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DESIGN OF WET MILLING THERMAL PROCESS PLANT TO PRODUCE 5 TONS PER DAY OF CASSAVA FUFU TO ENHANCE FOOD SECURITY IN NIGERIA

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ABSTRACT

Among the staple foods in Nigeria, cassava fufu is one of the most consumed among the most vulnerable and poor Nigerian populace, hence large scale production of fufu from cassava starch using the wet milling process technology could enhance food security in Nigeria. This research designed a Cassava Fufu Production Plant that could produce 5 Tons of cassava fufu per day. 181,441 Cassava Fufu Production Plants distributed evenly as 235 smallplants per Local Government Area in Nigeria are used. A heat generation of 434,661,562.50 kJ/kg shows that much heat is lost from the reactor, hence the need for use of suitable lagging material such as foam glass to enhance heat conservation. The fundamental dimensions of the reactor are: 0.07716 m^3 volume; 0.3 metre diameter; 1.0914 metre height; 0.09 metre impeller diameter; 0.75 metre length of jacket; 0.108 metre vertical distance between adjacent stirrer blades and 0.075 metre height of hemispherical head. A pay-back period of 2 years, 5 months, a rate of return of 41.38% and a net annual profit of ₦ 302,018.8188 shows that a cassava fufu production process plant if well managed could be economically viable in Nigeria. The Nigerian Government and the private investors are therefore encouraged to set-up the plants as much profit could be made from the investment.

Keywords: Food Security; Mass Balance; Energy Balances; Costing; Economic Evaluation.

1.0. Introduction

Among the staple foods in Nigeria, cassava fufu is one of the most consumed among the most vulnerable and poor Nigerian populace, hence large scale production of fufu from cassava starch using the wet milling process technology could enhance food security in Nigeria.

Based on the 1996 World Food Summit, World Bank (1996) defined food security as a condition when all people at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Shehu *et al.* (2019) stated that Cassava *(manihot esculenta)* is a widely known food security crop and about 80 % of Nigerians consume Cassava products (including Cassava Fufu) at least once a day.

Sheela *et al.* (2024) stated that Cassava plays significant role in the food security of rural poor and marginal farmers and is also recognized as an important industrial crop.

Sheela et al. (2024) further stated that Cassava is the third largest source of carbohydrates in the tropical region after rice and maize. Cassava tuber has been known to be a staple food in many parts of Nigeria. Cassava has versatile applications as food in Nigeria as it could be processed to various forms for human consumption. Padmini (2023) stated that Cassava Fufu is a versatile dish that can be paired with various nutritious soups and stews.

Considering the high rate of inflation, investment in cheap food sources could enhance realization of the Nigerian quest for food security, hence the need for the Nigerian Government and the private investors to invest more on large scale production of Cassava and Cassava Fufu. In recent times, food security has been one of the key point agenda in the economic development program of the Nigerian Government. Nevertheless, large scale processing results in low quality products. Processing in small reactors will improve product consistency. Moreover, Sami *et al.* (1999) stated that pollution problems have been associated with large scale cassava processing and care must be taken to address issues associated with pollution caused by large scale processing. Small size process plants will help eliminate pollution problems.

Small scale production process plants that ensure product consistency and of a number capable of meeting the demand of Nigerians evenly distributed in each Local Government Area in Nigeria could eliminate Perennial Scarcity of the Cassava Fufu in different locations in Nigeria. With this, Nigerians will no longer go for Undesired close substitutes due to scarcity of Cassava fufu in their residential or office locations.

This technical paper involves the design of a wet milling thermal process plantsfor the production of 5 Tons per day of Cassava fufu such as to enhance food security in Nigeria but will not go into the design of other auxiliary equipment in the process, though equipment by equipment mass balances and energy balances will be inculcated. Moreover, considering the importance of product quality in food production and reliability of design data, computer program will not be used in this design. This is to avoid possibility of runtime errors which might result in inaccurate design data. The use of manual calculations where possible could enhance design specification, good discussion of results obtained from inaccurate data

resulting from program runtime errors could hamper the technological development of Nigeria.

2.0. MATERIALS AND METHODS

2.1. Materials

The following materials were used for the research:

Cassava tubers, cassava peeler; cassava grater; steep tank; starch, water and fiber separator; Fufu processing reactor; Fufu storage tank; weighing balance, etc.

2.2. Methods

2.2.1. Process Description

Cassava tubers were peeled with knife, washed and ground in a cassava grater. In accordance with Danielle (2023) that Centre for Disease and Control (CDC) regulates that the tubers of sweet cassava be soaked in water for 4 – 6 days to reduce cyanide toxicity, the ground Cassava was soaked in a steep tank (wet milling) for a Hydraulic Retention Time (HRT) of five days and then routed to a water, starch and fiber separator which separated the fiber from the starch and water by the method of electrophoresis. The fiber separated were useful as animal feed and the starch was processed at 100°C (thermal) in a batch stirred tank reactor to produce fufu for human Consumption.

