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Development of an Automated Cassava Processing Machine using Intelligent Sensors.

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Abstract

Cassava is an essential crop in Nigeria which is processed into garri as a constituent for human food. It is also processed into other useful materials like gum, starch etc. Nigeria remains the largest producer of Cassava in the world. Unfortunately, cassava is extremely perishable, its processing is slow and labor-intensive which invariably leads to low productivity. In this paper, the efficiency of cassava was improved by developing a processing machine that automates the process using intelligent sensors. The stages involved from the cassava to garri processing was first identified and characterized for their various functions. The operation of the machine at each processing stage was modeled. After that, the electronic-based control and sensor mechanism were designed for the machine in each cassava to garri processing stage. An algorithm was developed to control the operation through the sensory units. The result from the developed cassava processing machine showed the average performance of the peeling efficiency and flesh loss was 73.67% and 3.63% respectively. The average grating efficiency was 92.79%.The cassava processing machine reduced processing time, drudgery and working hour.

Keywords: Cassava Processing Machines, Intelligent Sensors, Electronic control system, Peeling Efficiency**,** Grating Efficiency

I. INTRODUCTION

The development of any country is mostly affected if there is non-availability of uninterrupted and regulated power supply. Cassava is a major source of carbohydrates in the human diet being processed into garri as it is known in Nigeria. It is God's gift to the tropics because it can grow in poor soil even with inadequate rainfall. It is the commonest solid food in Nigeria consumed by over 130 million people. Nigeria is the world's largest manufacturer of cassava (Ikechukwu G.A and Maduabum A.I.V., 2016). Cassava production is fundamental to the economy of Nigeria as the country is the world's largest producer of the commodity. The starchy roots of cassava are a major source of food for more than 700 million people across the globe. Traditionally, cassava is processed before consumption. The unit operations involved in cassava processing after harvesting the tuber from the farm include peeling, grating, drying, milling, pressing, sieving, extrusion and frying. Processing of cassava is necessary because it serves as a means of removing toxic cyanogenic glucosides present in cassava tuber, preservation and yields varieties in cassava diets Nigerian's population grows at the rate of 3.5 percent annually (Kamal A.R and Oyelade O.A.2015) and this means that the food capacity must also grow commensurately. However, Cassava is extremely perishable and its processing is still largely done manually and locally. Cassava - garri processing is produced in rural areas by local women and unfortunately, its processing process by the rural people is slow, labor intensive, drudgery and stressful leading to post-harvest losses and low productivity. This has frustrated the rural people who use the traditional methods for cassava processing to give up the trade. The youths are no longer interested in cassava- garri production. Some have migrated to overcrowded cities since local livelihood opportunities that will enable businesses and households to thrive in their local domains are no longer there. It is no longer cost-effective. Without a proper solution to this problem, living is impossible. There will be laborious operations, time-consuming, grossly inadequate, inefficiency, low productivity and poor economy

The solution was to design an automated cassava processing machine that produces garri of high quality in a short period and reduce human labor.

II. THEORY OF WORK

- **Need for Cassava Processing**

Cassava is an essential crop in Nigeria and its products are found in the daily meals of Nigerians. Cassava contains 60 -70 percent moisture and has a shelf life of 2 to 3 days. Because of its shelf life, it needs to be consumed immediately or processed into another product form after its harvest. Cassava farmers are finding it challenging to process harvested cassava roots and end up selling at a meager price. However, with the help of research and development over the years, cassava crop can become a commercial crop plantation that will be grown in large quantities and converted into different product forms such as the starch, cassava chips, flour, ethanol, cassava pellets, livestock feed, alcohol/ethanol, textile, confectionery, adhesives, wood, food and soft drinks. These product forms are also of high demand in the global market. Seventy percent of the cassava produced in Nigeria is processed into garri and it is the most commonly traded cassava product. It has been discovered that traditional methods of processing cassava roots result in poor quality products that contain high levels of cyanide which is poisonous. Cyanide causes goiter and a nerve-damaging disorder that makes one unable to walk properly (Adekanye et al. 2015). Proper processing of cassava reduces cyanide levels, prolongs shelf life, reduces harvest losses and avoids contamination of the products.

