DESIGN AND DEVELOPMENT OF A CONTINUOUS FLUIDIZED-BED GARI DRYER

Ismail, S. O., Ojolo, S. J., Olatunji, O. O. and Ogunleye, I. O.
Department of Mechanical Engineering
University of Lagos, Lagos State, Nigeria; University of Ado, Ekiti, Ekiti State, Nigeria

ABSTRACT
Fluidization technique is a viable, reliable and more efficient method of producing hygienic gari. In this work, a hot air continuous fluidized-bed dryer for cassava particle was designed, constructed and tested. A feeding subsystem which includes hopper and rotary feeder was also designed and fabricated to control the particle feed rate into the drying column. A rectangular drying column of dimension 0.4m x 0.8m x 1.0m was constructed. A perforated rectangular plate was used as a distributor grid. The bed was tilted at an angle of repose 15° to assist the discharge of the product through product outlet. This machine also comprises a centrifugal blower, a temperature controller and a 9kW air heater. The dryer was tested using a drying temperature of 120° and 150°C at a varied time interval of 5mins and 2mins with variable blower operating conditions. The dryer took 22mins to attain a steady temperature of 150°C with blower on and 8mins when the blower is off. After feeding, it took 18mins to dry and roast or fry 2kg of gari at 150°C and 24mins at 120°C. In conclusion, this dryer is very efficient and productive when compared with the manual, local, convectional and modern existing techniques.

Keywords: Fluidization, Gari, Fluidized-Bed Dryer, Heater, Blower.

INTRODUCTION
With an estimated population of 150million people, a land mass of approximately 93,700square kilometre, and vast mineral and agricultural resources, Nigeria has substantial economic potential in its agricultural sector. However, despite the importance of agriculture in term of employment creation, its potential for contributing to economic growth is far from being fully exploited. The sectors importance has fluctuated with rise and fall in oil revenue. Over the past 10years, Nigeria agricultural sector has remained stagnant while the contribution of the manufacturing sector to the Gross Domestic Product (GDP) has declined over the same period. As at 2004, Nigeria is the largest producer of cassava in the world (FAO, 2009). Yet, Nigeria has a few cassava processors in this category of operation. The small and medium processing operations typically employ three to ten workers and are very sparse at present. Large scale cassava processing is virtually non-existing in Nigeria. The need for innovation in cassava processing techniques is enormous. Traditional cassava processing has a number of undesirable attributes; it is time wasting, low yields and lack of storage capacities.

Gari is a granulated white or yellow product-from cassava depending on production method. Gari is fermented gelatinized dry coarse flour, very popular in West Africa and a staple food in Nigeria, Ghana, and Togo. Gari frying is a complex procedure which in traditional processing depends for its success almost entirely on the skill of the operator. A traditional fire place consists of three stones supporting the frying pan. This causes a great deal of discomfort to the operator due to exposure to heat and smoke from the fire and steam from the wet cassava mash. At the same time the system is very inefficient in its use of fuel, energy consumption per unit of dried gari is considered to be too high. Even enclosing the fire on three sides will improve fuel consumption and reduce smoke blowing into the faces of the operator. The efficiency and ineffectiveness of frying and fire wood consumption are the most important issues in traditional production that need to be addressed most urgently. Falokun and Ogunyemi (1997) and Mayokun (2002), carried out a project work to design and construct a fluidized bed batch gari dryer which will effectively replace the local method of gari frying. But, they have lower efficiencies when compared with this type.

Fluidization is the operation by which solid particles are transformed into fluid like state through suspension in gas or liquid (Falokun and Ogunyemi (1997)). When a gas pass through a layer of particles supported by a grid at low flow rate, the fluid percolate through the void space between stationary particle. As the fluid velocity increased, the void age increases, this results in an increase in pressure drop on the particles. The pressure drop across the particle layer will continue to increase in proportion to the gas velocity till the particles in the bed divided; at this point the frictional force between particles and fluid counterbalances the weight of the particles.
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At this stage the bed is said to be incipiently fluidized. Fluid velocity at this point is known as minimum fluidization velocity.

