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A REVIEW OF THE PERFORMANCE OF MADE IN NIGERIA YAM PROCESSING MACHINES

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ABSTRACT

The review of the yam peeling machines in Nigeria is hereby presented in this paper. Yam is consumed in various processed forms as boiled, pounded, meshed into stick paste or dough, fried, roasted or baked and also consumed as chips, while the waste from the peeled off are fed to livestock or further processed into yam flour. The economical importance of yam cannot be over emphasized, as nothing is wasted. In all the unit operations involved in yam processing, several processes have been successful mechanized with the exception of the yam peeling process. The processing of yam tubers in homes, small scale and large scale industrial processors involved different operations in which the peeling of the tubers is a major task that cannot be neglected. Engineers involved in the development of peeling machines for tubers worked extensively on cassava mostly at the neglect of the yam tubers. However, yam peeling has remained a serious global challenge to professionals and processing engineers involved in yam processing operations and in design of systems. This study presents the few successfully works undertaken on yam peeling machines, highlights the features, prospects, performance evaluation and limitations of the yam peeling machines in Nigeria.

Key words: Yam, Peeling Efficiency, Output Capacity, Performance.

INTRODUCTION

Yam belongs to several plant species of the genus *Dioscorea (family Dioscoreaceae)* and is native to warmer regions of the globe. A number of the species are cultivated for food in the tropics. In West Africa and New Guinea to be specific, the cultivation of yam as a primary agricultural commodity is the occupation and the use of yam has high cultural significance in certain parts of Nigeria and Africa as a whole, (IITA,2010).

Okigbo (2004) reported that the benefits of yam consumption are numerous which includes delay ageing due to presence of Vitamins C, Vitamin B6 and antioxidants which help prevent wrinkles and other sign of ageing. The high level of vitamin A in yam makes it one of the staple foods that help in cell growth, particularly growth of hair, aid process of digestion, dilate vessels and stimulate bile flow.

The economical importance of yam cannot be over emphasized; as nothing is wasted. Yams, although regarded as mainly sources of carbohydrate but contains B vitamins. Yam can be eaten in a variety of ways as roasted, fried, grilled, baked, barbecued, smoked and most commonly boiled. Yam is also used as food for livestock. Yam tubers can be fried, grind into flour and stored for use. However, in Nigeria, a country known for production of large percentage of yam around the globe, it is believed that the supply of yam is lower than its high demand. (Okigbo and Ogbonnaya, 2006). Yam has energy content of about 30 billion kcal with a corresponding protein of about 0.66 million tonnes. Several species of yam are grown in the tropics and the temperate of the world (Innvista, 2009). It is the second most important root/tuber crop in Africa, after cassava with production reaching just under one third the level of cassava (FAO, 2008).Some yams are grown only for medicinal purposes and others for edible purposes. Of the edible species, *Dioscorea alata* (water yam) *Dioscorea cayenensis* (yellow yam), *Dioscorea rotundata* (white yam) and *Dioscorea esculenta*(lesser yam) are most common (IITA, 2008). *Dioscorea floribunda* and *Dioscorea composite* are rich in diosgenin and used for the manufacturing of oral contraceptive by the pharmaceutical industries (Mercola, 2018). The African yam (D*ioscorea spp*) contains *thiocyanate*. It has been suggested that *thiocyanate* is potentially protective against sickle cell anaemia (Agbai, 1986). Other common species of yam are *Dioscorea polystacha* (Chinese yam), D*ioscorea bulbifera* (air potato), *Dioscorea dumetorum* (bitter yam) and *Dioscorea tridida* (cucu-cush yam) . In Nigeria and West Africa diet, the yam tuber is a stable food and it is commonly said that yam is food and food is yam. Yam is consumed in social gathering and has importance in religious functions and the economic importance as it is witnessed in the pando yam production industries. While most of the yams produced are consumed locally, appreciably quantities are shipped to developed countries in temperate regions of the world. As reported by Irtwange (2018), yam has huge socio – cultural importance in West Africa such as marriages, thanksgiving and festivals. However, the utilization of yam should be beyond the traditional method of consumption such as roasted yam, boiled yam, pounded yam, poundo yam, amala, porriage yam, fried yam and boiled yam. There is need to broaden the consumption based beyond Africans in Diaspora by yam been prepared into cake, yam chinchin, yam fries and several other products.

