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DEVELOPMENT OF FERMENTATION EQUIPMENT

FOR LOCUST BEAN (PARKIN BIGLOBOSA)

BY

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CERTIFICATION

This is to certify that this project work meet the regulation governing the award of Post-Graduate Diploma in Agricultural Engineering and was keenly supervised and approved by the Department of Agricultural Engineering of Federal University of Technology Minna.
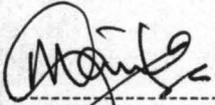
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12/01/2007

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Date

DEDICATION

This project is dedicated to Almighty Allah for His guidance and protection over everything from the beginning until the last day.

ACKNOWLEDGEMENT

I wish to extend my deep appreciation to my supervisor, Engr. Dr. M.G. Yisa, my parents and my son. Other appreciation goes to my collegues in the programme, all the lecturers for their moral support and guidance. I sincerely wishe to thank everyone for there efforts towards my success.

ABSTRACT

The research was on the design and fabrication of Bio-digester for locust beam. The need for the research was to enhance the production of 'dawa dawa'. Data were obtained by visitation to rural dweller in five local government of Nasarawa State. Fabrication material were obtained in Minna town and a galvanized iron sheet material, Solid steel shaft, Gate valve, Nipples, and hollow pipes. The design of the digester was based on aerobic principles, temperature, P_H, material balance. It was found out that fermentation takes place at 72 hours and at 30^0c for P_H of 8.3 and at 35^0c for P_H of 9.2. It was concluded that fermentation of locust bean can be done effectively without deterioration of the seed while inside the vessel. It was recommended that proper instrumentation be available and permanently fixed to the vessel for proper temperature reading.

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CHAPTER ONE

1.0 INTRODUCTION

Legumes are second to the cereals as important sources of human food. Legumes are the "meal" of vegetable world and are close to animal flesh in protein food value. Locust beans (Parkia biglobosa), is of the leguminous family and is one of the oldest African known food plant, yet it is not normally considered edible until after processing.

Dawa-dawa is one of the richest food condiments consumed predominantly in Northern Nigeria, Ghana, Mali and other West African countries. It gives flavour if added to soup; the seed is the richest in flavour among the food products of the world. Most food products from legume seeds are obtained by bacteria fermentation.

1.1 Statement of the Problem

The African farmers are peasants with little income, low level of technology, and cannot afford the use of modern techniques in order to enhance their production capacity, instead they rely on their inherent methods of dawa, dawa production using locally available materials, resulting in low harvest, labour intensive and other similar related constraint.

Other problems include possibilities of contamination using the local equipment which is nature dependent.

1.2 Background to the Study.

The evolution of materials science has aid the growth of modern Agricultural food processing industries, particularly the food and beverages industries. Most equipment use by rural dwellers are the rudimentary types, this study has developed an equipment the local material use in locust bean processing which engaged the use of polythene, Jutebag, leaves, basket and other primitive materials link to traditional tunes.

1.3 Aims and Objectives

The aim of these research works is to fabricate an equipment, using modern available materials for the processing of locust bean to achieve the following objective: -

(1).   To enhance the production of dawa. dawa through the use of modern incubation materials.

(2).   To reduce losses in the production operation by developing an efficient equipment to be implored instead of use of rudimentary which is prone to contamination.

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(3).   To increase products availability in the market for consumers, through a large scale production rather than the existing subsistent level of production.

1.4   Scope of the Study

This project is to develop equipment that can be used in fermenting locust bean seeds. It engaged the use of local materials to fabricate the equipment, and the natural micro-organisms (bacillus subtiles), are the only substrate readily available in the bean to facilitate the dehydration process.

1.5   Limitation

This project work is limited to design of a bio-digester which has the capacity of 50kg/batch.

CHAPTER TWO

2.0   Literature Review.

African locust bean is a perennial, leguminous tree. Parkia specie, was named after the scotish surgeon, Mango Park, who described the tree as one of the useful economic trees in Africa during his travels in the interior districts of Africa in 1799.

Although locust bean tree has been in existence and put into various traditional uses (including its fermented bean as flavouring agent) even before its discovery by Mango Park, no much attempt has been made to either propagate the plant or conduct research into its validity as a food and other scientific uses if any.

