American Journal of Multidisciplinary Research in Africa
Vol. 3(1), pp. 1-11, January, 2023

ISSN: 2769-0504
https://www.mprijournals.com/

Full Length Research

Cassava Grating Machines, Designs and Fabrication: A Review of Related Literature

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Accepted December, 19, 2022

Abstract: Cassava products produced in Nigeria varies, ranging from one product to another, mostly for direct human consumption after harvesting. This is because the emphasis of the promotion of cassava has been on its use as food. The use of the crop as a basic raw material for industrial purposes would improve industry in Nigeria. Cassava products has been diversified ranging from one product to another, such as the use of cassava in livestock feed, means that more maize and other feed materials used in the past can now be available for other uses such as cassava flour products like glucose for pharmaceuticals, food supplements, alcohol and other beverages. The need for improved method of extracting pulp from cassava for economic purposes made researchers to device improved method of achieving these extractions. However, this particular study describes a detailed review of the literature concerning cassava grating machines, design and fabrication in Nigeria. 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 and so forth. Hence, authors in this research reported that to achieve the call for a good design that assures effectiveness and quality of the processed products. The design was made using Autocad professional software while the fabrication was done using locally sourced materials. Findings from existing studies showed that cassava grating machines has been designed to be mechanically operated and in so doing cassava is fed through the hopper for grinding. Authors in this study also reported that the performance evaluation of cassava grating machines were carried out which gave the average collection efficiency of 93.25% and average grating efficiency of 86.1%.
***Keywords**:* Mechanical Advantage: Hopper: Grating Unit: Internal Combustion Engine: Shaft: Machineries: Design Calculation: Literature Review: Nigeria.
Cite this Article as: Abdulkadir, B. & Ajagba, G. C. (2023). Cassava Grating Machines, Designs and Fabrication: A Review of Related Literature. American Journal of Multidisciplinary Research in Africa, 3(1): 1-11.

1.0 Introduction of the Research

In Nigeria, cassava is mostly grown on small farms, usually intercropped with vegetables, plantation crops, yam, sweet potatoes, melon, maize, cucumber, cocoa yam, Okra and even Yam. Oyesola (1981) argued that cassava is planted by 20 –30 cm long cutting of the wood stem, spacing between plants is usually 1-1.5 meters. Intercropping with bean, maize, and other annual crops is practiced in young cassava plantations (Sanni, 2004; Bamiro, 2007; Abdulkadir et al., 2022; Olusesi & Joshua, 2022a). There are two common varieties of cassava, namely, the bitter and sweet varieties. The cyanide content differs as well as suitability for different growing and consumption conditions. The two varieties of cassava can be grown under different weather conditions. Oyesola (1981) posited that the higher cyanide is correlated to high yields. Nigeria is the world largest producer of cassava tuber, producing about 54 million tones of the world's cassava products. Over the past 25 years significant market opportunities for cassava have opened up in the animal feed industry, initially in the EEC (European Economic Community) countries but more recently for the rapidly expanding animal feed industries of tropical developing countries. Cassava roots compete with other carbohydrate sources, especially maize and sorghum, on the basis of price, nutritional value, quality and availability (FAO 2002). Cassava has several advantages compared with other carbohydrate sources, especially other root crops. It has a high productivity under marginal climatic conditions, which results in a low cost raw material. Root dry matter content is higher than other root crops at 35-40%, giving optimum rates of 25:1 or better. Over 85% consists of highly digestible starch (Bamiro, 2007; Olusesi & Joshua, 2022a). Cassava starch has excellent agglutinant properties which make it especially suitable for shrimps and fish feeds, replacing expensive artificial agglutinants.