According to (Izekor and Olumese, 2010), yam is an important dietary element for many West African people. It is rich in starch and can be prepared in many ways. It is available all year round unlike other seasonal crops. These characteristics make yam a preferred food and a cultural important food security.

The nutrients in yam are minerals such as magnesium, calcium, phosphorus and also vitamins such as riboflavin, an vitamins A,C,E and K including carbohydrates, fats, crude proteins (Opara, 1999; Okigbo and Ogbonnaya, 2006). Oyenuga (1981) reported that yam is rich in calcium which Strengthens the bones, phosphorus, riboflavin, niacin an as well vitamins that aid immune function, slow down aging and improve healing. Yam contains potassium which serves as an important compound of cell and body fluid and also helps in controlling heart rate so as to avoid hypertension as well as regulating blood pressure. Dioscuri, a storage protein found in yam can also be used to cure people suffering from hypertension (Niba, 2003).

Figure 1: The Main Yam Producing States in Nigeria and Its Numerous Uses (www.finelib.com)

According to Irtwange (2018), the yam value chain development is imperative as there are more than eighteen yam based product that need to be promoted in Nigeria and globally in addition to flours, chip and pharmaceutical grade starch etc. Nigeria remain the world's largest producers of yam which account for 61.7 percent of the global production of the root crop while there are over 60 varieties of yam. The rising profile of yam in Nigeria has led to yam now being placed on the Anchor borrower programme of the Central Bank of Nigeria and ministered by Nigeria Incentive Based Risk Sharing System for Agricultural Lending (NIRSAL) and this is because:

i. yam is the preferred stable food in West Africa,
ii. it is consumed by a combined population of about 300 million
iii. it has the value of $13.7 billion exceed all other Africa staple crops equivalent to the combine valve of cassava, maize, millets, sorghum and rice.

However, all categories of yam processing required the peeling of the skin covering the fleshy tuber before it can be processed into any useful form and drying for appropriate preservation of yam. For drying which is avenue for preservation of yam, the peeling of the yam tuber is a necessity before sliced into smaller thickness allowing for faster drying. The peeling not only improves the suitability of the yam for processing but also improves the palatability of food product. Moreover, peeling of yam is generally done manually, this traditionally hand peeling is assumed to be the norms.
Either in the household or for industrial use, the tubers need to be initially peeled. Peeling is time consuming and required large work force to actualize. Manual yam peeling poses a great task when required in large quantities and many numbers of people are engaged in the hand peeling operation with enormous wastes. More so, problems associated with manual peeling includes losses as a result of inefficiencies of those involved in the operation, time losses, drudgery experience by the work force, blood contamination from accidental knife cut during peeling operation and time loss in operation mostly by large scale industries involved in yam flour industries.

It is not a secret that the industries involved in yam processing in Nigeria are faced with peeling problems especially for commercial usage. Peeling and cutting done manually involves tedious process and the labour requirement is always large in making the product ready for final consumption. The processing of peeling itself in most cases is done unhygienic, low efficiencies and sometimes there are incidences as injury or human hazard that are incurred during the process of peeling.

Yam Production

Yam is the common name for some plant species in the genus *Dioscorea* (family *Dioscoreaceae)* that form edible tubers. These are perennial herbaceous vine cultivated for the consumption of their starch tubers in Africa, Asia, Latin America, the Caribbean and Oceania. Yams are monocot relate to lilies and grass. Native to Africa and Asia, yam tubers vary in size to about 1.5meter in length and 70kg in weight. There are over 600 varieties of yam and 95 percent of these crops are grown in Africa. Yams are farmed on about 5 million hectare in about 47 countries in the tropics and subtropics of the world (IITA, 2010).

Table 1: Change of Yam Production, Cultivation Area, Yield And Consumption Of Africa.

Location	Cultivated Area ('000ha)	Yield (t/ha)	Production ('000t)	% of world
World	4,928	10.5	51,778	100.0
Africa	4,443	10.8	49,833	96.3
West Africa	4,178	10.6	48,101	93.0
Nigeria	3,045	11.5	35,017	67.7
Cote d'Ivoire	820	8.5	6,933	13.4
Ghana	299	11.9	3,550	6.9
Benin	205	8.8	1.803	3.5
Togo	63	10.2	638	1.2

Sources: FAO, 2010

More than 54 million ton of yams are produced in sub – Sahara Africa annually on 4.6 M ha. Over 95% of this production lies in a five country yam belt that includes Nigeria, Benin, Togo, Ghana and Cote d'Ivoire. Although yam production in Africa is 40 percent that of cassava, the value of yam production exceeds all the other African staple crops and is equivalent to the combine value for the top three cereal crop , maize, rice and Sorghum.