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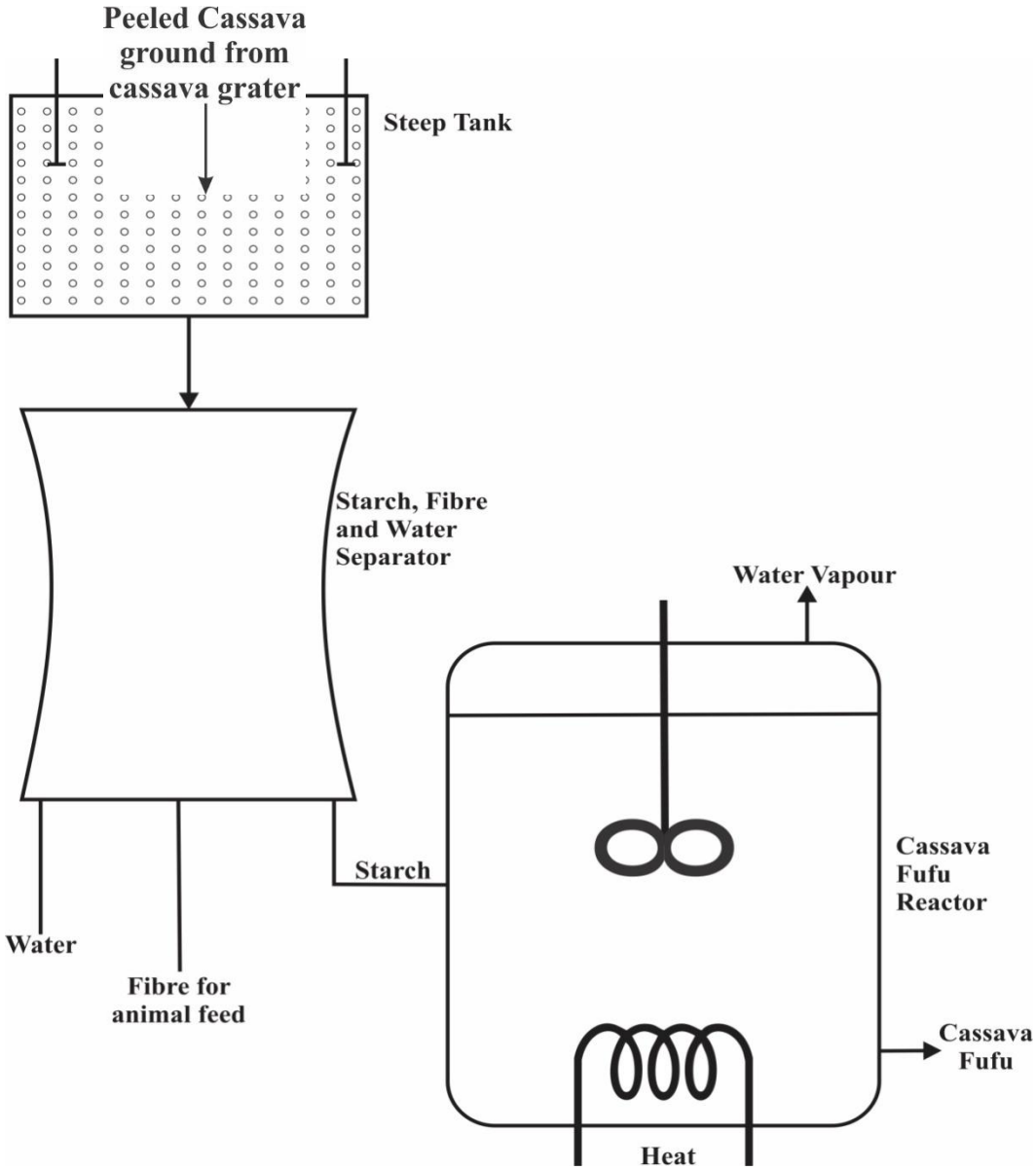


Fig. 1: Process-Flow for the Production of Cassava Fufu using Wet Milling Process.