Adetan *et al.* (2003) stressed that the potential disadvantages of cassava roots are their bulk and rapid perishability, there low protein content, and the presence of cyanide in all root tissues, having about 70% moisture content. Through simple processing the disadvantage of bulk and perishability can be overcome. Oyesola (1981) added that natural drying is widely used to achieve this objectives drying also reduces moisture, volume and cyanide content of the roots. The dried cassava product thus has only one disadvantage with respect to other carbohydrate feed sources: low protein content which may be supplemented from other sources, particularly legumes (Onabolu, 2002). However, for the export market, where transportation over thousands of kilometers is necessary, further processing to produce high density pellets is carried out to minimize transportation cost. Presently, in Nigeria, the product of cassava usually locally consumed and exportation is limited because the products do not always meet the international standard for health foods. Thus, the need to encourage small scale (home production) of cassava product to ensure quality of products and good hygienic values (Oyesola, 1981). Cassava is a tuberous starchy root crop of the family Euphorbiaceae (Kochlar, 1981). It is a popular crop worldwide known for drought tolerance and for thriving well on marginal soils, a cheap source of calories intake in human diet and a source of carbohydrate in animal feed (Kordylas, 2002). It grows well in areas with annual rainfall of 500-5000mm and full sun, but it is susceptible to cold weather and frost (Oyesola, 1981). Nigeria is by far the highest producer of the crop in the world with production level estimated at 49 million tons per year (Uthman, 2011; Gebeyehu et al., 2022; Owhe-Ureghe et al., 2022).

Ndaliman (2008) suggested that processing cassava into finished or semi-finished products often involves all or some of the following operations, depending on the desired end-products; peeling, washing, grating, chipping, dewatering, fermentation, pulverizing, sieving, pelletizing, and drying/frying. Up till now, most of these operations are still being done manually, and they are generally labor intensive, hazardous in nature, time consuming and unsuitable for large scale production (Adetan *et al.,* 2003*;* Quaye *et al.,* 2009), due to their low output capacity among other negative attributes. Oyesola (1981) reported that, the traditional method of grating involves placing of the local grater, which is made of perforated metal sheet on the table where it is convenient for effective use and brushes cassava tuber on the sheet metal. The cassava turns into pulp and drop into container that is being used to collect the grated pulp cassava in his design used a wooden grater in which the cassava forced into a hopper is rubbed against the grater which is being electrically powered. Enhanced quantity of cassava can be grated using this method. However the durability of grating is low because of its wooden nature. Ndaliman (2008*)* described a pedal operated cassava grinder which is powered by human efforts applied to pedal. The grinder pulverizes the cassava tubers into paste which can pass through a wine sieve. The effective performance of the design was at 60% also designed a single action grater. The machine assembly is powered mechanically or manually in case of electricity failure (Ndaliman, 2008; Ukonu et al., 2022; Abdulkadir & Ajagba, 2022). Apart from faster grating rate, it required less time involvement. The grating drum is made of metallic pipe that carries a perforated plate which served as the grater. Though, its efficiencies (sample weights of 2.0kg of Cassava) were found to be 91.95% (electrical), and 70.4% (manual). However, it's through-put with time may not meet the market demand. This innovation was carried out in order to fabricate a machine that can grate large volumes of cassava or other tubers especially on site and it is limited to freshly harvested cassava with moisture content in the range of 68.2 - 77.8% wet basis.

