel's propensity to rust over time and subsequently degrade processed products' quality.

Regarding cassava processing, several machines have been developed to take the place of manual labor. These consist of hand graters, hammer mills, motorized graters, peelers, slicers, chippers, and mechanized graters (43). These machines were mechanized, but their performance indicators were still constrained based on the studies conducted a more thorough performance evaluation of an automated combined cassava grater or slicer using two distinct varieties of cassava, he noticed that the size and variety of the cassava tuber had an impact on the machine's operation (44). The attempts made in the study area have generally resulted in the development of several cassava peeling machines; however, the uneven weight, size, and shape of the tubers have led to comparatively low-performance evaluation results (40).
In the case of Ethiopia, farmers cannot afford to acquire this developed technology because the majority of the

research work on the development of cassava processing machines was done outside the nation and required hard currency. As a result, some research was done to close the gaps in the cassava processing industry and address the lack of locally developed and constructed machinery. According to the review, there is a cassava grating, slicing and peeling machine for the processing of cassava in Ethiopia with good performance results. Nevertheless, the developed cassava processing machine had the following shortcomings or restrictions: This machine's capacity was too low, its efficiency and percentage loss were not assessed, its outlet was not positioned in the correct inclination, the grating machine's hopper was not the right length, the inclined portion of the hopper was not positioned in the correct inclination, forcing the users to push cassava with wood, and the drum's length and diameter were inadequate. From reviewed cassava grating technologies, the grater developed by Erchafo (30) had the highest performance results when compared to other graters whereas peelers developed by Fadeyibi et al. (45), had better results recorded rather than others also the cassava slicer developed by Abdulkadir noted good performance results from other slicers that reviewed (46).

From the review study, it was observed that the maximum grating capacity, efficiency, and loss for developed graters were recorded as 500 kg h^{-1}, 97%, and 8.44% but the minimum grating capacity, efficiency, and loss were noted as 60 kg h^{-1}, 91.56% and 2.5%. The maximum peeling capacity, efficiency, and flesh loss for developed peelers were obtained as 306 kg h^{-1}, 95%, and 5.09% whereas the minimum peeling capacity, efficiency, and loss were obtained as 60 kg h^{-1}, 70.45%, and 4.3% respectively.

Table 1. Performance results for selected cassava processing machines reviewed.

Machine types	**Author/s**	**Speed (rpm)**	**Capacity (kg h^{-1})**	**Efficiency (%)**	**Loss (%)**
Cassava graters	Esteves et al. (2019)	857.4-1424	283.26	91.56	8.44
	Erchafo (2024)	1100 - 1400	272 - 471	97	2.5
	Opandoh (2014)		300-500		
	Ndaliman (2006a)	-	60	92.4	-
	Temam (2020)	-	114.94	-	-
	Awotide et al. (2014)	-	150	-	-
	Apodi et al. (2018)	-	300	-	-
Cassava slicers	Anyim et al. (2020)	99	22	91.05	-
	Wangkuanklang et al. (2021)	60	198	87.6	13.89
	Aji et al. (2013)	-	360	95.6	-
Cassava chippers	Fadeyibi et al. (2017)	-	225	-	-
	Ndukwu et al. (2020)	450-600	49-118	60-90	-
	Awulu et al. (2015)	300-400	103.8	86.7	-
Cassava peelers	Hassan (2017)	30-60	120	82.8	4.3
	Temidayo et al. (2021)	-	105.1	87	-
	Le (2012)	-	60-100	95	5

4. CONCLUSION

The investigation of the effectiveness of developed cassava processing technologies was carried out on cassava graters, slicers, chippers, chopper, and peelers. The throughput capacity, efficiency, percentage of loss, and other performance parameters were reviewed for the developed graters, slicers, chippers, and peelers for cassava tuber processing. Many different designs of cassava processing machines have been developed worldwide; some are more economical for large-scale industries than for small-scale use; others have low throughput capacity, poor efficiency, high loss, and food contamination because mild steel rusts easily and lowers the quality of the processed product. It can be observed from the review that the researchers, research Centers, governmental and private agencies or institutions have contributed to the development of cassava processing technologies. Processing cassava tubers in batches at a time has been made feasible by technological advancements in processing machinery, which has increased the crop's marketability by processing it more quickly. The machines developed so far still have a significant role in tuber processing; the abrasive graters are mostly grating tuber. From the review assessment, it was observed that the electric motor has replaced the manual source of operating power in most machines currently. According to the review results, the lowest grating capacity, efficiency, and loss were observed as 60 kg h^{-1}, 91.56% and 2.5%, while the maximum grating capacity, efficiency, and loss were recorded as 500 kg h^{-1}, 97% and 8.44%. Depending on the review, most research development work on cassava processing was carried out on grating and peeling but some works were conducted on others. Based on the review, it was determined that to achieve the desired results, the majority of cassava processing machines still require additional redesign and improvement.