2.2.2. Kinetic Analysis Equations

i. Hydrolysis of the Starch

$$(C_6H_{10}O_5)_n + n\,(H_2O) \xrightarrow[\text{Stirring}]{\text{Heat}} (C_6H_{12}O_6)_n \quad (1)$$

(Starch from cassava) — Water — (Amylose chain of glucose units)

ii. Number of Moles of Starch

$$\frac{\text{Mass of Starch}}{\text{Molar Mass of Starch}} \quad (2)$$

iii. Number of Moles of Cassava Fufu

$$\frac{\text{Mass of CassavaFufu}}{\text{Molar Mass of CassavaFufu}} (3)$$

iv. Order of Reaction

n = 1, the sum of exponents of concentration terms in the rate law = 1 **(4)**

v. Rate Constant

Slope or Gradient of concentration versus time graph = 0.02 mol/m^3 **(5)**

vi. Rate of Reaction

$$r_A = kC_A \quad (6)$$

vii. Yield of Cassava Fufu

$$\frac{\text{Moles of CassavaFufu}}{\text{Moles of CassavaStarch}} \times \frac{100}{1} (7)$$

vii. Fractional change in Volume

$$\varepsilon_A = \frac{\sum_{CR} - \sum_{CP}}{\sum_{CR}} (8)$$

Where $\sum_{CR}$, the reactant stoichiometric coefficient,

$\sum_{CP}$, the product stoichiometric coefficient

ε_A , the fractional change in volume.

ix. The Conversion (X_A)

$$X_A = 1 - \frac{C_A}{C_{A0}} \quad (9)$$

Where C_A is the final concentration of the starch,

C_{A0}, the initial concentration of the starch

x. The Time of the Reaction

$$t = \int_{C_{A0}}^{C_A} \frac{dC_A}{-r_A} \quad (10)$$

Where C_A, is the final concentration of the starch,

C_{A_0}, the initial concentration of the starch,

$-r_A$, the rate of reaction

xi. Loose Bulk Density of Cassava Fufu

$= 4.40 \pm 0.23\ kgm^{-3}$ **(11)**

Tolerance limits might be neglected

xii. Density of Cassava Fufu

$= 4.40\ kg\ m^{-3}$(by experiment) **(12)**

xiii. Volume

$$\frac{\text{Mass}}{\text{Density}} (\mathbf{13})$$

xiv. Number of Batches

$$\frac{\text{Operational Time}}{\text{Reaction Time}} (\mathbf{14})$$

xv. Space Velocity or Dilution rate

$$\frac{V}{V_R} = \frac{\text{Volumetric Feedrate}}{\text{Volume of Reactor}} (\mathbf{15})$$

xvi. Space Time

$$\frac{1}{\text{Dilution Rate}} (\mathbf{16})$$

2.2.3. Mass Balance Equations

(a) Steep Tank

i. Overall Balance

$C + W = M$ **(17)**

Where C is mass of cassava starch

W, mass of Water

M, mass of Mixture

ii. Component Balance

$$CX_s + WX_s = MX_s \quad (18)$$

For starch in the mixture

$$CX_f + WX_f = MX_f \quad (19)$$

For fibre in the mixture

$$X_s + X_f + X_w = 1 \quad (20)$$

$$X_w = 1 - (X_s - X_f) \quad (21)$$

iii. Kilogram of Starch and Fibre

$$M(X_s - X_f) \quad (22)$$

iv. SteepWater

$$M(1 - (X_s - X_f)) \quad (23)$$

v. Kg of Solids in the Steepwater

% of starch and fibre × kg of steep water **(24)**

vi. Kg Starch and Fibre

kg starch and fibre – kg of solids in the steep water **(25)**

vii. Kg Steep Water

kg steep water + kg of solids in the steep water **(26)**

viii. Quantity of Cassava Tuber Needed

$$[Plant\ Capacity\ in\ kg] \times \frac{1}{[\%\ of\ Starch\ in\ Cassava\ Tuber]} \quad (27)$$

ix. Quality of Cassava Fufu Produced

$$\frac{[Plant\ Capacity\ in\ kg]}{\left[\begin{matrix} No.\ of\ Hours\ of \\ Operation\ per\ day \end{matrix}\right]} \times \left[\begin{matrix} No.\ of\ Hours\ of \\ Operation\ per\ day \end{matrix}\right]$$

x. Quantity of Cassava Fufu Produced

= The Plant Capacity (28)