Research into various uses of locust bean started only recently in the 20th Centaury and most of the work has been centered on the human and livestock uses of the plant products. It is also interesting to note that almost all of the research works carried out so far are mainly from the West African countries (Nigeria and Ghana, in particular) where fermented seed of the plant are used as flavouring agent.

The fruit of locust bean has a high nutritive value especially the powdery material which is of immense value owing to its richness in carbohydrate: and the seeds on account of their containing a high % of protein and fats.

Therefore, the powdery material and the seeds of locust bean plant, though different in character are both of satisfactory composition as food stuffs (Bull. Imp. 1922).

In addition, the protein present in the seeds is of high quality owing to the presence of high Lysine content ranging from 6.17g/kg of nutrient for the fermented bean to 6.79g/kg of nutrient for the unfermented bean. This value is similar to that in whole egg; but its utilization is likely to be impaired by insufficiency of other essential amino acids, particularly Methioniod and Tryptophan and supplemented feeds with this amino acids provide good balance and economical ration for farm stock (Oyenuga *et al,* 1973).

Fermented African locust bean is used generally as a flavouring agent through West Africa where it is given different names by different communities. It is called daddawa by Hausa, Iru by Yoruba, whilst Sounbela or Soumbera is used by the French speaking countries. It has various other local names such as Kpaluga, by the Kusasis and Dagombas of Northern Ghana Kinda in Sieraleone and Neteton in Gambia (Campbell – Platt 1980).

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During its preparation, African locust bean seeds are boiled and left to ferment in baskets or calabash trays lined with either pawpaw or banana leaves or sacks made of jute at room temperature for about two or more days. The fermentation which is by chance inoculation is by various sub species of bacillus subtilis group and staphylococcus specie (Odunfa 1981).

During this period of fermentation, biochemical change occur due to the enzymic activities produced by the fermenting micro organism, heat is evolved and volatile ammonical substances are produced imparting the characteristic odour on the product (Odunfa 1985).

2.1   Variety of Locust Bean Trees.

African locust been is a perennial tree. Different species are found in Africa, South East Asia and tropical South America. The trees are natural plants that grow widely in forests and they are fairly distributed all over the natural grasslands of Northern states and savannah zones of Oyo and Kwara States of Nigeria.

The trees are of medium size with empound leaves and numerous leaflets. Parkia species belong to the order leguminous family mimosacea and have 24 or 26 chromosomes.

The three main species of parkia are indigenus to Africa. In West Africa, the savanna species parkia biglobosa, reaches a height of about 25m and it is the main source of food in this region. The forest specie parkia biocolor, which reaches about 35m in height, is used less as a source of food because of its general in-accessibility in the forest area, and the availability of a wider range of alternative foods. The third specie, parkia fiheoidea welwex olive, which reaches up to 35m in height, is found in the secondary and gallery forest of central and East Africa. It is also present in the derived savanna bordering the northern edge of the forest in West Africa.

The main Asia species, parkia speciosa hask, is indigenous to Malaysia and Indonesia. It reached the height of 25m in height. The second major is parkia vox burghii G. Don, reaches 27m in height.

The main specie in tropical South America is parkia species similar to that found in Asia.

This project work would be carried out on African species particularly Parkia biglobosa found in savanna region in Nigeria.

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2.2 Food Uses Of Parkia Trees

In West Afirca, the major food from parkia species is produced by fermentating the cotyledon of the seeds (with the tester removed). The resultant strongly smelling black product, is usually formed into different shapes as may be desired and is called dawa-dawa in Hausa, iru in Yoruba, Ogiri in Ibo and Kula in Nupe. It is usually eaten with sorghum or millet based dumpling and porridges.

The seeds can be roasted and used as a coffee substitute known as cafedu in Sudan. In East Africa, parkia beans are not established part of the daily diet, but they are some times used as an encouraged food during droughts. The whole pod can be used as cattle food.