A continuous fluidized bed dryer is a machine in which a continuous flow of damp, granular material is conveyed over a perforated bed, through which air is blown to bring about fluidization (Jumah, 1995). Drying occurs because of the direct contact between the damp material and the hot air blown through it. In a continuous fluidized process, the particles are perfectly mixed, the bed temperature is uniform and is equal to the product and exhaust gas temperature. Efficient and intimate contact of the fluidizing air with the particles is achieved. Better fluidization quality and fluidizability is enhanced as the feed material is continuously charged into the fluidized bed of relatively dry particles.

Considering the previous works that have been done on continuous fluidized bed dryer and other drying methods and inherent disadvantages, it is pertinent to develop a better drying technology which will avert those disadvantages. Hence, this project was designed, constructed and performed the following overall advantages:

- Provides a continuous drying process, dries gari hygienically through mechanical operation using a continuous fluidized bed dryer, provides a device which produce uniform colour, texture and other sensorial properties, reduces manual drudgery, increases productivity and develops a locally fabricated feed rate control mechanism.

MATERIALS AND METHOD

DESIGN OF THE FLUIDIZED-BED CONTINUOUS DRYER

A fluidized bed continuous dryer with a capacity of 100kg of cassava mash was designed. The basic design parameter obtained from the wet cassava particles are the density of wet particles, particle diameter, and the range of drying temperature utilized. The first two parameters were experimentally determined as 617.19kg/m³ and 435.25μm by Ogunleye and Adeyemi (2009) and Ogunleye (2003). Also drying temperature of 200°C maximum value was used. The design calculations are obtained as follows:

Fluid Bed Column

- A rectangular column for a continuous fluidized bed dryer is selected as to allow adequate residence time for the particles before their discharge from the outlet. Assuming that the length, width, and height of the column are 800mm, 400mm and 1000mm respectively, therefore the area of the column is calculated as thus:

  \[ \text{Area of the column, } A_{br} = L \times B = 0.8 \times 0.4 = 0.32m^2 \]

  \[ \text{Volume of rectangular bed } = \frac{\text{mass}}{\text{density}} = \frac{M_p}{\rho_p} = \frac{617.19}{0.32} = 0.0162m^2 \]

- The height of the bed prior fluidization \( H_b \) is obtained as:

  \[ H_b = \frac{V_{br}}{A_{br}} = \frac{0.0162}{0.32} = 0.051 \]

- The physical height of the column \( H_{cr} \) is expressed as \( H_{cr} = H_b + TDH \)

  \[ \text{Where } TDH = \text{Transport Disengagement Height} \]

- It is the region within which solid loading falls back into the bed while the smallest particles are carried out of the off take tube. This was obtained experimentally from the correlation of Horio, et al, 1980 as:

  \[ TDH = \sqrt[3]{d_{eq}} \]

  \[ \text{Where } d_{eq} = \text{the equivalent volume diameter of the bubbles at bed surface.} \]

- In this design, a total column height of 1.00m was used.

That \( H_{cr} = 1.00m \)

Fluidization Velocity

- The velocity of air at the point of incipient fluidization is usually determined by the use of Ergun Equation. But, the correlation derived primarily for a fixed bed is not the best to be used to determine the maximum fluidization velocity. The result of Though imp (1981) is used for estimating the maximum fluidization velocity, \( U_{mf} \)

  \[ Re_{mf} = \sqrt[2]{(31.62 + 0.0425 \pi R_t)} \times 31.6 \]
\[ R_{mf} = \frac{d_p P_d H_{mf}}{\mu^2 g} \]

And

\[ 1 - \left[ \frac{\rho_g}{\rho_p} \right] \]

where \( \rho_g \) = density of the particles during fluidization

and \( \rho_p \) = density of fixed loosed particles.

\[ \rho_p = \frac{617.19}{1 - 0.386} = 1005.2 \]