2.2.4 Energy Balance Equations

i. Steep Tank

$$E = m.\Delta H \quad (29)$$

$$\Delta H = CP_{mean}\,\Delta T \quad (30)$$

$$CP_{mean} = \frac{\left[Sum\ of\ Specific\ Heat\ Capacity\ of\ each\ component\right] \times \left[Mass\ each\ compenent\right]}{Total\ Mass\ of\ all\ Components} \quad (31)$$

ii. **Energy Inlet into the Steep Tank and Water, Starch/Fibre Separator**

$$E_{in} = m.CP_{mean\ in}\,\Delta T + \Delta kE \quad (32)$$

iii. **EnergyOutlet frominto the Steep Tank and Water, Starch/Fibre Separator**

$$E_{out} = m.CP_{mean\ out}\,\Delta T + \Delta kE \quad (33)$$

Heat of Mixing

iv. Energy Inlet into the Cassava Fufu Reactor

$$E_{in} = m.CP_{mean\ in} \times T + \text{Heat of Reaction} \quad (34)$$

v. Energy Outlet of the Cassava Fufu Reactor

$$E_{out} = m.CP_{mean\ out} \times T \quad (35)$$

2.2.5. Heat Generation in the Reactor

i. Quantity of Heat (Q)

$$\Delta H_{rxn}.F_{A_O} \quad (36)$$

Where ΔH_{rxn} is the heat of reaction in the reactor

F_{A_O}, the feed rate into the reactor

ii. Energy in the reactor

$$\boldsymbol{m}.\Delta H = m.CP_{mean\ in}.T \quad (37)$$

iii. The specific heat Capacity of starch

= 1.638 kJ/kg K. (38)

iv. Heat of Reaction

$$\Delta H_{rxn} = m.CP_{mean}.T \quad (39)$$

$$q = \Delta H_{rxn} \times F_{A_O} \quad (40)$$

v. Overall Heat Transfer Coefficient

$$Q = UA\,\Delta T \quad (41)$$

$$U = \frac{Q}{A\,\Delta T} \quad (42)$$

vi. Heat Generated per Unit Volume

$$\frac{\text{Heat Generated}}{\text{Volume of the Reactor}} = \frac{Q}{V_R} \quad (43)$$

vii. 1 Watt hour = 3600 Joules (44)

That is 1 Watt = 3600 Joules per hour

viii. $$\frac{\left[\frac{kJ}{hr} \times 8\ hours\right]}{\left[\frac{3600\ Joules}{8\ hours}\right]} = \frac{kW}{L} \quad (45)$$

ix. $$\frac{kW}{L} \div L = kW \quad (46)$$

x. Heat Generated per Surface Area

$$\frac{Q}{A} = \frac{Q}{2\pi rh + 2\pi r^2} \quad (47)$$

2.2.6. Fundamental Dimensions of the Cassava Fufu Reactor

i. Volume of the Reactor:

$$V_R = \frac{N_{A_0}}{t.k.CA_0} \int_0^{X_A} \frac{dX_A}{(1-X_A)(1+\varepsilon_A X_A)} \quad \textbf{(48)}$$

Where: V_R is the Volume of the reactor

N_{Ao}, the number of moles of starch

t, the Hydraulic Retention Time

k, the rate constant

C_{Ao}, the initial Concentration of the starch

X_A, the fractional conversion

ε_A, the fractional change in Volume

ii. Height of the Reactor (h)

$$h = \frac{V}{\pi r^2 h} \quad \textbf{(49)}$$

iii. Impeller Diameter of the Reactor (Di)

Di = 0.3 × Diameter **(50)**

iv. Length of Jacket (j_l)

$\frac{1}{4} \times 10D$ **(51)**

v. Vertical Distance between Adjacent Stirrer Blades (JL)

$JL = 1.2 \times Di$ **(52)**

vi. Height of Hemispherical Head

$\frac{1}{2} \times$ Radius of hemisphere **(53)**

vii. Volume of hemispherical Head

$\frac{\frac{1}{3}\pi r^3}{2}$ **(54)**

2.2.7. Costing Equations

i. Purchased Equipment Cost (PEC)

Market Price + Procurement Cost (55)

ii. Physical Plant Cost (PPC)

PPC = PEC (1 + f_1 + …… +f_a) (56)

iii. Fixed Capital (FC)

FC = PPC ((1 + f_{10} + f_{11} + f_{12}) (57)

Where $f_1$to f_{12} are cost factors

iv. Working Capital (WC)

WC = 10% of the Fixed Capital (58)

v. Cost of Capital

Cost of Sourcing for Capital + the bank charge paid + the bank interest paid on the Principal Capital that was borrowed (59)

vi. Total Investment (TI)

Fixed Capital + Working Capital (60)

vii. Operating Cost (OPC)

Fixed Cost + Variable Cost (61)

viii. Direct Production Cost (DPC)

Operating Cost + 20% of the Operating Cost (62)

ix. Total Cost (TC)

Total Investment + Direct Production Cost (63)

2.2.8. Economic Analysis

i. Net Annual Profit (NAP)

Sales of Cassava Fufu - Cost of Capital Operating Cost - Fixed Capital (64)

ii. Net Present Value (NPV)

$$\frac{\text{NAP} \times \text{n}}{(1+\text{r})^{\text{n}}} (65)$$

Viability Tests

NPV – TI > 0

iii. Pay-Back Period (PBP)

$$\frac{\text{Total Investment}}{\text{Net Annual Profit}} (66)$$

iv. Rate of Return on Investment (ROI)

$$\frac{\text{Net Annual Profit}}{\text{Total Investment}} \times \frac{100}{1} (67)$$