2.3 Types of Fermenters

The process of fermenting locus beans is still a traditional art done in homes. The use of rudimentary utensils leads to unpredictable quality products. The steps involved in the traditional method are shown in a flow chart presented below (Fig. 1)

$= H_2O$ $\longrightarrow$ Locust bean seeds

↓

Boil for 12 or more hours

↓

Dehull by pounding and pressing between palms

↓

Wash – seed coats removed

↓

Cotyledons boiled again for 2 hours

↓

Drained through a raffia sieve

↓

Spread whilst hot in wide calabash trays

↓

Fermented for 36 hours or more, salt added as a preservative

↓

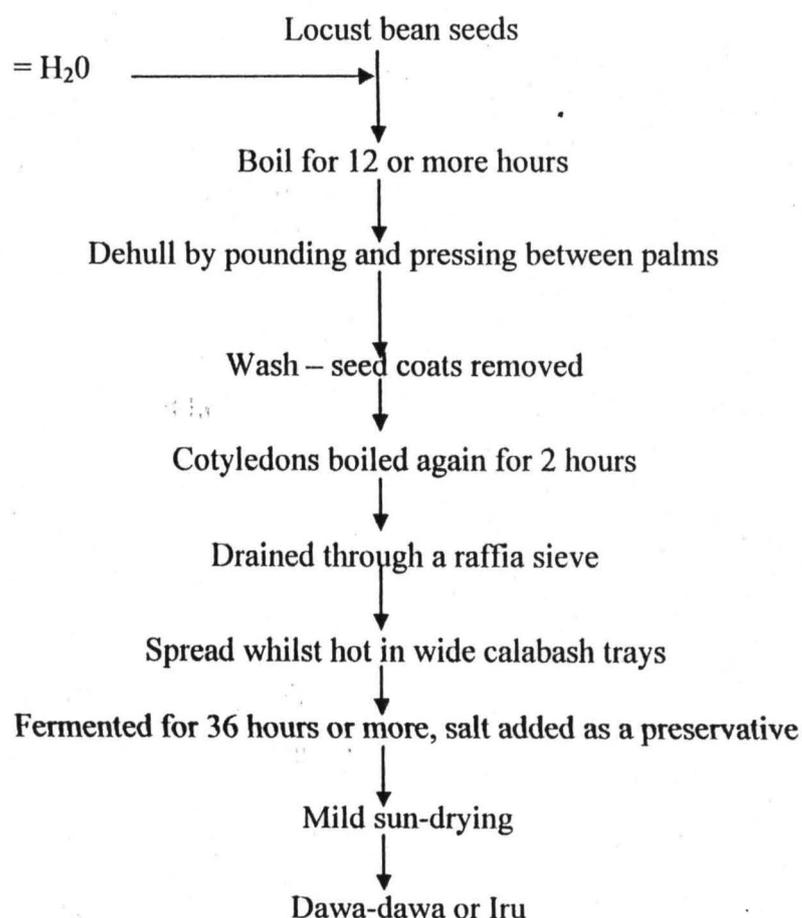Mild sun-drying

↓

Dawa-dawa or Iru

Fig. (1) Flow chart of fermentation of locus beans (Daddawa).

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The above flow chart outline the steps involved in the processing of fermented locust been used as a condiment. Though the procedure may be slightly different due to cultural and regional differences, the above steps are the general methods adopted for the local production of dawa dawa production (Especially in Nigeria).

During fermentation period, cotyledons are packed in sacks lined with pawpaw or banana leaves and covered.

Occasionally woodash may be added to the fermenting beans at the start of fermentation. Pawpaw leaves and woodash are said to introduce fermenting organism and provide conducive environment for fermenting organisms. The beans are left to ferment for normally two to three days although as with any traditional tuned practice, there may be variation in this time from two days. It was reported that in Japan, the fermentation is usually inoculated with selected pure cultures of bacillus subtiles (Ohta, 1986); unlike the traditional practice which rely on natural contamination for the bacteria to be inhibited. In many cases however, the major bacteria involved are strains of Bacillus subtiles (Sundhagul, 1972; Antai and Ibrahim, 1986; Ohta 1986; Aderibigbe and Odunfa, 1988; Sarkar et al, 1994). The bacteria favoured by the high ambient temperature of 25 – 30^{0}c grow in fermenting mass and produce viscous strain of invilaginous materials which link the bean together by the end of the fermenting period, by which time the beans have drained in colour from light brown to dark brown, and they have become softer.