Thus

\[ \rho_p = \frac{1005.2 kg}{m^3} \]

\[ Ar = \frac{4.45 \times 10^{-3} \times 1.21 \times (1005.2 - 1.21) \times 9.81}{1.84 \times 10^{-6} \times 9.81 m} \]

Therefore, \( Ar = 31.02 \times 10^4 \)

\[ Re_{mf} = \sqrt{(31.62^2 + 0.0425 \times 31.02 \times 10^4)} - 31.6 = 87.48 \]

\[ \mu_{mf} = 0.299 m/s \]

\( Ar \) is calculated to be \( 31.02 \times 10^4 \) and \( \mu_{mf} \) is \( 0.299 m/s \)

Mass flow rate at minimum fluidization, \( \dot{M}_{mf} = A_{br} Re_{mf} \rho_a \) where air flows into the bed at a temperature of 120°C. The air density is obtained from Thermodynamic Table at this temperature is \( \rho_a = 0.899 kg/m^3 \) and it is equal to density of dry gas at low pressure.

\[ \dot{M}_{mf} = 0.899 \times 0.32 \times 0.299 = 0.086 kg \]

Pressure Drop across Fluidized Bed (\( \Delta P_B \))

When a fluid flows through a bed of particles, it will exert a dry force upon the particles resulting in a pressure drop across the bed as the fluid approach velocity is increased, pressure drop across is magnified when the drag force is sufficient to support the weight of the particles in the bed, the bed is said to be fluidized. The pressure drop across the bed (\( \Delta P_B \)), remains constant (even with further increases in fluid velocity) and equal to the effective weight of the bed per unit area.

\[ \frac{\dot{M}_p}{\rho_{px} H_{br}} (\rho_p - \rho_a) g \]

\[ \frac{10}{1005.2 \times 0.32 \times (1005.2 - 617.19) 
\]

\[ \Delta P_B = 18.33 Pa \]

Pressure Drop across Air Heater (\( \Delta P_H \))

Pressure drop across the air heater is due to sudden expansion \( \Delta P_{esp} \) at the entry of the heater and sudden contraction \( \Delta P_{conta} \) at the exit.

\[ \Delta P = \left[ 1 - \frac{A_1}{A_2} \right] \left( \frac{V^2}{2} \right) \rho \]

Where \( A_1 \) = cross sectional area of pipe

\( A_2 \) = Cross sectional area of rectangular heater box

The air heater is assumed to be coiled and the dimension of the chamber or box is taken into consideration. Therefore, the cross sectional area is

\[ \pi D \]

\[ A_1 = \frac{4}{4} = (3.142 \times 0.1) / 4 = 0.007855 m^2 \]

\[ A_2 = L \times B = 0.8 \times 0.4 = 0.32 m^2 \]
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\[ \frac{A_1}{A_2} = \frac{0.007855}{0.32} = 0.0245 \, m^2 \]

\[ \Delta P_{exp} = \left[ 1 - \frac{A_1}{A_2} \right] \frac{\left( \frac{2.79^2}{2} \right)}{\rho} \]

\[ = \left( 1 - 0.0245 \right) \cdot \frac{\left( \frac{2.79^2}{2} \right)}{\rho} = 4.556 \, Pa \]

\[ F_{ostr} = (1 - 0.0245) \cdot (3.812)^2 \cdot 0.899 = 3.330 \, Pa \]

Pressure Drop across the Distribution Grid

For stable operation,

\[ \Delta P_d = 0.15 \quad \text{for} \quad U_g = 1 - 2 U_{inf} \]

\[ \Delta P_d = 0.15 \times \Delta P_b = 0.15 \times 118.33 \, Pa = 17.75 \, Pa \]

Pressure Drop across in Cyclone

According to Mayokun (2002), pressure drop in an industrial cyclone varies between 0.1 to 0.2kpa. For the purpose of this design the extreme pressure drop is used for the selection of a blower of high capacity for a successful fluidization operation.