2.2.9. Number of Cassava Fufu Production Plants for Enhancing Food Security in Nigeria

i. Volume of Cassava Fufu eaten (m^3)

Number of Nigerians that eat

$$\frac{\left[\begin{matrix}\text{Cassava Fufu} \times \text{Volume of Cassava fufu eaten} \\ \text{by each Nigerian in Litres}\end{matrix}\right]}{100 \text{ Litres}} (68)$$

ii. Number of Small Cassava Fufu Production Plants Needed in Nigeria.

$$\frac{\text{Volume of Cassava Fufu eaten } (m^3)}{\text{Volume of Reactor } (m^3)} (69)$$

iii. Number of Cassava Fufu Production Plants Needed per Local Government Area in Nigeria

$$\frac{\text{Number of Cassava Fufu Production Plants Needed in Nigeria}}{\text{Number of Local Government Areas in Nigeria}} \quad (70)$$

3.0. RESULTS AND DISCUSSION

3.1. Kinetic Data

Parameter values could be used in calculations to obtain the experimental results that could lead to kinetic evaluation of the cassava fufu production process are as in Table 1.

Table 1: Kinetic Data

Parameter	Value
Density of Cassava Fufu	4.40 kgm^{-3}
Volume of Cassava Fufu	1136.363636 m^3
Specific Heat Capacity of Starch	1.638 kJ/kg .K
Temperature of the Reactor	373 K (100 °C)
Change in Temperature	(373-298) 75 K
Operational Time per Day	8am - 4pm (8hours)
Number of Batches per Day	10

Thevalues in Table 1 could be used in the relevant equations.

3.2. Reaction Kinetics

The quantity of starch and cassava in the reaction process and products is as shown on Table 2.

Table 2: Reaction Kinetics

Parameter	Starch	Cassava Fufu
Molar Mass	162 g/mole	180 g/mole
Moles	30.864 moles/day	27.78 moles/day
Yield	-	90 %
Conversion	1.0	-
Selectivity	-	100 %

At a conversion rate of 0.5 increased to 1.0 by manual recycling, a yield of 90% of cassava fufu could be obtained. This shows that much production of cassava fufu from cassava starch could be expected. A yield of 90 % shows that 90 % of the product formed from the cassava starch processing was the desired product (cassava fufu). The by-product (fibre) useful as farm manure and animal feeds had been removed at the pre-treatment stage making the selectivity for the desired product to be 100 %.

3.3. Kinetic Evaluation

The Values of other Kinetic Parameters are shown on Table 3.

Table 3: Kinetic Evaluation

Parameter	Value
Order of Reaction	1
Rate of Reaction	0.004 mols/m^3/hr
Rate Constant	0.02 mol/m^3
Space velocity or Dilution Rate	5.5728 per Hour
Space Time	0.1794 Hours

A rate of reaction of 0.004 mol/m^3hr shows that 0.004mols of cassava starch was converted to products every hour. An order of reaction of one shows that the exponents of concentration terms in the rate law summed to unity. A rate constant of 0.02 mol/m^3 shows that 0.02mol of cassava starch was converted to cassava fufu for every one m^3 of cassava starch processed. A dilution rate or space velocity of 5.5728 per hour shows that 5.5728 of reactor volume of cassava starch was being fed into the reactor every hour. A space time of 0.1794 hour shows that one reactor volume of cassava starch was being processed in the reactor every 0.1794 hours.

3.4 Mass Balance

Table 4: Mass Balance across Equipment

Equipment	Component	Kg in	Kg out
Steep Tank	Cassava	3,281.25	-
	Water	6,000.00	-
	Fibre and Starch Suspension	-	2,299.89375
	Steep water	-	6,981.35625
	TOTAL	**9281.25**	**9281.25**
Starch, Water/ Fibre Separator	Fibre/starch Suspension	2,299.89375	-
	Steep water	6,981.35625	-
	Fibre	-	658.96875
	Water	-	5995.6875
	Starch Suspension	-	2626.59375
	TOTAL	**9281.25**	**9281.25**
Cassava Fufu Reactor	Starch Suspension	2,626.59375	-
	Water Vapour	-	2001.59375
	Cassava fufu	-	625.00
	TOTAL	**2,626.59375**	**2,626.59375**

Table 4 confirms the law of conservation of mass which states that matter can neither be created nor destroyed but can be transformed from one form to another as $kg_{in} = kg_{out}$ for all equipment.