- **Processes of Cassava Production**

The basic processes required in the production of Garri from cassava are:

a. **Sorting:**Cassava rootsare sorted to select healthy roots (without rot or other damage) after harvesting.

b. **Peeling and washing:** Cassava roots are peeled to remove the outer brown skin and thick inner layer and washed to get rid of stains and dirt.

c. **Grating**: The peeled cassavas are grated into a mash to remove the cyanide. To produce large quantities of cassava, Farmers need it.

d. **Dewatering and fermenting:** This completes the process of removing cyanide from the cassava mash. The water content in the mash that was produced during grating is decreased using a hydraulic press. Fermentation follows for a few days.

e. **Granulating**: The fermented mash is mechanically reduced in size to produce fine granules of a greater surface area known as grits

f. **Roasting**: The grits are then roasted or fried in a hot frying tray or pan to form the final dry and crispy product.

g. **Sieving:**The Garri is sieved to separate fine granules from coarse particles, a grinder is used for crushing the large granules into smaller ones.

h. **Packaging**: The garri is weighed and then packed for marketing.

(Ikechukwu et al. 2016).

- **Intelligent Sensors**

Intelligent sensors consist of primary sensing elements, excitation control, amplification, analog filtering and data conversion. Intelligent sensors are used for measuring one of the physical properties likeTemperature, Resistance, Capacitance, Conduction, Heat Transfer, etc. They are different intelligent sensors such as Temperature Sensor, Proximity Sensor, IR Sensor (Infrared Sensor), Pressure Sensor, Light Sensor, Flow and Level Sensor

- **Temperature Sensor**

Temperature Sensor senses and measures the changes in the temperature. The temperature changes correspond to change in resistance or voltage. Different types of temperature sensors are Thermistors, Thermocouples, Resistive Temperature Devices, Temperature Sensor ICs, etc. Application of temperature sensors is found in mobile phones, air conditioning systems, automobiles, computers and industries.

- **Proximity Sensors**

Proximity Sensors is a sensory device that identifies the presence of an object using different techniques like Optical, Ultrasonic, Hall Effect, Capacitive, etc. It is a non-contact type sensor. Applications of Proximity Sensors are Mobile Phones, Car Parking system, Industries (object alignment), Ground Proximity in Aircrafts, etc.

- **Infrared Sensor (IR Sensor)**

Infrared Sensor is light-based sensors that are used in various applications like proximity and object detection, automobiles, Robots, Industrial assembly, Robots, Industrial assembly. Two types of Infrared Sensors are the transmissive Type and the reflective Type. In the transmissive infrared Sensor, the transmitter and the detector are positioned in a way they are facing each other and the sensor detects any object that passes between them. In the Reflective infrared sensor, the transmitter and the detector are adjacent to each other. An object is being detected when any object comes in front of the sensor.

- **Ultrasonic Sensor**

Ultrasonic sensors are used to measure the distances of an object. It is a non-contact type sensor that measures the velocity of an object using a Doppler shift property of the sound wave. In the doppler shift, the frequency is higher than that of the human audible range.

III. METHODOLOGY

The peeling machine was designed to peel 20kg of cassava tubers with an average length of 150mm at 150 rpm. The cassava tubers are fed in a circular drum that has rotary motion making the cassava to move in motion and come in contact with a perforated tool for peeling to occur. The design parameters for the peeling machine are

Circular drum volume$(V) = \pi r^2 h$ (1)

$$V = \pi * 2ft^2 * 2.25ft = 14.13ft^3$$

Power to peel cassava $(p) = mgrv$ (2)

$$= mass * g * radial\ distance * velocity$$

$$= 20kg * \frac{9.8m}{s^2} * 0.304 * \frac{2\pi * 150}{60}$$

$$(p) = 935.47watts = 1.25hp$$

Coefficient of friction for mild steel in cassava is μ = 0.364. Therefore chute inclination is

$\phi = \tan^{-1}\mu = \tan^{-1}(0.364) = 20°$ speed transmission ratio$= \frac{small\ \ pulley\ \ diameter}{Large\ \ pulley\ \ diameter}$ (3)

$$STR = \frac{D_s}{D_l} = \frac{5"}{20"} = 1/4$$

Center distance between the pulley(c)

$$c = \frac{D_s + D_l}{2} + D_s \qquad (4)$$

$=\frac{5"+20"}{2} + 5"=17.5"$

Belt length for the pulley(l)

$$l = \frac{D_s + D_l}{2} + 2c + \frac{(D_l - D_s)^2}{4c} \qquad (5)$$

$$(l) = \frac{5"+20"}{2} + 17.5" + \frac{(20"-5")^2}{4*17.5"}$$

$(l) = 33.21"$ =0.84m

A shaft diameter of 25mm was used in this operation. In the peeling machine, the peeling and washing process occurs and the peeled cassava is transferred to the grating process through the chute that was connected to the circular drum peeler. The grating unit made up of high carbon steel and teethed cylinder grates the cassava tubers. The grated cassava pass through the cylinder to the exit of chute .the grating house volume is 1.2ft^3

The pressing unit extracts the grated pulp by applying pressure to reduce the moisture using a screw press mechanism. The screw press will dewater the cassava grates. All units were made up of high carbon steel to avoid chemical reaction to the cassava.