\[ \Delta P_c = 2000 \, Pa \]

Total Pressure Drop and Blower Selection

The total pressure drop is the sum of the various pressure drops calculated previously across each component of the plant.

\[ (P_t) = \Delta P_d + \Delta P_{exp} + \Delta P_{con} + \Delta P_{cy} \]

\[ = 118.33 + 3.96 + 4.56 + 3.33 + 15.37 + 2000 = 2145.55 \, Pa \]

Therefore, a blower appropriate for this equipment should be able to deliver air at a mass flow rate greater than 0.086kg/s against a pressure drop greater than 2175.55Pa.

Design of Distributor Grid

We have various forms of distributor grid, for this design the percolated and multi-orifice plate is used because it is easier to produce and cheaper.

According to Mayokun (2002), the fraction of open area of distribution for fluidization is exposed as

\[ F_{or} = \frac{U_{mb}}{C_d \rho} \sqrt{\left( \frac{\rho_a}{2\Delta P_d} \right)} \]

Where \( C_d \) is the drag coefficient and is taken to be 0.6 and \( U_{mb} \) is greater than \( U_{inf} \). Density of gas in Wind ton is given by

\[ \rho_a = \frac{V_{WT}}{M_{inf}} = 118.33/287 \times 393 \quad \text{at the temperature of} \quad 120 \text{°C}. \]

\[ \rho_a = 1.049 \times 10^{-3} \, kg/m^3 \]

\[ \frac{M_{inf}}{0.086} \]

\[ U_{mb} = \frac{P_0 \times a_{or}}{0.099 X 0.32 X 10^{-3}} \]

Where \( U_{mb} \) is the velocity of gas in Wind ton

\[ U_{mb} = 256.10 \, m/s \]

\[ F_{or} = \frac{U_{mb}}{C_d \rho} \sqrt{\left( \frac{\rho_a}{2\Delta P_d} \right)} = \frac{256.20}{0.6} \sqrt{\frac{1.049 \times 10^{-2}}{2 \times 17.75}} \]

\[ = 3.283 \]

Selected orifice diameter is 4mm

Given that the ratio of centre hole spacing, \( s \) to diameter of orifice is

\[ \frac{S}{d_{or}} \]

\[ \sqrt{F_{or}} = \sqrt{3.283} \]

\[ = 0.5256 \]

\[ S = 0.0021 \, m \]

The perimeter of the distributor is \( 2(L+B) = 2 (0.8 + 0.4) = 2.4 \, m \)
An equivalent square distributor will be 4L where L is the length of the square distributor.
4L = 2.4, therefore L = 0.6

\[ L = \frac{0.6}{N} \]

\[ N = 0.0021 \]

\[ = 285.71 \]

\[ N^2 = 285.71^2 = 81632.65 \]

\[ N^2 = 81633 \]

Therefore the total number of the orifice that must be drilled on the distributor grid is 81633.

Power Rating of the Heating Element

The element is required to raise the temperature of 0.086kg/s of air from 25°C to 160°C, therefore heat required, Q is expressed as:

\[ Q = M \cdot C_p \Delta \theta \]

Where \( C_p \) is the specific heat capacity of air at constant pressure and is equal to 1.005kJ/kg

\[ Q = 0.086 \times 1.005 \times 135 = 11.67 \text{KJ} \]

\( \Delta \theta \) is the change in temperature.

Assuming an efficiency of 70% is used, actual quantity of heat

\[ Q_{ac} = \frac{Q}{\eta} = \frac{11.67}{0.7} = 16.67 \text{KJ} \]

Energy

\[ \frac{3.61}{3.61} = \frac{3.61 \times 10^6}{4.618 \times 10^3} \text{kw/h} \]

Power supplied, \( P = IV \)

Where \( V = 220V \) and \( P = 3600 \)

\[ P = \frac{220}{3600} \]

Hence, \( I = 16.36 \text{A} \)

\( V = IR \)

\[ V = \frac{220}{16.36} \]

\[ R = 13.44 \Omega \]

Design of Cyclone

The cyclone diameter can be calculated for a selected inlet velocity. Cyclone is designed to give an inlet velocity between 9 and 27m/s.