3.5 Energy Balance

Table 5: Energy Balance across Equipment

Equipment	Inlet $kJhr^{-1}$	Outlet $kJhr^{-1}$
Steep Tank	108,692.562	108,692.562
Starch, Water/ Fibre Separator	99,266.7667	99,266.7667
Cassava Fufu Reactor	3,574,578.266	3,574,578.266

Table 5 confirms the first law of thermodynamics as the total amount of energy is conserved. Total Energy In = Total Energy Out for each of the equipment in the process.

3.6. Heat Generation in the Reactor

3.6.1. Heat Generated in the Reactor

Heat generated in the reactor helps understand the quantity of heat so as to control it by the use of heat generation methods or heat conservation methods. Heat generated in the reactor is as shown on Table 6.

Table 6: Heat Generated in the Reactor

Parameter	Value
Heat of Reaction (ΔHrx_n) kJ/kg	695,458.50
Feed rate into the Reactor ($F\boldsymbol{A_0}$) (kghr-^{1})	625
Overall Heat Transfer Coefficient ($kJm^{-2}K$)	4,958,391.939
Heat Generated (kJ/kg)	434,661,562.50
Heat Generated per surface Area ($kJm^{-2}.K$)	4,958,391.936
Heat Generated per unit volume	5,633,249.903 kJm^{-3}
	75,109.99871 $kJm^{-3}K$
	1174.39654 kW/L
	15.22027657 kW

434, 661, 562.504 kJ/kg of heat generated in the reactor shows much heat is generated and hence the need for heat conservation with the help of suitable lagging materials such as foam glass.

3.7. Volume of the Reactor

3.7.1. Values of parameters for calculating Volume of the Reactor

Values of the parameters used for calculating for the volume of the reactor are as in Table 7.

Table 7: Values of parameters for calculating Volume of the Reactor

Parameters	Value
Number of moles (NA_O) Moles per day of starch	30.864 moles/day
Initial concentration (CA_O) of the starch	0.4 mol/m^3
Reaction time	50 minutes
Rate constant (K)	0.02 mol/m^3
Conversion (X_A)	1.0
Fractional change in Volume (ε_A)	0.5
Volume of the reactor (VR) m^3	0.07716 m^3 =77.16 Litres

At an initial concentration of 0.4 moles/m^3, 30.864 moles of cassava starch was converted to cassava fufu at a rate constant of 0.02 mol/m^3 in a reactor of volume 0.07716 m^3

3.8. Reactor Fundamental Dimensions

Values of the dimensions of the key parts and components of the cassava fufu reactor as calculated from suitable equations are as shown on Table 8.

Table 8: Reactor Fundamental Dimensions

Parameter	Value
Volume of the Reactor (m^3)	0.07716
Diameter of the Reactor (m)	0.3
Radius of the Reactor (m)	0.15
Height of the Reactor (m)	1.0914
Impeller diameter of the Reactor (m)	0.09
Length of Jacket (m)	0.25
Vertical distance between adjacent stirrer blades (m)	0.108
Height of hemispherical head (m)	0.075
Volume of Hemisphere (m^3)	0.00177

A reactor of 0.07716 m^3 volume; diameter 0.3 m; radius 0.15 m and height of 1.0914 m is needed to convert cassava starch to 5 Tons per day of cassava fufu product.

3.9. Design Features

a. Head: Hemispherical

Coulson (2009) stated that a hemispherical head is the strongest shape capable of withstanding twice the pressure of a torrispherical shape of the same thickness, hence an hemispherical head is used.

b. Wall Thickness

Coulson (2009) gave 14 mm as the minimum thickness for a vessel of diameter 300 mm. Hence, wall thickness of the reactor = 14 mm.

c. Vessel pressure

Coulson (2009) gave a pressure of 1bar.

d. Spacing between Jacket and Vessel Wall = 50 mm

(Coulson, 2009), spacing must be high enough to enhance insulation.

e. Thickness of jacket

The Thickness of jacket = 50 mm. Lagging must be thick enough to enhance heat conservation.

f. Lagging Material: Foam glass (cellular glass made by fusing powdered glass with carbon particles). Foam glass is dense enough to allow for attachment of fittings and sealing and does not absorb moisture.

g. Cover for Lagging

Aluminummetal sheet (0.5 mm thick) is used to cover lagging.Aluminum is cheap enough and is non-corrosive.

h. Support: concrete pillars are used as support because concrete cannot conduct electricity.

3.10. Materials selection

a. Material of Construction

Stainless steel was chosen as the material of construction because it does not easily get corroded.

b. Jacket

Steam is chosen as the heating fluid to be used in the Jacket to conserve heat because steam is readily available. Cooling water is chosen as the cooling fluid in jackets to reduce heat because Cooling water is readily available.

c. Stirrer Driver

Roshton Turbine is chosen as the stirrer driver because Roshton Turbine is more robust and of high efficiency.