The odour of the beans would change from an initial sweet bean odour to strong protolystic ammoniac smell, due to bacterial protolytic enzymes action. The bean may be moulded into plate shaped or left in mass for onward packaging.

2.3 Operational Performance of Fermenters

Different rates of fermentation could easily be noticed with different incubation materials; this is as a result of the fact that during fermentation the range of PH varies with the type of incubation materials and ambient temperature. However, Table 1 shows a comparative analysis of the various materials used with different ranges of temperature and PH. This shows that at 30^{0}C gmelina leaves sample had the highest range of increase in PH from 6.48 to 7.98, while jute bag sample has the lowest range from 6.48 – 6.86. The same was observed at 35°Cwith 6.48 – 8.25 and 6.48 – 7.25 gmelina leaves and Jute bag sample respectively, Table 2. The observed range of increase is in accordance with that obtained by Antai and Ibrahim (1986). Odunfa (1981) also recorded PH increase of up to

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8.1 during the first 30 hours of fermentation. However, the difference in rate of fermentation exhibited by the incubation materials could be due to their physical properties. Gmelina show a higher fermentation rate than banana leaves due to the porosity of the leaves and since the beans fermentation is carried out by aerobic bacilli (Washin and Steikraus, 1980), the more porous gmelina leaves allow more air to enter the system thus supporting growth of the fermentation organisms and encouraging fermentation while polythene shows lower rate because heat is generated much and air is not allowed into the system due to its non porous nature. The Jute bag sample shows the lowest fermentation rate (PH range of 6.48 – 6.70 at 35^0C). Other possibilities are the micro-flora on the leaves contributing to the fermentation rate in some of the leaves or the temperature which usually affects microbial growth and activity. The increase from 30^0C – 35^0C may contribute to the higher fermentation rate observed.

Compositional analysis is shown in Table 3. The protein content increased from 24.85% in raw beans to 30.5% for gmelina leaves at 30^0C and 35^0C respectively followed by banana leaves and polythene bag in that order with Jute bag showing the least increase from 24.8% to 25.9% and 27.0% at 30^0C and 35^0C respectively. This trend agrees with that of Campbell – Platt (1980), who reported an increase from 30.0% - 38% and attributed it to organisms bacillus subtilis associated with fermentation.

Table 1 Means scores, of smell, color and texture of dawa-dawa fermented in different incubation materials.

	FERMENTATION 30^0C			FERMENTATION 35^0C		
Sample	Smell	Colour	Texture	Smell	Colour	Texture
Gmelina	2.7b	3.8bc	3.1c	5.4a	4.3a	4.7a
Banana	2.5b	3.4bc	3.0cd	4.1a	3.ab	4.3a
Jute bag	2.5	2.6cd	2.2c	1.0c	1.3e	1.0b
Polythene	2.4b	2.3d	2,4d	2.3b	2.4cd	1.8e

Table 2 Means scores for overall acceptability of 'Dawa-dawa' fermentation in different incubation materials.

SAMPLE	FERMENTATION AT 30%	FERMENTATION AT 35%
Gmelina	3.0c	4.9a
Banana	2.9c	4.3a
Jute bag	2.3cd	1.0b
Polythene	2.5cd	2.0d

2.4   Method of Fermentation

Although traditional equipment are still in contemporary use. It was reported that various incubation materials have been employed locally by many researchers to facilitate the production of 'daddawa' from locust bean Antai and Ibrahim (1986) used banana leaves with a clean calabash as holding container; Odunfa (1983) used Jute bag with basket as holding container, while Owen et al, (1997) employed direct inoculation of the bean with a pure strain of bacillus subtilis with a vented Petri dish as holding container. However, all previous studies on methods of fermentation and types of equipment employed, largely still remain at subsistent or laboratory level and have not reported on any large/mass production of fermented locust bean, using modern material to fabricate.

CHAPTER THREE

3.0 Materials and Methods

Theoretical background

In carrying out this work, the materials used were all locally sourced from the local market. Materials of construction of this digester is also locally obtained from the building material market in Minna. All the materials for construction were selected based on availability, low cost and reliability. Table 3.0 summarizes the list of materials used.

Food process means primarily the whole process from raw materials to final product. The equipment used enables the required changes to be made with a little waste of materials and energy as possible. Therefore the use of stainless-steal is best recommended for most food processing operation.