The electronic-based control and sensor mechanism were designed for the machine in each cassava to garri processing stage and it is shown in fig.1

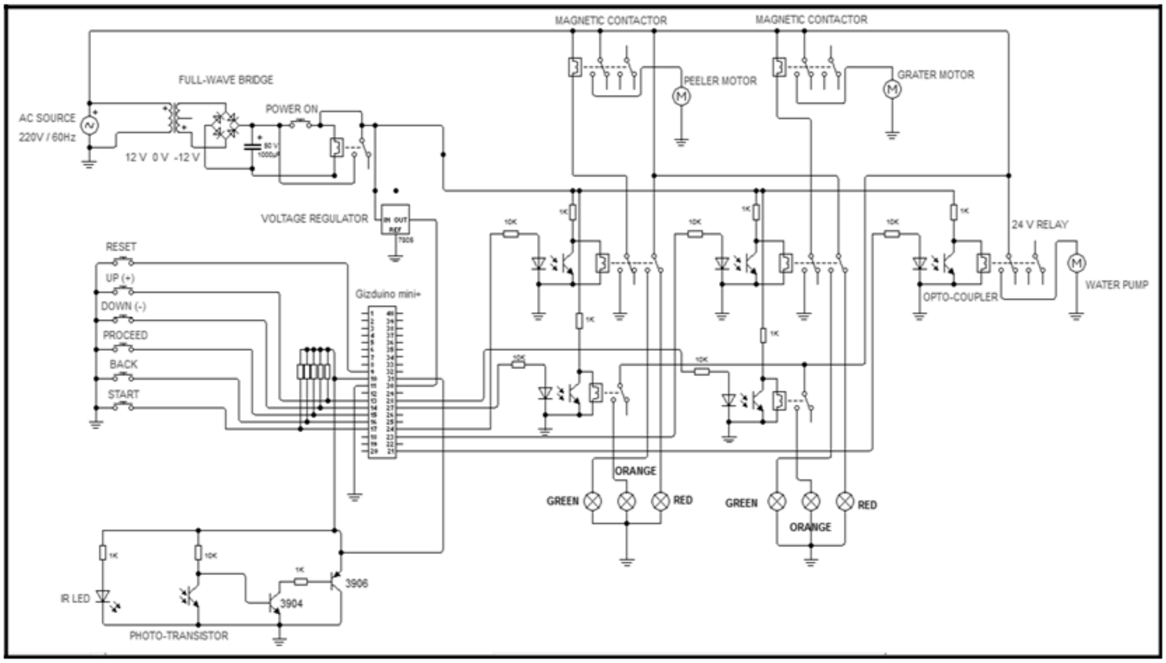

Fig 1 Circuit Layout of an automated cassava processing machine

12V to -12V transformer, full-wave rectifier, and 50V capacitor were used to have a 24 V DC power supply output. A 5V voltage regulator was added to isolate the supply for the microcontroller and other 5V components

Anytime cassava passes and blocks the infrared(IR) sensor, a low logic output is received by the Gizduino Mini+ microcontroller which drives the high powered motors and water pump. Opto-couplers were connected to 24 volts relay to isolate the microcontroller from high voltage lines. From the 24V relay, the magnetic contactors with overload relays were connected to trigger the motors using 220V power. The relay switches on the water pump while the bulbs connected to relays indicate stop, ready and go. The algorithm was developed to control the operation through the sensory units.

IV. RESULTS

The automated cassava processing machine was fabricated as shown in fig. 2.