Schematic Drawing of the Cassava Fufu Reactor

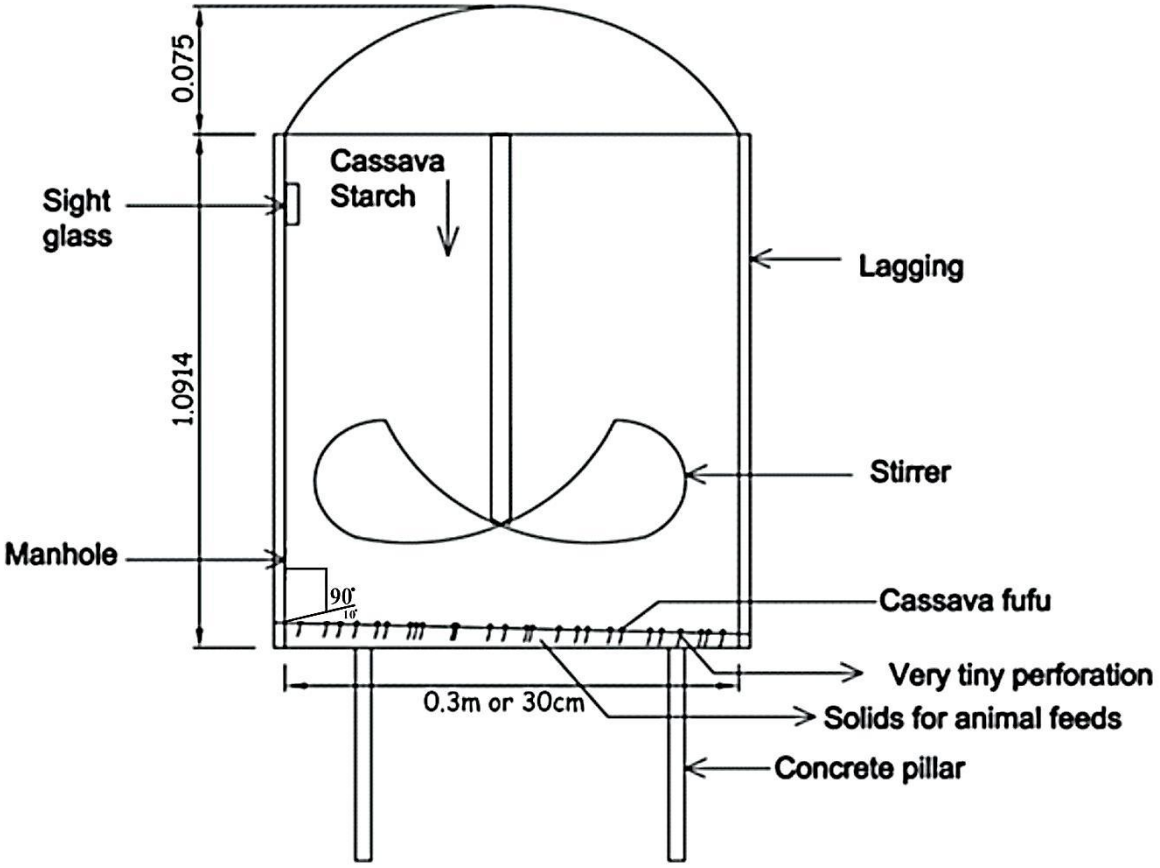


Fig. 2: Sketch of the Cassava Fufu Production Reactor.

3.11. Number of Cassava Fufu Production Plants Needed for Enhancing Food Security in Nigeria

Results obtained from the calculations for the number of Small wet milling thermal reactors needed for the production of Cassava Fufu to enhance food security Nigeria are as in Table 9.

Table 9: Number of Cassava Fufu Production Plants Needed for Enhancing Food Security in Nigeria

Parameters	Value
Volume of Reactor	0.07716 m^3
Number of Nigerians that eat Cassava Fufu	14 million
Amount Consumed per Nigerian	1 Litre per Day
Amount Consumed by Nigerians	14,000 m^3
Number of Reactors in Nigeria	181,441
Number of Local Government Areas in Nigeria	774
Number of the Reactor per Local Government Area	235

235 of these Small cassava fufu reactors should be installed in each Local Government Area in Nigeria. This could enhance food security in Nigeria. Where there is consumer apathy, the

cassava fufu should be exported to other countries thereby increasing Nigeria export earnings.

3.12. Costing and Economic Evaluation

3.12.1 . Costing

Cost analysis to enable the Nigerian Government and the Private Investors to determine whether the investment is a profitable one so as to source for capital and set-up the plant is as illustrated in Table 10.