Table 2: The Top 5 Yam Producing Countries in Africa in 2013

Rank	Country	Production, m/ton	% of World Total
1	Nigeria	40,500,000	64.2%
2	Ghana	7,074,574	11.2%
3	Cote d'Ivoire	5,731,191	9.09%
4	Benin	3,177,265	5.03%
5	Ethiopia	1,191,809	1.89%

Source: FAOSTAT data 2015.

Nigeria remains the world's largest producers of yam, which account for 61.7 percent of the global production of the root crop while there are over 60 varieties of yam. The value of $13.7 billion exceeds all other staple crops equivalent to the combine value of cassava, maize, millet, sorghum and rice (Irtwange, 2018). Yam is predominantly produced in Benue, Niger, Taraba, Cross River, Kogi, Enugu, Kaduna and Ondo State in Nigeria.

Morphology of Yam

According to Onwueme, (1978), the yam tuber grows from a corm – like remains attached to the tuber after harvest and sprouts developed from it. When the corm separates from the tuber sprouting occurs from the tuber near the point at which the corm was attached. A transverse section of a mature yam tuber shows it to be composed of four concentric layers are:

i. Corky periderm - The outer portion of the yam tuber, it is a thick layer corn cells. Often cracked, but which provides an effective barrier against water loss and invasion by pathogens. `
ii. Cortex- a layer located immediately beneath the cork, comprising thin – walled cells with very little stored starch.
iii. Meristematic layer – elongated thin – walled cells under the cortex. Sprouts are initiated from this layer.
iv. Ground tissue –the central portion of the tuber, composed of thick – walled starchy cells, with vascular bundles ramifying throughout the mass. Most yams are essentially composed of water, starch, small quantities of protein and other minor constituents.

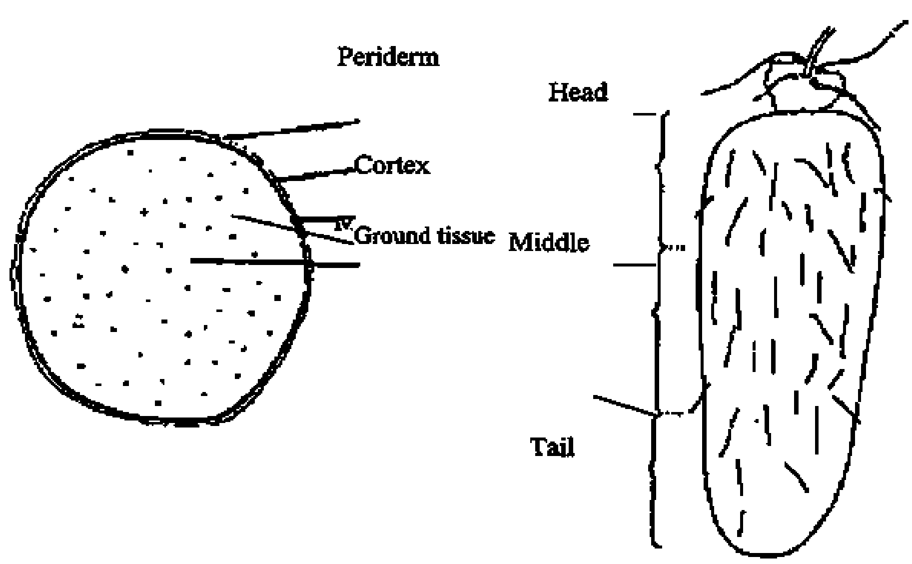

Figure 2: General Morphology and cross section of yam tuber (Onwueme, 1983)

Yam Peeling Machines

Adetoro (2012) developed a mechanical yam peeling machine, which utilized a drum eccentrically mounted on a shaft rotating at various speeds ranging between 20rpm and 50rpm. The speed of rotation was derived by means of pulleys and belts arrangement with the spins on the drum as the abrasive that does the peeling. The machine which accommodated six tubers at a time had an average efficiency of 95.97%, percentage loss after peeling as 3.95% and a capacity of 10.8gs^{-1}.