Fig 2 Automated Cassava processing machine

The automated cassava processing machine was tested using different cassava sizes on three trials to verify if the efficiency of peeling, grating and pressing was satisfactory.The cassava tubers were loaded into the peeling unit with a mass of 20kg per batch and all operation data from input to output was recorded for analysis. The calculations were done using the following equations

Peelingefficiency(PE)% P.E=$\frac{weight\ of\ peels\ removed}{total\ weight\ of\ peels} * 100\%$ (6)

Flesh loss(FL) %

FL=$\frac{weight\ of\ flesh\ removed}{total\ weight\ of\ flesh} * 100\%$ (7)

The result of the peeling and washing test is presented in table 1

Table 1 Peeling and Washing test

	Trial 1	Trial 2	Trial 3	Average
Weight of Tubers(kg)	20	20	20	
Peeling and washing period	4mins	4mins	4mins	
Weight of peeled tubers(kg)	17.8	18	18.3	
Weight of peels and Flesh loss tubers(kg)	2.2	2	1.7	
Weight of peels not peeled by machine(kg)	0.4	0.3	0.2	
Weight of Flesh loss (kg)	1.01	0.65	0.34	
Weight of peels (kg)	1.7	1.8	1.8	
Peeling efficeiency(%)	70	75	76	73.67
Flesh loss(%)	5.5	3.5	1.9	3.63

Graphical representation of peeling efficiency and flesh loss is shown in fig.3

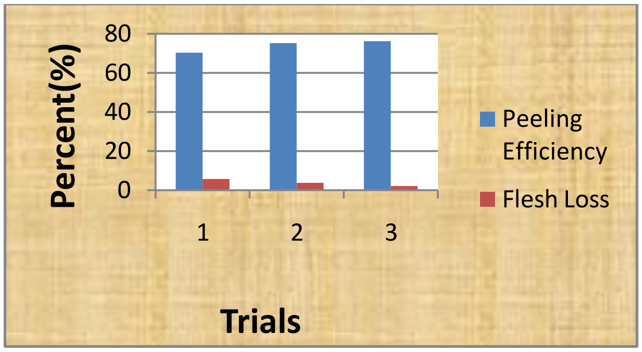

Fig 3. Peeling and Flesh loss efficiency

The result showed that the percentage of peeling efficiency increases while the flesh loss percentage decreases. Their average performance was 73.67% and 3.63% respectively.

The peeled cassava is grated and pressed and the efficiency is obtained by using equation 8

$$Grating\ efficiency(\eta)$$

$$\eta = \frac{weight\ of\ cassava\ grated\ and\ pressed}{weight\ of\ peeled\ cassava} \quad (8)$$

The grating and pressing capacity (β) is obtained using equation (9)

$$\beta = \frac{weight\ of\ cassava\ grated\ and\ pressed}{time\ taken} \quad (9)$$

The result from the grating and pressing are presented in table 2.

The graphical representation is shown in fig 4

Table 2 Grating and Pressing test

	Trial 1	Trial 2	Trial 3	Average
Weight of peeled tubers(kg)	17.8	18	18.3	
Duration of Grating and Pressing	15mins	17mins	18mins	
Weight of Grated and Pressed Cassava (kg)	16.5	16.7	17	
Grating and Pressing Efficiency. (%)	92.7	92.77	92.9	92.79
Grating and Pressing Capacity (kg/hr)	66	58.9	56.7	60.53

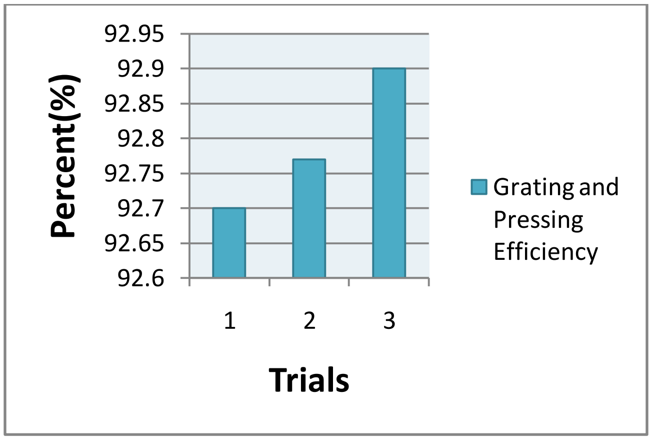

Fig 4 Grating and Pressing Efficiency

The result showed that the percentage of grating and pressing efficiency increases as the number of trials increases. Its average performance was 92.79%.

V. CONCLUSION

An automated cassava processing machine using an intelligient sensor was developed and tested. The efficiency of each unit was verified and the overall performance of the machine was good. Cassava processing machine produces garri in a short time, reduces cost, minimizes waste and reduces human drudgery. The fabricated machine can be improved by regulating the motor speed during peeling as well as increase the surface area in contact for grating cassava tubers by increasing the diameter of the teethed cylinder

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