REFERENCES

1. Kassu, K., Kusse, K., & Tadesse, A. (2020). Demonstration and popularization of processing, post-harvest handling and utilization of cassava food products in semen Ari Woreda of South Omo Zone, SNNPR. International Journal of Agricultural Extension, 7(3), 215–222. https://doi.org/10.33687/ijae.007.03.2942

2. Bayata, A. (2019). Review on the nutritional value of cassava for use as a staple food. Sci J Anal Chem, 7(4), 83–91.

3. Sengar, R. S. (2022). Cassava processing and its food application: A review. The Pharma Innovation Journal, 11(5): 415-422.

4. Olaoye, R. A., Afolayan, O. D., Adeyemi, K. A., Ajisope, L. O., & Adekunle, O. S. (2020). Adsorption of selected metals from cassava processing wastewater using cow-bone ash. Scientific African, 10.

5. Adebayo, W. G., & Silberberger, M. (2020). Poverty reduction, sustainable agricultural development, and the cassava value chain in Nigeria. In The Palgrave Handbook of Agricultural and Rural Development in Africa, 525–551.

6. Amelework, A. B., Bairu, M. W., Maema, O., Venter, S. L., & Laing, M. (2021). Adoption and promotion of resilient crops for climate risk mitigation and import substitution: A case analysis of cassava for South African agriculture. Frontiers in Sustainable Food Systems, 5(3), 617783.

7. Feyisa, A. S. (2021). Current status, opportunities, and constraints of cassava production in Ethiopia-A review. Journal of Agriculture and Food Research, 11(3), 51.

8. Otekunrin, O. A., & Sawicka, B. (2019). Cassava, a 21st century staple crop: How can Nigeria harness its enormous trade potentials. Acta Scientific Agriculture, 3(8), 194–202.

9. Kebede, A., Teshome, B., Wondimu, A., Belay, A., Wodajo, B., & Lakew, A. (2012). Detoxification and consumption of cassava based foods in South West Ethiopia. Pakistan Journal of Nutrition, 11(3), 237

10. Wellens, J., Raes, D., Fereres, E., Diels, J., Coppye, C., Adiele, J. G., Ezui, K. S. G., Becerra, L. A., Selvaraj, M. G., Dercon, G., & Heng, L. K. (2022). Calibration and validation of the FAO AquaCrop water productivity model for cassava (Manihot esculenta Crantz). Agricultural Water Management, 6(2), 107491. https://doi.org/10.1016/j.agwat.2022.107491

11. Misganaw, C. D., & Bayou, W. D. (2020). Tuber yield and yield component performance of cassava (Manihot esculenta) varieties in Fafen District, Ethiopia. International Journal of Agronomy, 2020.

12. Huang, T., Luo, X., Wei, M., Shan, Z., Zhu, Y., Yang, Y., & Fan, Z. (2020). Molecular cloning and expression analysis of sucrose phosphate synthase genes in cassava (Manihot esculenta Crantz). Scientific Reports, 10(1), 1–12. https://doi.org/10.1038/s41598-020-77669-9

13. Egbeocha, C. C., Asoegwu, S. N., & Okereke, N. A. (2016). A review on the performance of cassava peeling machines in Nigeria. Futo Journal Series (FUTOJNLS), 2(1), 140–168.

14. Enidiok, S. E., Attah, L. E., & Otuechere, C. A. (2008). Evaluation of moisture, total cyanide and fiber contents of garri produced from cassava (Manihot utilissima) varieties obtained from Awassa in Southern Ethiopia. Pakistan Journal of Nutrition, 7(5), 625–629.

15. Okoli, I. C. (2020). Cassava waste as feedstuff 1: Cassava peel production, processing, and nutrient composition. Research Tropica.