In this process a batch of 50kg of beans, were prepared by cleaning, sieving, winnowing and removal of foreign materials. The experiment was carry out under room temperature (29^0-30^0C). The batch was packed into the incubator and completely covered. Air was now delivered into the system continuously so as to ensure that it was uniformly administered, this was insure that the rate at which microbial activities takes place was highly stimulated to enable the microbes to inhibit the dehydration of the materials.

The temperature was noted after each 24 hours interval and compaired with raw materials temperature. To help ensure uniform air circulation in the system a stirrer was used to stirrer intermittently to mix the materials thoroughly so that fermentation could be achieved uniformly in the system.

3.1 Design Consideration

Most processed food are manufactured by mixing, separation or dehydration of several components of materials. The components often vary widely in composition or its functional properties. Therefore, it becomes imperative to calculate the exact amounts that must be used for these productions. To prepare a batch, the amount of ingredients needed in the system and the required interval to mix the materials for uniformity. The basis of these material balance or mass balance is to obey law of the conservation of mass starting that "mass can be neither created nor destroyed" thus all mass.

The knowledge of approximate composition of the individual components and the desired quantity of final product are often the necessary data. The calculation takes the form of a system of linear equations having many unknown parameters.

Table 3a.   Summary of raw materials and construction materials

S/NO	MATERIALS
1	Raw locust been 50kp weight
2	Galvanized iron sheet 2.5 mm gauge left
3	Angle iron
4	Electrode gauge 12 mm
5	Thermometer
6	Belt and pulley
7	Elect6ric motor

Sources: Market survey

Table 3b. Showing percentage in composition of some element in protein base food

ELEMENT	% COMPOSITION
Carbon	50
Nitrogen	16
Hydrogen	7
Sulphur	0.3
Phosphates	0.3

Sources: Ihyekoronye and Ngoddy.

3.2   Major Components of the System

The major components of the bio-digester include the following: -

A.   **Air Delivery Units:** - These units comprising of air duck that delivery air into the system.

B. **The Stirrer Units:** - This incorporated into the cylindrical vessel for the sole aim of intermittent stirring of the materials to allow a uniformed distribution of air coming into the vessel. Since fermentation is aerobic, the need for the air to circulate is highly desired. The stirrer consists of impellers a flat blade stationed at equal interval and is crank by a lever.

C. **The Thermometer:** - Is an indispensable instrument forming one of the component, it is used to take the temperature readings of the condition of material during fermentation process.

D. **The Incubator:** -   This is the main container, it contains the material and inside is located the stirrer.

E. **The Input Unit:** - The hopper is the inlet point where the materials poured into the vessel, it has a baffle to slow down the rate of feed of material into the vessel.

F. **The Outlet Unit:** - This is the point where the fermented product is collected.

3.3   Design of Each Components of the Digester

A.   Digester capacity   = 50kg of feed/batch

Let;

i)   The apparent density of the food material be = ρ_b in Kg/m^3

ii)   The volume occupied by materials be = V_b in (m^3)

Therefore the volume occupied by a 50Kg feed / batch could be found using these relationship.

$$Density = \frac{Mass}{Volume}, \; Mathematically \; represented \; \rho_b = \frac{m}{V_b} \dots\dots\dots\dots eqn \,(1)$$

Where

ρ_b =   Bulk density of materials

m   =   Mass or quantity of materials

Vb   =   Total volume occupied by materials

Therefore, from above relation

$$V_b = \frac{m}{\rho_b} = \frac{50kg}{\rho_b} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots(2)$$

Laboratory analysis carried out from a representative sample of 299.1g of locust bean, the result was as follows;

i)   Mass of samples (M_S) =   299.1g

ii)   Volume of samples (V_S) =   500ml

iii)   Volume of water (V_w) =   200ml

iv)   Total volume of samples (V_T) = $V_W + V_S$

v)   Void ratio (e)   = $\dfrac{Vlolume \; Occupied \; by \; water}{Total \; Volume \; of \; Constituent}$

Putting the values into equation (1)

Hence;