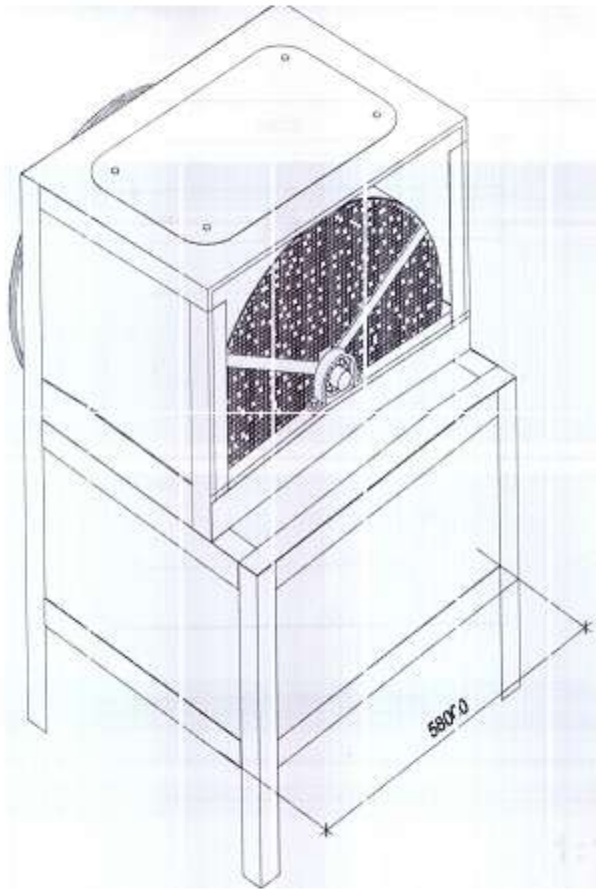

Figure 3: Mechanical yam peeling machine

Ayodeji *et al* (2015) developed a power operated a yam peeling and slicing machine which has two components harnessed together which does the peeling and slicing of yam in a pilot yam flour processing plant. The components of the machine consist of electric motor, peeling chamber fitted with peelers, auger shaft for transporting the tubers and roller for the clamping and aligning the tubers. The machine peels the yam at relatively high angular velocity of the rotary peeling brush. The study noted that the peeling time was fairly constant for all tubers and the orientation and size of the tubers affects the effectiveness of peeling to a great extent. The average efficiency of the machine was 87.86% with an average peeling time of 12.2seconds.

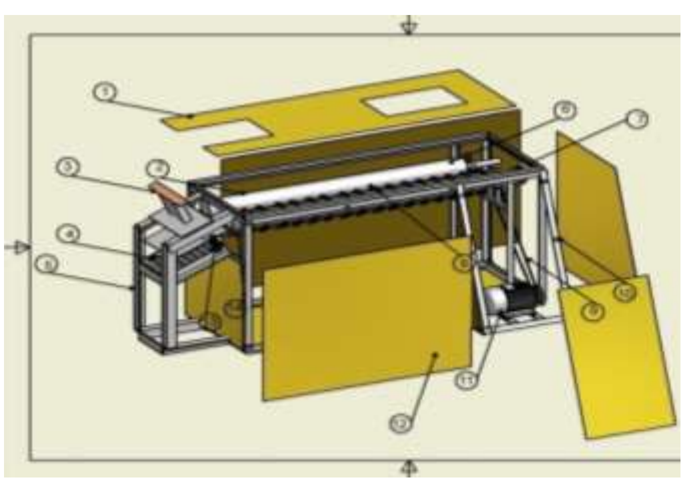

Figure 4: Exploded view of yam peeling and slicing machine

Part listed: 1. Protective hood; 2. Rear cover; 3. Slicer handle; 4.Slicer; 5.Slicer unit frame; 6. Idle roller; 7. Pulley; 8. Peeler Shaft; 9. V- belt; 10. Motor House Frame; 11. Electric motor; 12. Front Cover; 13. Slicing Unit; 14. Auger Shaft.

Ukatu *et al* (2005) developed Industrial yam peeler. The machine make use of three peeler arms which are spring loaded and peeler blade fixed to the peeler arms and which scrape the tuber body by a pre – set depth. It also consists of a peeler ring on which the peeler arms are mounted and driven thing a chain drive and the peeler ring housing the peeler arms have toothed structures that acts as opener which initiate the opening of the aperture when in contact with the tuber. The machine performance was characterized by peeling efficiency, peeling losses and throughput rate. It peels at the rate of 16mm of tuber length per econ irrespective of the tuber size and shape. Peeling efficiency range from 62.7 - 80% while material recovery ranged from 82.7 - 88.8 %. The machine performance was not affected by tuber mass, tuber diameter and moisture content.