16. Steve, R. N. and Chitundu, D. (2007). Cassava as drought insurance: Food security implications of cassava trials in Central Zambia. Research in Agriculture and Applied Economics, 45(1), 106-123.
17. Ramalingam, D. (2018). How Cassava production could solve the food insecurity problems. International Journal of Management and Development Studies, 7(1), 31–52.
18. Adiele, J. G., Schut, A. G. T., van den Beuken, R. P. M., Ezui, K. S., Pypers, P., Ano, A. O., Egesi, C. N., & Giller, K. E. (2021). A recalibrated and tested LINTUL-Cassava simulation model provides insight into the high-yield potential of cassava under rainfed conditions. European Journal of Agronomy, 124, 126242.
19. Oyejide, J. O., Orhorhoro, K. E., Afoegba, S. C., & Olaye, M. (2018). Design and fabrication of an improved plantain processing machine. Nigerian Journal of Technology, 37(3), 656. https://doi.org/10.4314/njt.v37i3.14
20. Adetan, D.A., Adekoya L.O. and Aluko, O.B. (2003). Characteristic of some properties of cassava root tubers. Journal of Food Engineering 59: 349 – 353.
21. Davies, R. M., M. O.Olatunji & W. Burubai (2008).Mechanization of cassava processing in Iwo Local Government Area of Osun State, Nigeria. World Journal of Agricultural Sciences, 4(3), 341-345.
22. Oduor, L. A., Owino, W., Ateka, E. M., & Ambuko, J. (2017). Effect of surface coatings on the shelf life and quality of cassava. Journal of Food Research, 7(1), 46. https://doi.org/10.5539/jfr.v7n1p46
23. Ndaliman, M. B. (2006a). Development of Cassava grating machine: A dual-operational mode. Leonardo Journal of Sciences, 9, 103–110.
24. Onu, O. O., Onyenwoke, A. C., & Simon, K. J. (2016). Mechanizing postharvest processing operations : A panaceafFor food security and sustainable rural development. American Journal of Agricultural Research, 1(01), 24–30.
25. Franca, A. S., & Oliveira, L. S. (2011). Potential uses of fourier transform infrared spectroscopy (FTIR) in food processing and engineering. Food engineering, 211-227.
26. Apodi, J., Akidiweasagadunga, P., & Kwablaamedorme, S. (2018). Design and construction of a manually operated cassava gratting machine for the post-harvest unit of the Department of Agricultural Engineering of BOLGATANGA Polytechnic. International Journal of Advanced Research in Science, Engineering and Technology, 5(10), 7091–7098. www.ijarset.com
28. Ndaliman , M. B. (2006). Development of Cassava Grating Machine: A Dual-Operational Mode. Leonardo Journal of Sciences, 103-110
29. Awotide, B., Abdoulaye, T., Alene, A., & Manyong, V. M. (2014). Assessing the extent and determinants of adoption of improved cassava varieties in southwestern Nigeria.
30. Temam, M. (2020). Mohammed temam development and evaluation of power driven cassava grater and chipper machine. International Journal of Engineering Research. https://doi.org/10.33329/ijoer.8.5.1
31. Erchafo, A. (2024). Performance evaluation of diesel engine operated cassava grating machine. Turkish Journal of Agricultural Engineering Research, 5(1), 49–65.
32. Esteves, D. U., Pantuhan, G. P., Serviñas, M. O., & Malasador, J. S. (2019). Design, fabrication and performance evaluation of motor-operated cassava grater. In Mindanao Journal of Science and Technology, 17 (1), 227-241.
33. Osei Seth. (2020). A Review on the performance of some cassava peeling machines developed. North American Academic Research.orth American Academic Research , 3(02) 97-165.
34. Anyim, C. O., Okorie, N. U., & Odoemelam, L. E. (2020). Nigerian Agricultural Journal. ScienceDirect, 51(3), 178–184.
35. Wangkuanklang, V., Meeklangsaen, W., Suntudprom, J., Akkarakultron, P., Phasinam, K., & Watcharinrat, D. (2021). Designing and constructing a cassava-slicing machine for household use. International Journal of Mechanical Engineering, 6(3), 536–540.
36. Aji, I. S., James, E., Ejovwoke, A., & Mshelia, D. A. (2013). Development of an electrically operated cassava slicing. Arid Zone Journal of Engineering
37. Fadeyibi, A., Osunde, Z. D., Egwim, E. C., & Idah, P. A. (2017). Performance evaluation of cassava starch-zinc nanocomposite film for tomatoes packaging. Journal of Agricultural Engineering, 48(3), 137-146.
38. Nwakuba, N., Ndukwu, M., & Afam, G. (2020). Development and optimization of a manual fed cassava root chipper for household cassava processors. Turkish Journal of Agricultural Engineering Research, 1(2), 283-295.
39. Awulu, J. O., Audu, J., & Jibril, Y. M. (2015). Development of cassava (Manihot) chipping machine using electric motor cum manual operation. J. Harm. Res. Eng, 3(2), 78–84.
40. Hassan, A. B. (2017). Design and fabrication of a cassava peeling machine. https://doi.org/10.9790/3021-02630108
41. Olukunle O J, Akinnuli B O, (2013). Theory of an automated cassava peeling system. International Journal of Engineering and Innovative Technology, 2(8), 177-184.
42. Rikzx Lymier. (2017). An optimization machine for cassava products production (Combined cassava peeler and grating machine).

43. Oluwole L, Adio M A, (2013). Design and construction of a batch cassava peeling machine. Journal of Mechanical Engineering and Automation, 3(1), 16-21.

44. Bruinsma, D., & Nout, R. (2020). Choice of technology in food processing for rural development. In Rural Households in Emerging Societies, 225–249.

45. Ugochukwu O C, Michael O, Edwin C O, Christian E O, (2016). Performance evaluation and optimization of single barrel cassava grating machine on selected fresh and stored cassava species, IOSR Journal of Mechanical and Civil Engineering, 13(4), 31-38

46. Fadeyibi, A., Gana Yisa, P. M., & Peter Alabi, K. (2017). Design of a dual-operated cassava Chipper. European Mechanical Science, 1(3), 104–110. https://doi.org/10.26701/ems.336370

47. Abdulkadir B H, (2012). Design and Fabrication of a cassava peeling machine. IOSR Journal of Engineering, 2 (6), 01-08