Volume occupied by a 50Kg of locust beam would be;

$$V_b = \frac{50K/g}{997K/g/m^3} = 0.05m^3$$

The configuration of digester = cylindrical, volume of a cylinder= $\pi r^2 h$

Assuming the height of cylinder to be 1.0m

Therefore

$$\pi r^2 h = 0.05m^2$$
$$r = \sqrt{\frac{0.05}{1 \times 3.142}}$$
$$r = 0.126m$$

Diameter of cylinder (D) would be = 0.126 x 2 = 0.252m

B. **Design of Cylinder Vessel**

When a cylinder object is subject to a very high internal pressure, the walls of the cylinder must be extremely thick to withstand the effect of tensile stress or compressive stress due to the pressure. The distribution of stress is shown in fig. 4 In accordance with the maximum shear theory of failure, the tangential stress is maximum at the inner surface and minimum at the outer surface as shown in fig. 4b

Let;

d = Diameter of the cylinder   =25.2cm

h = Assumed height of the cylinder to be   = 1.0m

t = Thickness of the cylinder   =0.018m

To determined the thickness of the cylinder, a ratio of the thickness (t) of the shell to its diameter (d) is found, mathematically represented as;-

$$\frac{t}{d} = x\ 100 = \frac{0.018m}{0.252m} = 0.07\%$$

where;

t = Wall thickness of shell

d = Shell diameter

The cylinder is a thick wall shell since ratio is greater than $^1/_{10}$. Therefore with the following assumption; the total force acting on the longitudinal section which is equal to the intensity of pressure (p) on wall, to the projected area. Mathematically denoted as;

P x d x L ....(1)

Where

p = Pressure on wall of cylinder

d = diameter of cylinder

L = Length or height of cylinder

The total resisting force acting on the cylinder walls can also be obtained from these formular;

f_a = force actin on cylinder
t = Thickness of cylinder
l = Lenght or height of cyclinder

Therefore f_a = 2tl ....(2)

Equating equation (1) ....x (2)

f_a x 2tl = p x d x l

making f_a a subject

$$f_a = \frac{P \times d \times \cancel{4}}{2t\cancel{4}}$$
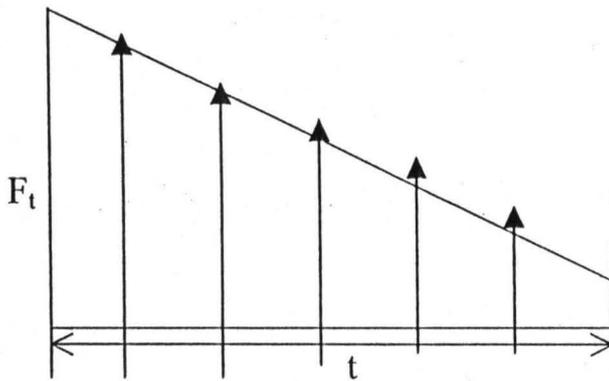
$$f_a = \frac{pd}{2t}$$

$$= \frac{1 \times 10^2 N/m^2}{2 \times 0.018m} = \frac{25200}{0.036}$$
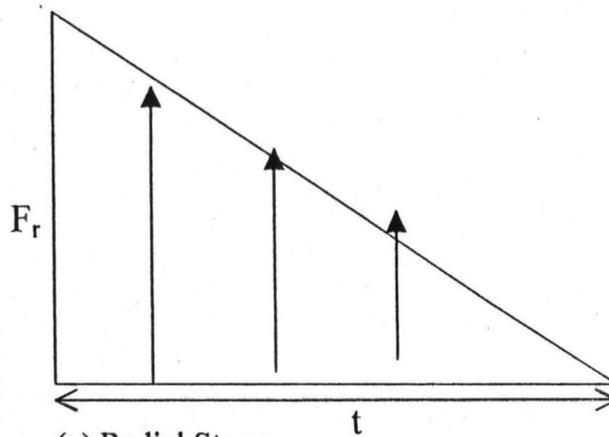
$$f_a = 700000 N/m^2$$