For an extreme value of inlet velocity

\[ M_{nf} = \frac{A_c}{V_s} \]

(Mayokun, 2002)

Where \( A_c = \text{Area of cyclone} \)

0.086

\[ A_c = \frac{27}{V_s} = 3.19 \times 10^{-3} \text{m}^2 \]

The duct area of a standard cyclone is 0.1Dc²

Hence, 0.1Dc² = 3.19 \times 10^{-3}

3.19 \times 10^{-2}

Dc = \frac{0.1}{0.178} = 0.178 \text{m}

Residence Time

If the particles are small, very porous and sufficiently wet to contain free moisture, the drying rate remains constant throughout the drying process. On the other hand, if the solid particles initially contain surface moisture, falling rate period will occur after a short period of constant rate drying.

The equation for calculation of the residence time is given as:

\[ t_r = \frac{M_p}{F_p(1 + x_0)} \]

(Zacharias, et al., 2003)
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$F_p$ is the material flow rate on the dry basis, $M$ is mass hold up of the dryer and is correlated with the volume hold up, $H$ of the dryer as follows;

$$M = (1-\epsilon) \rho H$$

where $\rho_s$ is the solid density.

The volume hold up is directly correlated to the dryer size geometry.

$$M = (1.0386) 617.19 \times 0.0162 = 6.139kg$$

Assuming that gari particles have initial moisture content of 52.9%

$$F_p = 10kg \text{ wet solid} \times 1kg \text{ dry solid} \times 30\text{mins} \times 30\text{mins}$$

$$= 3.633 \times 10^{-2} \text{kg/s}$$

$$tr = \frac{6.139}{3.633 \times 10^{-2} (1 + 0.529)} = 0.02372 = 258.8s$$

Design of Particle Feeding Subsystem

Feeders are devices that introduce variety of materials into the dryer at a controlled, specified rate. Feeding system of various types and configurations are used for storing, conveying, dosing and controlling dryer feed. It should be noted that the particle storage tank, the bin, or hopper (for this case) and feeder is an integral unit of dryer system, and should be selected and designed as such.

The rotary feeder of length 240mm and 200mm external diameter with six blades at angle 60º to each other was designed. The feeder is being powered by belt pulley mechanism.

Physical Size of the Rotor for the Feeder

The size of the rotor for the control of the feed rate is given by the product of its diameter and the length

$$\text{Physical rotor size} = D_R \times L_R$$

Assuming that the diameter of the rotor is 180mm and the length is 250mm

$$\text{Physical Rotor size} = 0.18 \times 0.25 = 0.045m^2$$

Drive mechanism for particle feeding subsystem

The design of drive mechanism for the feeding of gari particulates is based on belt pulley analysis. Generally, pulleys are made of cast iron, steel fibre, or various kinds of woods.

In selecting materials for the pulley, some factors such as weight, cost, availability, durability and machinability of the material must be considered.

In cognizance of these, cast iron was selected for the design of the pulley of the rotary feeder.

For good fluidization, a sufficient residence time of cassava particulates must be ensured. The belt drive, the speed of the driving unit (electric motor), centre-to-centre distance, and other similar operating conditions were selected.

In this project work, V-Belt was selected because it does not easily slipped off the groove, the gripping action result in greater frictional force and lower belt tension.