2.0 Literature Review of Archival Research

2.1 Current Cassava Harvests and Processing Practices

Cassava products produced in Nigeria varies, ranging from one product to another, mostly for direct human consumption after harvesting (Nweke et al., 2002). This is because the emphasis of the promotion of cassava has been on its use as a food. The use of the crop as a basic raw material for industrial purposes would improve industry in Nigeria. Cassava products has been diversified ranging from one product to another, such as the use of cassava in livestock feed, means that more maize and other feed materials used in the past can now be available for other uses. Diverse uses of cassava flour food products such as its glucose for pharmaceuticals products as well as food supplements, and to make alcohol and other beverages, would enhance farmers to cultivate more because of its financial benefits (Kolawole *et al.,* 2007; (Ndaliman, 2008; Abdukladir & Ajagba, 2022)*)*. There is a gap between industrial processors and producers of cassava products that must be strengthened. The Federal government of Nigeria's mandate to include 10% HQCF (High Quality Cassava Flour) flour in all products of wheat flour for bread-making has led to farmers and food processors demanding equipment and machinery to increase production. The Raw Materials and Research Development Council (RMRDC) of the Federal Ministry of Science and Technology has organized stakeholders' workshop on cassava research and development with discussions centered on increasing technology for cassava production, processing and export. The need to develop adaptable machinery for cassava production and processing has become increasingly important (Fajemilehin & Jinadu, 1992).

2.1.1 Constraints to Cassava Processing

Constraints to cassava processing include the absence of efficient equipment; appropriate processing technologies, machines, and tools (Ajagba, 2018; Fajemilehin & Jinadu, 1992). These are not easily affordable and sometimes unavailable at the farm level. The currently available ones were merely fabricated without thorough engineering research. Presently, the equipment available is the grater, dryer, and dewatering machines with the absence of frying machines. Some success was recorded with graters and some dewatering tools. The dewatering tools work in batches while factories need a continuously-working machine for better production. Almost all the processing of cassava requires the roots to be peeled at one stage or another, and no efficient peeler is on the market. One of the greatest constraints to cassava processing is drying, which takes up to four days to complete when using sunlight; the available dryers are expensive beyond the famers' means (Bamiro, 2007). Engineers at home and abroad have made many attempts towards the development of cassava harvest and processing methods. These include manual and semi-mechanized/mechanized methods carried out in the farm and in laboratories (*Agbetoye, 2003*).

2.1.2 Cassava Harvests

Manual harvesting tools such as cutlasses and hoes with some harvesting aids have been designed to assist manual harvesting of cassava. The aids include the hand-operated levers, wooden crowbars and manually operated fork-lifter (JBSTAINO 2019; Kolawole et al., 2007). The development of mechanical harvesters for cassava dated back when Cantamby tried unsuccessfully to harvest cassava using Prairie moldboard ploughs with different structural configurations. After him follows, Makanjuola and Moldenhawer who experimented with four machines for harvesting cassava;

1. inverting the whole ridge and roots with a moldboard plough body;
2. Drawing a moldboard share (with the board removed) below the soil level
3. Using a moldboard plough to divide the ridge along the crest; and
4. Pulling specially designed blades (different shapes of diggers) to cut below the tubers (*Bamiro, 2006*).

2.1.3 Soil Dynamics to Improve Cassava Harvesting

The important criteria for the development of a cassava harvester are the lifting force and energy requirement. Based on an agro-physical parameter study of cassava roots at the time of maturity, and view of soil disturbance systems, it was summarized that the lifting force and energy requirement for cassava harvesting can be reduced by a process of pre-lift soil loosening.

2.1.4 Evaluation of Tools for Soil Loosening

One of the critical steps in the effective harvesting of cassava is soil loosening in the root zone before lifting the cassava tubers out of the soil. This can be done both in terms of reducing the lifting force and to prevent tuber damage (Oriaku et al., 2021; Olusesi & Joshua, 2022b). Therefore, three soil-loosening devices were modified for pre-lift soil loosening in cassava harvesting, and evaluated for performance in terms of soil disturbance and soil forces acting on them in a laboratory soil bin and in the field under similar soil characteristics. These devices consist of the L-tine, A-blade, and a combination of a curved chisel tine working at a depth of 0.1 m ahead of a L-tine. Experiments indicate that of the three devices, the A-blade performed least in the soil loosening forces and specific resistance followed by the L-tines. Furthermore, the results indicate that the L-tines are most suitable for pre-lift soil loosening in cassava harvesting due to their simplicity of fabrication, the reduced damage to cassava roots and adjustable width. The results show that a harvester incorporating L-tines as the pre-lift soil loosening device (requiring a draught force of 18.6kN/m) is technically feasible (IITA 2006).