In the manually operated ginger peeler developed by Charan *et al* (1993), brushes were made of coconut fibre as abrasive material for peeling. Agrawal *et al* (1983) developed an abrasive brush type peeling machine. The operation of which was improved upon by Agrawal *et al* (1987). The peeler consists essentially of two continuous brush belts being driven in opposite direction with a downward relative velocity by a variable speed electric motor.

Other means identified by Hassan (2012) for peeling cassava aside manual were chemical method, steaming and mechanical methods. The chemical method involves chemical actions and thermal shock which leads to softening and loosing of the skin using caustic soda (NaOH). Steaming method subject the tubers to high steam pressure over a short period of time to avoid partial cooking (or eventual cooking). Mechanical method includes mechanical means of peeling, aimed at peeling a large number or a batch at a time. Many mechanisms devised for this purpose includes the continuous process, abrasive belt conveyors and batch abrasive types among others.

Onorba (2010) developed a domestic yam peeling machine using pressurized steam techniques. The machine consists of heating compartment, sprayers, rollers and peelers. The heating compartment is where the water is heated to produce steam. A set of sprayers located in the peeling chamber sprays steam on the yam tuber to weaken the bark. The rollers rotate the yam for the peeling processes. The average rate of peeling was 0.52mm/sec with efficiency of 47.8%. The study showed that tubers of lower moisture content offer higher resistance resulting in lower efficiency. The machine designed however can only handle yam tubers not more than 30cm in length, not too curved in shape.
Ojolo *et al* (2016) designed and fabricated a yam peeling machine with a dual operation. The machine utilizes spring loaded peeling knife and power screw mechanics during peeling operations. The machine evaluated performance and the peeling efficiency ranged between 71.2 and 100%. The peeling rate was 11.15mms^{-1} during motorized operation and 3.45mms^{-1} during manual operation. The peeling loss ranged from 3.67 to 14.29% during motorizes operation and from 3.91 to 16.96% when the machine was operated manually.

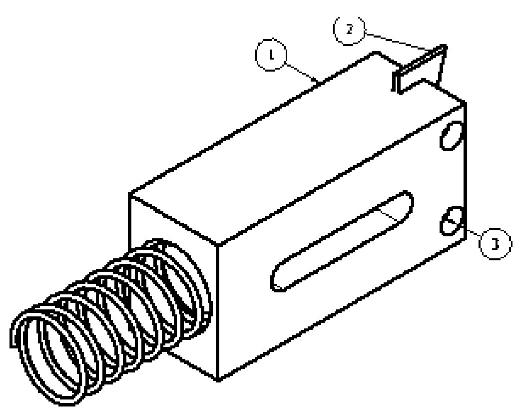

Figure 5: The peeling knife assembly (Ojolo *et al*, 2016)
(1-knife holder; 2-peeling knife; 3-Fastener)

Table 3: Authors and their Contributions to Yam Peeling Machine - Reviewed Literatures

Type of machine	Name of Author(s), year	Performance/ Efficiency
Industrial yam peeler, making use of three peeler arms which are spring loaded and peeler blades as the peeler arms which scrapes the tuber body by a pre set depth.	Ukatu *et al*, 2005	Material recovery ranged from 82.7 - 88.8 %. Peeling efficiency range from 62.7 - 80%.
Domestic yam peeling, using pressurized steam techniques.	Onorba , 2010	Limited to yam tubers not more than 30cm in length and not too curved in shape. Efficiency is 47.8%
Yam peeling machine which utilized a drum eccentrically mounted on a rotating shaft.	Adetoro, 2012	The machine accommodated six tubers at a time An average efficiency of 95.97%, percentage loss after peeling as 3.95% and a capacity of 10.8gs^{-1}.
Yam peeling and slicing machine with two components, one arm does the peeling while the other arm does the slicing of the yam into a pilot yam flour processing plant.	Ayodeji *et al*, 2014	The average efficiency of the machine was 87.86% with an average peeling time of 12.2seconds.
Yam peeling machine, utilizes spring loaded peeling knife and power screw during peeling operation.	Ojolo *et al*, 2016	The peeling loss 3.67 - 14.29% during motorizes operation and from 3.91 to 16.96% when the machine was operated manually. Efficiency is 71.2- 100%.