Speed Ratio of the Belt Drive

The objective of the belt drive speed analysis is to determine the diameter of the main shaft pulley that will produce the required force that rotates the blade in order to discharge the gari into the distribution bed.

$$\text{Speed ratio} = \frac{N_m}{N_a} = \frac{D_a}{D_m}$$

(Khurmi, 2006)

where $N_m=1450rpm$ and $D_m=150mm$.

$$N_a = \frac{1430 \times 50}{280} = 255.36rpm$$

Peripheral Belt Speed

It is given by $V = \omega r$

$$V = \frac{2\pi N_a D_a}{60} x \frac{D_a}{2} = \frac{2 \times \pi \times 2555.36 \times 0.28}{60 \times 2} = 3.74m/s$$

Angle of Lap $\theta$

$$\cos \left( \frac{\theta}{2} \right) = \frac{D_p - D_m}{2c}$$

(Hannah, 1998)
\[ \theta = \cos^{-1} \left[ \frac{D_s - D_m}{2C} \right] = \cos^{-1} \left[ \frac{0.28 - 0.05}{2 \times 0.5354} \right] \]

\[ \theta = 155.17^\circ \]

Tensions due to Centrifugal Force on Belt

\[ T_c = MV^2 \]

\[ T_c = 1.06 \times 3.74 = 3.96N \]

Tensions \( T_1 \) and \( T_2 \) on the Belt

The power of the motor is 1.5KW

\[ P = T_1 \left( 1 - \frac{1}{e^{\mu \theta}} \right) V \]

(Khurmi, 2006)

Since \( \frac{T_1}{T_2} = e^{\mu \theta} \), where \( \mu \) is the coefficient of friction between the belt and the pulley

\[ \mu = 0.2 \]

\[ T_1 = \frac{1.5 \times 10^2}{\left( 1 - \frac{1}{e^{0.2 \times 155.17}} \right)} = 4.01N \]

\[ \frac{T_1 - T_c}{T_2 - T_c} = e^{\mu \theta \cos \beta} \]

(Khurmi, 2006)

Where \( \beta \) is the semi angle of pulley groove
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Fig. 1.0: Rectangular fluidising column with hopper and product discharge

Hopper

Maintenance Gate

Product Discharge

Fig. 2.0: The Feeding and Discharging Components of the Machine.

\[ \beta = 16^\circ \]
\[ 4.01 - 3.96 = e^{155.17 \times 0.5 \times \cos 16^\circ} \]
\[ \frac{T_2}{3.96} = e^{155.17 \times 0.5 \times \cos 16^\circ} \]
\[ T_2 = 3.96N \]
Design and Development of a Continuous Fluidized-Bed Gari Dryer

The mass flow rate is kept at maximum level to know the efficiency of the blower and the temperature of the heater was regulated with the aid of a thermocouple connected to the temperature controller/regulator, coupled with a relay (contactor) sensing the heat gain from the column. When the heater reaches the specify temperature, the signal is sent to the regulator to de energize the contactor thereby putting off the heater, the temperature of the heater reduces, a signal is sent to the contactor which energizes the heater in order to maintain the temperature of the column at the set temperature of the controller. The feed rate is controlled by the rotary feeder which is an integral part of the drying system.

Experimental Procedure

The tools and equipment used in the experimental procedure include: Multi-meter, Stop watch, Electric weighing balance, Nylon bag for samples, Sieved wet cassava mash. 2000g of sieved wet cassava mash was measured and put in a nylon bag. This is repeated in four places. It is labelled A, B, C, and D.

At the start of the experiment the temperature of 150°C was selected. The blower was off without feeding of cassava mash and the time taken by the column to reach the set temperature was recorded. Also the time taken by the column to reach the set temperature was also measured with blower on.

The following method was adopted to determine the optimum condition under which the continuous fluidized bed dryer can be operated.

Method 1: At the temperature of 150°C, the cassava mash was fed into the fluidizing column through the rotary feeder and the blower was switched off for 5mins as the feeding progresses. The blower was then switched on and off at an interval of 5mins until the cassava mash was dried.

Method 2: The blower was switched off for 5mins while the feeding progresses and it was subsequently switched on and off at an interval of 2mins until the cassava mash was dried.

Method 3: The blower and the heater was started at the same time while the loading progresses. And it was subsequently varied at an interval of 2mins.

Method 4: The blower was on first at the temperature of 120°C, it was then off and subsequently on and off at time interval of 2mins.