2.2 Strength of Cassava Tubers

Strength properties are important data required to predict the behavior or resistance to damage of crop materials during mechanized harvesting. Tubers are extremely susceptible to damage during mechanized harvesting of cassava due to the application of vertical and/or horizontal force on the root by the harvesting tool. The bending strength of mature cassava roots (TMS 30572) was determined experimentally using a simple and portable device. Results show that the bending strength varies along the length of the root tuber and also depends on the moisture content of the tubers. While the lower portion has an average bending strength of 5.9 N/mm2, the upper portion nearest the stalk has a value of 7.1 N/mm^2 *(Nweke et al., 2002*).

2.3 Rheological Properties of Cassava

Experiments have been performed to determine some rheological properties of cassava. The properties studied include the tensile, compressive and shear strengths, elasticity and hardness. These properties were investigated under five tuber moisture content levels of 70, 65, 60, 55 and 50%. Results that were obtained show that the higher the moisture content of the tuber, the lower the tensile, and compressive and shear strength (*Sanni, 2004*). However, the lower the moisture content, the lower the degree of elasticity. Average modulus of elasticity of 0.50, 0.70, 0.84, 1.02 and 2.50 N/mm2 were obtained at moisture contents of 70, 65, 60, 55 and 50% (wet basis), respectively. Furthermore, it has been shown that the higher the tuber moisture content, the lower the resistance of cassava to cutting and the lower the penetrometer resistance. This study has provided information that is relevant for the design of machines for cassava harvesting, processing and handling (Oladele et al., 2007; FAO 2005).

2.3.1 Processing: The spoilage of cassava roots occurs within three to four days after harvesting and they are either consumed immediately or processed into a form with better storage qualities. The bulkiness and high ability to perish of harvested roots make immediate processing of the tubers necessary. The simple processing methods available, includes pounding, grating or chipping, to convert the cassava roots to acceptable products are too slow. Onabolu et al. (2002) opined that the operations involved in cassava processing depend on the needed end product. In general, the processing stages in cassava include peeling, washing, grating, chipping, drying, dewatering/fermentation, pulverization and sieving/sifting and frying. Peeling is the first operation performed after the cassava tubers have been harvested. It involves peeling off the cassava tuber outer skin with a knife. The next stage is grating: this is done with graters, but in older times cassava tubers were grated on a piece of galvanized metal sheet, punched with about 3 mm diameter nails leaving a raised jagged flange on the underside. The grating surface was fixed on a flat wooden frame. This method is tedious and takes a lot of time and endangers the operator's fingers (Grace, 2003).

2.3.2 Peeling: Peeling is the first operation performed after the cassava tubers have been harvested and mechanized. The peeling method is yet to be fully developed due to factors that include the irregularity in the shape of the cassava tuber. Attempts have been made by engineers, including the National Centre for Agricultural Mechanizations (NCAM), whom developed the abrasive peeler machine. Perhaps the most successful motorized cassava peeler was exhibited and demonstrated by the Federal University of Technology, Akure, (FUTA), Nigeria. The peeler received a prize for outstanding innovative design. With the development of a functional peeling machine, the mechanization of cassava processing will be further enhanced (*Olukunle, 2005*).

2.3.3 Grating: Grating is the process of converting tubers into pulp, or the process of converting a crystal solid into powder. The next operation after cassava tubers peeling is grating. Mechanized cassava graters have been designed and are replacing manual grating in many locations in West Africa such as Nigeria, where *gari* is produced. A typical cassava grater consists of a wooden drum rotor of about 270mm in diameter, covered with a perforated tin sheet. These are usually powered by electric motors or diesel/petrol engines, which save time and are less injurious than manual grating methods (*Ndaliman, 2005*).