Table 10: Cost analysis

Parameter	Value
Purchased Equipment Cost (PEC)	₦ 619,600.00
Physical Plant Cost (PPC)	₦ 650,580.00
Fixed Capital (FC)	₦ 663,591.599
Working Capital (WC)	₦ 66,359.1599
Cost of Capital	₦ 1,241,256.1283
Total Investment (TI)	₦ 729,950.758999
Fixed Cost	₦ 39,815.4958989
Variable Cost (VC)	₦ 253,317.957995
Operating Cost (OPC)	₦ 293,133.453893
Direct Production Cost (DPC)	₦ 351,760.144671
Total Cost (TC)	₦ 1,081,710.90366
Selling price of one Reactor	₦ 20,000.00
Number of plants needed	181,441.00
Cost of the 181,441Cassava Fufu Reactors	₦ 3,628,820,000.00
Selling price of 1kg of cassava fufu	₦ 500.00
Sales from one production plants	₦ 2,500,000.00
Sales from all the 181,441 production plants	₦ 453,602,500,000.00

High profitability rate is expected as a sale of Cassava Fufu from one production plant (₦ 2,500,000.00) is higher than the Total cost of the plant (₦ 1,081,710.90366).

3.12.2. Economic Analysis

Economic analysis to enable the Nigerian Government and the Private Investors determine whether the investment is economically viable in Nigeria, so as to source for capital and set-up the plant is as illustrated in Table 11.

Table 11: Economic Analysis

Parameter	Value
Net Annual Profit (NAP)	₦302,018.8188
Net Present Value (NPV)	₦ 3,344,409.94556
NPV-TI	₦2,614,459.18656
Total Investment (TI)	₦729,950.758999
Rate of Return on Investment (ROI)	41.375%
Pay-Back period	2 years, 5 months

The Plant is economically viable as the difference between the Net present Value and the Total Investment is greater than Zero as in Anyanwu (1994). A pay-back Period of 2 years, 5 months is low enough. This shows that the loan taken to build the Plant can be repaid in a short period of 5 years, 5 months. A rate of return ofinvestment of 41.375% is quite reasonable.

4.0. CONCLUSION

A Cassava fufu wet milling thermal process plant for processing cassava starch to cassava fufu has been designed. The plant will produce 5000 kg/day of cassava fufu using a continuous stirred tank batch reactor of 0.07716 m^3 volume. Other fundamental dimensions of the reactor are: Diameter 0.3 m; Radius 0.15 m; Height 1.0914 m; Impeller diameter 0.09 m, Length of Jacket 0.25 m; Vertical distance between adjacent Stirrer blades 0.108 m and height of hemispherical head of 0.075 m. A Sketch of the reactor is shown in Figure 2. The use of the reactor could enhance large scale production of the staple food (Cassava fufu) such as to enhance speedy realization of the Nigerian quest for food security in Nigeria. Costing and economic analysis show that each 181,441 of these cassava fufu production plants evenly distributed in Nigeria as 235 Cassava Fufu Production Process Plant in each Local Government in Nigeria could be very economically viable in Nigeria as sales of the Cassava Fufu Product (₦2,500,000.00) is higher than the total cost of the plant (₦ 1,081,710.90366). Moreover, the Net Present Value (NPV) minus the Total Investment (TI) is greater than zero. A payback period of 2 years, 5 months and a rate of return on investment of 41.375% show that a cassava fufu production process plant if well managed could be economically viable in Nigeria. The Nigerian Government and the Private Investors are therefore encouraged to set-up the plant as much profit could be made from the investment.

5.0. RECOMMENDATIONS TO THE NIGERIAN GOVERNMENT

It is recommended that:

a. Number of Cassava Fufu Production Plants.

235 of these small Cassava Fufu Production Plants be installed and evenly distributed in each Local Government Area in Nigeria. This will enhance effective processing and quality assurance in the production of cassava fufu, considering that it is easier to operate and manage small reactors compared to big ones. Moreso, considering that the product is meant for human consumption, the dietary qualities and consistency could better be maintained in small reactors than in very large ones. This could enhance speedy realization of the Nigerian quest for food security in Nigeria.

b. Enforcement of Regulatory Standards

It should be ensured that Regulatory Standards for the quality of the cassava fufu product are complied with as stipulated by appropriate regulatory agencies. Regulations should ensure that the dietary qualities and consistency of the cassava fufu is maintained through effective processing and quality assurance in the production of cassava fufu.

c. Investment in Large Scale Farming and Cassava Fufu Production

The Nigerian Government and the Private Investors should invest in large scale cassava farming as well as in the cassava fufu production reactors as much profit could be made from the investment.

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