$$\approx \underline{\underline{700 KN/m^2}} \quad Stable$$
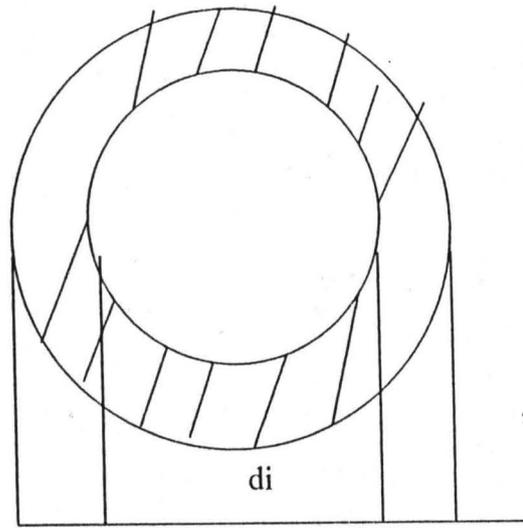
(a) Inner wall of cyliner

(b) Tangential Stress

(c) Radial Stress

Fig.3. Showing Forces/Stress Over the Cylinder Wall.

C. Design of Stirrer Shaft

The power introduced into a solid mixing systems by a paddle is determined by the following;-

i) The speed of rotation

ii) The configuration of the impeller

iii) The physical properties of the materials

Assuming the dimensions of the paddle are in a definite geometric ratio with impeller then the power input to the agitator can be expressed as a function of the following variables;

$P = f\ (N, D, \rho, \mu, g)$

Where ;

N = Rotational speed of impeller

D = Diameter of impeller

ρ = Density of materials

μ = Viscosity

g = Gravitational force

(i) Assuming the density of material to be equivalent to that of cassava paste $=23.5 Kg/m^3$

(ii) Assuming the viscosity μ to be $= 9.60 Nm^2$

(iii) Acceleration due to gravity (g) $= 9.81 m/s^2$

But power $= \dfrac{Workdone}{Time}$

$$\dfrac{Force \ x \ dis\tan ce}{Time}$$

:. Mathematically, $P = \dfrac{F \; x \; d}{t}$

Force = Mass x acceleration x heights

F = mgh

:. F $= 50\text{kg} \times 9.81\text{m/s}^2 \times 1.0\text{m}$

$= 490.5 \text{Kg/s}^2$

:. P $= \dfrac{490.5 Kg/s^2}{3600s} = 0.1363 \; x \; 1000 = 136.3 watts$

Design for Strength

To design a shaft for strength the following equation can be used;

Let;

P = Power transmitted by a shaft

$P = \dfrac{2\pi NT}{60}, w$

Where;

T $=$ Torgue transmitted

N $=$ Speed of rotation of shaft

Assuming that the shaft is made from steel, 0.2% C – HR, with ultimate tensile stress of 490.0mN/m^2, denoted by (f_{ult}) from standard design table values of various material can be obtained and used to find the required shaft diameter.

Let;

L $=$ Length of shaft $=$ 1.2m

f_{ult} $=$ The ultimate tensile stress be 490.0mN/m^2 "standard tables"

f_S $=$ Design stress = 0.18 x $f_{u;lt}$

Therefore design stress for the shaft is;

$$f_{ult} \quad = \quad 490.0 mN/m^2$$

$$\therefore f_S \quad = \quad 0.18 \times f_{ult}$$

$$f_S \quad = \quad 0.18 \times 490.0$$

$$f_S \quad = \quad 88.2 mN/m^2$$

But power $\quad = \quad \dfrac{2\pi n mt}{60}$

Where;

n $\quad = \quad$ Speed of rotation $\quad = \quad$ 250rpm

mt $\quad = \quad$ torsional moment of shaft

p $\quad = \quad$ Power, 0.5Kw

Since;

$$mt \quad = \quad \dfrac{9500 \times p}{n}$$

$$mt \quad = \quad \dfrac{9550 \times 500}{250}, Nm$$

$$mt \quad = \quad 19100 Nm$$

Then going back to the power equation and substitute the values of Mt, becomes;

$$P \quad = \quad \dfrac{2\pi n mt}{60}, Kw$$

$$P \quad = \quad \dfrac{2 \times 3.142 \times 250 \times 19100}{60}$$

$$P \quad = \quad \underline{0.500 Kw}$$

Let;

$$f_S \quad = \quad \text{Maximum shear stress}$$

but $f_S = \dfrac{16mt}{\pi d^3}$, *for solid shaft*

Using the above formular, the value $f_S = 88.2mN/m^2$

Therefore;

$$88.2 \times 10^6{}_{mm} = \frac{16 \times mt}{\pi d^3},$$

$$d^3 = \frac{16 \times 19100}{3.142 \times 88.2 \times 10^6},$$

$$d = \sqrt{\frac{305600}{277124400}} = 0.033m \approx \underline{33mm}$$

Therefore shaft diameter choosen is <u>35mm</u> diameter.