2.3.4 Dewatering: This is a means by which the moisture content of the cassava pulp is reduced. It is simply a process of removing water from the cassava before frying. After pressing, the de-watered cassava mash is a solid cake, which has to be broken up and sieved to remove the large lumps of ungraded cassava and fiber and to obtain product of the same type. Uniform particle size is important because it makes for a more uniform roasting of individual particles during the frying operation. Indeed, smaller particles take less time and energy to roast; sieving the final product of *gari* ensures uniformity of the product (*Kolawole et al.,* 2007).

2.3.5 Roasting/drying

Frying and bagging are the final operations in *gari* processing. In this final process of cassava processing, the solid cassava cake can be fried manually or by the use of mechanical fryer (Agbetoye, 2003). The sifting is done by rotary sifter and toasting operations can be done with an automated *gari* fryer. These newly developed machines can save *gari* producers from the hassles and drudgery that comes with the final phases of the production of this popular staple in Nigeria. Processing of cassava into its products such as chips and pellets requires machines such as peeling and washing machines, chipping machines, dryers and packaging equipment. Many of the machines are not available in commercial quantities in the market and are not cost effective. The development of these machines including their commercial manufacture to feed the rapidly expanding processing factories is important (*Sanni, 2004*).

3.0 Mechanical Advantages of Cassava Grating Machine

The machine is mechanically operated cassava grating machine that requires only the action of filing the hopper with cassava to grind it into pulp (Grace, 2003; IITA 2004). Its mechanical advantage includes durability, portability, ease of operation and mobility. Significant market opportunities for cassava have opened up the animal feed industry, initially in the EEC (European Economic Community) countries but more recently for the rapidly expanding animal feed industries, of tropical developing countries. Cassava roots compete with other carbohydrate sources, especially maize and sorghum, on the basis of the price, nutritional value, quality and availability. Cassava has several advantages compared with other carbohydrate sources especially other root crops. It has a high productivity under marginal climatic conditions which results in a low cost raw material. Root dry matter content is higher than other root crops at 35-40%, giving optimum rates of 25:1. The potential disadvantages of cassava roots are their bulk and rapid perish ability, their low protein content, and the presence of cyanide in all root tissues, having about 70% moisture content. Grating is the transformation of cassava tubers into pulp. Usually, peeled cassava is fed into the hopper then to the grating drum which rotates at a constant speed. The most common graters are made of the horizontal axis cylinder with serrated metal surface. The abrasion action of the cylinder surface grinds against the cassava roots and reduce them to a mash (*Olumide, 2004*). However, before then, stone graters existed.

3.1 Kinds of Cassava Grating Machines

3.1.1 Stone Graters

Stone graters are presumed to be used for grating of food stuff with the used of stone on the surface of another stone. The most important foodstuff been grated is the cassava root (tuber). Ethnographic evidence showed that, a large grater (about 1.5m long) could last for about 35 years. Refurbishing of the board was done after 10-15 years. Both light and dark quartzites of the same technical properties are used to obtain a decorative pattern on the face of the finished grater board (Walker & Wilk, 1979).

Plate 1: **Stone Grater** (Staino, 2019)

3.1.2 Traditional Graters

Over the years, several designs to reduce the stress in the manufacture and use of graters have been brought up. The traditional method of grating cassava was by pounding it in a mortar with a pestle. Later, artisans developed hand graters. In most traditional and remote areas, hand graters are still used. This is made of tin or galvanized iron with perforations usually done with a 3mm nail and hammer. This leaves a raised jagged flange on the underside. The sharp protruding rims of the nail openings are turned outside and then mounted onto a flat piece of wood (Habibat, 2004). Using hand graters can constitute labor, time consuming and dangerous. It takes about 10 to15 working hours to grate a tone of peeled cassava (Cork, 1985). The peeled cassava is grated after an hour of washing to drain off excess water for easy handling, otherwise roots become too slippery to handle. Care and some skill are needed when grating manually to avoid grating of the fingers. Also, it is not possible to grate the whole root. About 3-5% is left ungrated (Flach, 1990: Bencini, 1991).