Katsuyama *et al* (1975) listed several types of peelers used to peel a variety of fruit and vegetables such as steam peelers (for carrot and root vegetables), mechanical peelers and chemical peelers. Also Lisa (2002) listed some other peelers as Rotating cage peelers, U – bed design and raging bull peeler. The Table 3 shows the summary of brief contributions by various authors who have worked on the development of different kinds of yam peeling machines in Nigeria.

However from all the literatures reviewed on peeling generally, five methods of peeling identified are the use of abrasive action, chemical, heat, manual and mechanical peeling system. In the mechanical peeling system involves scraping the tuber skin with abrasive action, brushes made of coconut fibres, belt, peeling blades which scrape the tubers body at a preset depth and some used punched holes in the drum to perform the peeling action. As a result, most of the yam tubers are not totally peeled having the yam skin - bark intact.

The Chemical method was noticed used for peeling of cassava. The disadvantages of chemical use for peeling includes difficulties in controlling the penetration of the chemical into the cassava tuber, difficulty in the removal of the chemical traces which may be poisonous and the cost of acquiring the caustic soda.

In using the Steaming method for peeling, the tubers could be subjected to steaming beyond the required time which can lead to cooking.

From literatures reviewed, it was observed that most of the yam peeling machines that we have presently made used of abrasive and mechanical method for peeling. These methods for peeling have not yielded the desired results. The effectiveness and the efficiency of the machines range from 60 – 90%. Existing tuber peeling machines developed so far face problems of high tuber loses and moderate efficiency, meaning that the peel is not properly or completely removed due to high variability of the root size and cortex thickness (Egbeocha *et al*, 2016). Large tubers have been peeled with low efficiency and breakage and crushing of roots have been reported in some instance.

There is therefore a need for an efficient and cost effective tuber peeling machine for a clean peeling operation in the cause of tuber processing. Hence, the proposed Lathe turning mechanism and not another method to solve this peeling problem as recommended by Abdulkadir (2012). Mores so, the concept of lathe principle for the peeling of yam was bore out of the operation done by the lathe on wood and metal respectively. In this case yam tuber will be fixed in position but rotates about its axis while the peeling tool moves along the length of the yam' tuber removing an appreciable amount of peels as chips. This method employs the principle of turning using the lathe machine mechanism bark or skin can be removed by the cutting tool. Turning is one of the basic function of the lathe machine, in which the work piece is rotated about it axis and the cutting tools is fed into it. In the process shearing away unwanted material. The work piece for turning is held by means of holding devices while it rotates.

Conclusion and Recommendation

It is observed from literature that major research works on peeling of tubers focused on cassava peeling machines mostly, this could be attributed to the attention given to cassava by successive government in Nigeria as cassava tuber is easy to be cultivated under varied climatic and soil condition and a major stable low income crop cultivated in the tropics in contrast to the challenges of mechanization of yam production. Although in cultivation, 40% of yam production is to that of cassava. Cassava is Africa's second most important stable food after maize and secondly probably because Nigeria is the world's leading cassava producer until recent. Cassava transformation agenda in Nigeria has been on for awhile before yam got the attention of government recently. Other reason could be the fact that the cultivation of yam is on the higher side to that of cassava which is cheaper. The establishment cost of cassava production is generally is low as stem cuttings are main input. Yams are planted on heaps and ridges with the planting materials as yam sets or seed yam as addition cost. Cassava also have low peel remover at low or moderate speeds and has the highest peeling efficiency. More so, the tender skin of the yam tuber and the peeling losses envisaged as a result of its peculiarity likely informed the limited attention given to yam peeling machine. The Table 3 gives a summary of authors and works on the development of yam peeling machines in Nigeria. Limited works on yam peeling machines exists whereas numerous unlimited works have been completed and some are still ongoing on cassava peeling machines to date. Challenges and opportunities in the Nigeria yam value chain to include yam processing equipment, yam peeling machines and mechanization of yam products among others. The successfully development of an accurate, fast and cost effective yam peeling machines would removed drudgery and the bottleneck involved in yam peeling operation. Finally it will eliminate to a great extend most of the problems experienced by yam tuber processor with an overall improvement in productivity and timeliness in the processing of yam tubers.

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