The result shows that it takes 22mins for the bed to reach a maximum temperature of 150°C with blower working and it takes just 8mins for the bed to reach the maximum temperature of 150°C without blower. This is because the blower tends to redistribute heat to every part of the system so there are losses at the openings of the system.

From method 1, the cassava mash become dried at 130°C, however the product obtained was not edible because it was not cooked before it begin to burn.

From method 2, the gari mash begins to cake as the cooking process advances. It was also observed that the mash was well cooked at 120°C and it takes 18mins to achieve the cooking and drying. As the temperature increases beyond 120°C rapid burning begins.

Table 1.0: Bed temperature variation with time when the blower is on.

<table>
<thead>
<tr>
<th>Time(min)</th>
<th>Temperature(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>30</td>
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<tr>
<td>2</td>
<td>43</td>
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<td>4</td>
<td>46</td>
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<td>18</td>
<td>120</td>
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<td>20</td>
<td>140</td>
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<tr>
<td>22</td>
<td>150</td>
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</tbody>
</table>

Table 2.0: Bed temperature variation with time when the blower is off.

<table>
<thead>
<tr>
<th>Time(min)</th>
<th>Temperature(°C)</th>
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<tbody>
<tr>
<td>0</td>
<td>30</td>
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<tr>
<td>2</td>
<td>60</td>
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<td>4</td>
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<td>6</td>
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<td>150</td>
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From method 3, the gari mash did not cake, however it was not cooked before it begin to burn at 140°C. The optimum result was obtained with method 4, caking was not as pronounced as in previous cases. The gari mash was cooked at 115°C and dried at 120°C. It took 25mins for the gari mash to be cooked and dried. As the time increases the temperature remain constant and burning began to occur. Comparing the result and the edibility of the sample obtained at difference temperature and blower operating conditions, it is seen that the sample obtained at 120°C with the blower on first and then off at 2mins interval is preferred. This also saves cost with respect to the amount of electrical energy utilized for drying.

Table 3.0: Cassava mash drying temperature with time, when the blower is on and then off at an interval of 5mins.

<table>
<thead>
<tr>
<th>Time(min)</th>
<th>Temperature(°C)</th>
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<tbody>
<tr>
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<td>25</td>
<td>90</td>
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<tr>
<td>30</td>
<td>130</td>
</tr>
</tbody>
</table>

Table 4.0: Cassava mash drying temperature with time with blower off and on at 2mins interval.

<table>
<thead>
<tr>
<th>Time(min)</th>
<th>Temperature(°C)</th>
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</thead>
<tbody>
<tr>
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<td>28</td>
<td>120</td>
</tr>
<tr>
<td>30</td>
<td>120</td>
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</table>

Table 5.0: Cassava mash drying temperature with Time when the blower is first on and then off at 2mins interval.

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<th>Time(min)</th>
<th>Temperature(°C)</th>
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</thead>
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<tr>
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</tr>
<tr>
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<td>10</td>
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</table>

CONCLUSION AND RECOMMENDATIONS

CONCLUSION
This machine was tested using a drying temperature of 120°C and 150°C at a varied time interval of 5mins and 2mins with variable blower operating conditions. The dryer took 22mins to attain a steady temperature of 150°C with blower on and 8mins when the blower is off. After feeding, it took 18mins to dry and roast or fry 2kg of gari at 150°C and 24mins at 120°C. In conclusion, this dryer is very efficient and productive when compared with the manual, local, convensional and modern existing techniques. Hence, Fluidization technique for drying has been observed to be a very effective and efficient option to be harnessed to enhance large scale production of high quality gari.

RECOMMENDATIONS
Further work is required to fully optimize the overall drying processes such as designing of the blower and particle feeding sub-system such that single motor can efficiently and effectively drive both the blower and the rotary feeder. Also, incorporation of stirring mechanism to achieve even stirring of the particle is recommended. Production processes should also be improved. Modelling of the drying processes in the continuous fluidized-bed dryer should be encouraged.