Plate2. Traditional Grater

3.1.3 Improved Graters

These are owned by individual contractors who grate at a fee or by a group of processors and require 1-6Hp engines. The major intervention in cassava processing was the introduction of a medium-scale motorized cassava grater by the Agricultural Engineers Ltd in 1966 (FAO 2008; Adetan et al., 2006). The cassava grater presented a great innovation in cassava processing since grating is central to traditional processing of cassava in Ghana. Since then, several equipment manufacturers including engineering firms, research institutes, university departments, small-scale artisanal shops, blacksmiths and mechanics have developed and produced various types of cassava processing equipment (*FAO 2005*). Farmers are able to utilize mechanized graters because diesel and gasoline are readily available. Mechanized graters have therefore shifted labor constraints from grating to the labor intensive tasks of harvesting, peeling and roasting, hence eliminating the fermentation process of cassava (*FAO 2008*).

Plate 3: **Improved Graters** (NANS Cassava Grater)

3.1.4 Pedal Operated Engines

These are usually used in areas where electricity, petrol and diesel are scarce. It consists of a pedal chain mechanism which is connected to a belt drive which turns the shaft on which the grater drum is mounted. It usually has a capacity of 60kg/h. The belt drive mechanism transmits power and speed from the chain drive to the drum. A flywheel which serves as a reservoir of energy is connected to the transmission system. This machine makes use of the gravitational movement of the cassava as well as the gradual movement during grating. The following mathematical considerations were made;

$$T= \frac{P}{W} \quad \text{Equ. (1)}$$

Where

T = Torgue
P = Power
W = Angular acceleration

Plate 4: Pedal Operated Grater (Ndaliman, 2006)

4.0 Methodology of the Study

The need for improved method of extracting pulp from cassava for economic purposes made researchers to device improved method of achieving these extractions. However, this particular study describes a detailed review of the literature concerning cassava grating machines, design and fabrication in Nigeria. 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 and so forth.

5.0 Conclusion of the Study

In this study, authors reported that cassava products produced in Nigeria varies, ranging from one product to another, mostly for direct human consumption after harvesting. Authors found that cassava based products are predominant in Nigeria and this could be because there is an emphasy on the promotion of cassava as a food based product and for industrial usage. Furthermore, they opined that the use of the crop as a basic raw material for industrial purposes would improve industry in Nigeria. Cassava products has been diversified ranging from one product to another, such as the use of cassava in livestock feed, means that more maize and other feed materials used in the past can now be available for other uses such as cassava flour products like glucose for pharmaceuticals, food supplements, alcohol and other beverages. However, authors stressed on the need for improved method of extracting pulp from cassava for economic purposes made researchers to device improved method of achieving these extractions. Hence, authors in this research reported that to achieve the call for a good design that assures effectiveness and quality of the processed products. The design of cassava grating machine could be made using Autocad professional software while the fabrication could be done using locally sourced materials. Findings from existing studies showed that cassava grating machines has been designed to be mechanically operated and in so doing cassava is fed through the hopper for grinding. Authors in this study also reported that the performance evaluation of cassava grating machines were carried out which gave the average collection efficiency of 93.25% and average grating efficiency of 86.1%.

6.0 Acknowledgement

My profound gratitude goes to my supervisor, Mr. Abdulkadir Bakare (B. ENG. M. ENG), for his endless support and guidance towards getting this article completed. I must acknowledge with gratitude the effort of my mentor Dr. Akintunde Ajagbe, Publisher and Editor in Chief, Maryland Publishing and Research Institute, Inc. USA, for his powerful words of encouragements, guidance and most especially for making my dream of publishing this work come into fruition by funding the publication. I am glad to be a member of your online mentoring program which has shaped me to become a better person in writing journal articles.

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