D. **Material Balance**

In order to determined the material balance in the system the following relation were used,

Let

P = pressure energy posses by the materials

V = volume occupied by materials

$U = \dfrac{\text{mass of a unit weight of material}}{\text{Gravitational constant.}} = \dfrac{1}{g_C}$

In these systems, since the material is homogenous, the mass of the material taking parts in the process is constant and the material is undergoing dehydration process. Under this circumstance energy and mass are inconvertible and the sum of the two is constant.

Let,

U_1, = Initial mass of material into the system.

And U_1, = $\dfrac{1}{g_c}$ = $\dfrac{50kg}{9.81m/s}$

U_1, = $\underline{5.09kg\ /m/s}$

Since the initial mass of material entering the system equal the mass leaving the system an equilibrium is established, U_2 now becomes 5.0 9kg/m/s.

Using Boyle's law, as general relationship between pressure, volume and temperature of a given mass, usually referred to as the equation of state. "$P_1\ V_1 = P_2\ V_2$"

where

$V_1 =$ is the initial volume of material

P_1 = initial pressure energy possessed by the materials

P_2 = increase in pressure energy of material

V_2 = change in volume of material

With the following assumption

Let;

(i)   Density of air (ρ_a) to be = 0.0808 lb/ft^3

But 1 lb/ ft^3 = 16.018kg/m^3

0.0808 lb/ft^3 = 11.3kg/ m^3

(ii)   Assuming P_1 = the atmospheric pressure standard = 1 x 10^5 N/m

Using the equation of state,

$P_1 v_1 = P_2 v_2$,   at constant temperature it now becomes;

$P_1 = 1$ x 10^{5}N/m

$V_1 = 0.05$m^3

$P_2 = P_1$

But V_1 + air density into material

= 0.05 + 11.3kg/m^3

 = 11.35kg/ m^3

But   density (ρ_a) = $\dfrac{\text{mass}}{\text{Volume}}$

11.35kg/ m^3 = $\dfrac{50\text{kg}}{\text{Volume}}$

Volume = $\dfrac{50\text{kg}}{11.35\text{kg/ m}^3}$

= 4.41 m^3

The new volume V_2 = 0.05 m^3 + 4.41 m^3

$V_2 = 4.5 \text{ m}^3$

From $P_1 v_1 = P_2 v_2$

P_2 now becomes

$$P_2 = \frac{P_1 v_1}{V_2} = \frac{1 \times 10^5 \text{ N/ m}^2 \times 0.05 \text{ m}^3}{4.5 \text{ m}^3}$$

$$= \frac{5000 \text{N/m}}{4.5 \text{ m}^3}$$

$P_2 = 1111.11 \text{ N/ m}^2$

Let form a liner equation to represent the form of material into the system.

Air + product + enzymes + heat $\longrightarrow$ product + enzymes + change in heat.

Therefore let ;

$U_1 + P_1 v_1 + q = U_2 + P_2 v_2$

$= (U_2 + P_2 v_2) - (U_1 + P_1 v_1)$

$= (5.1 \text{kg}_{/m/s} + 1111.11 \text{ N/ m}^2 \times 4.5 \text{ m}^3) - (5.1 \text{kg/m/s} + 1 \times 10^5 \text{ N/m} \times 0.05 \text{ m}^3)$

$= 5005.1 \text{kg/m/s} - 5005.1 \text{kg/m/s} \qquad q = 0$

Therefore since heat is not involved to balance the material it was found that according to "literature", Lysine content of raw locust bean is found to be 6.7g/kg and 6.17g/kg for fermented bean. Hence to find the amount of enzymes present we use the equivalent Lysine content from the linear equation we can equally balance the equation knowing all parameter involved.
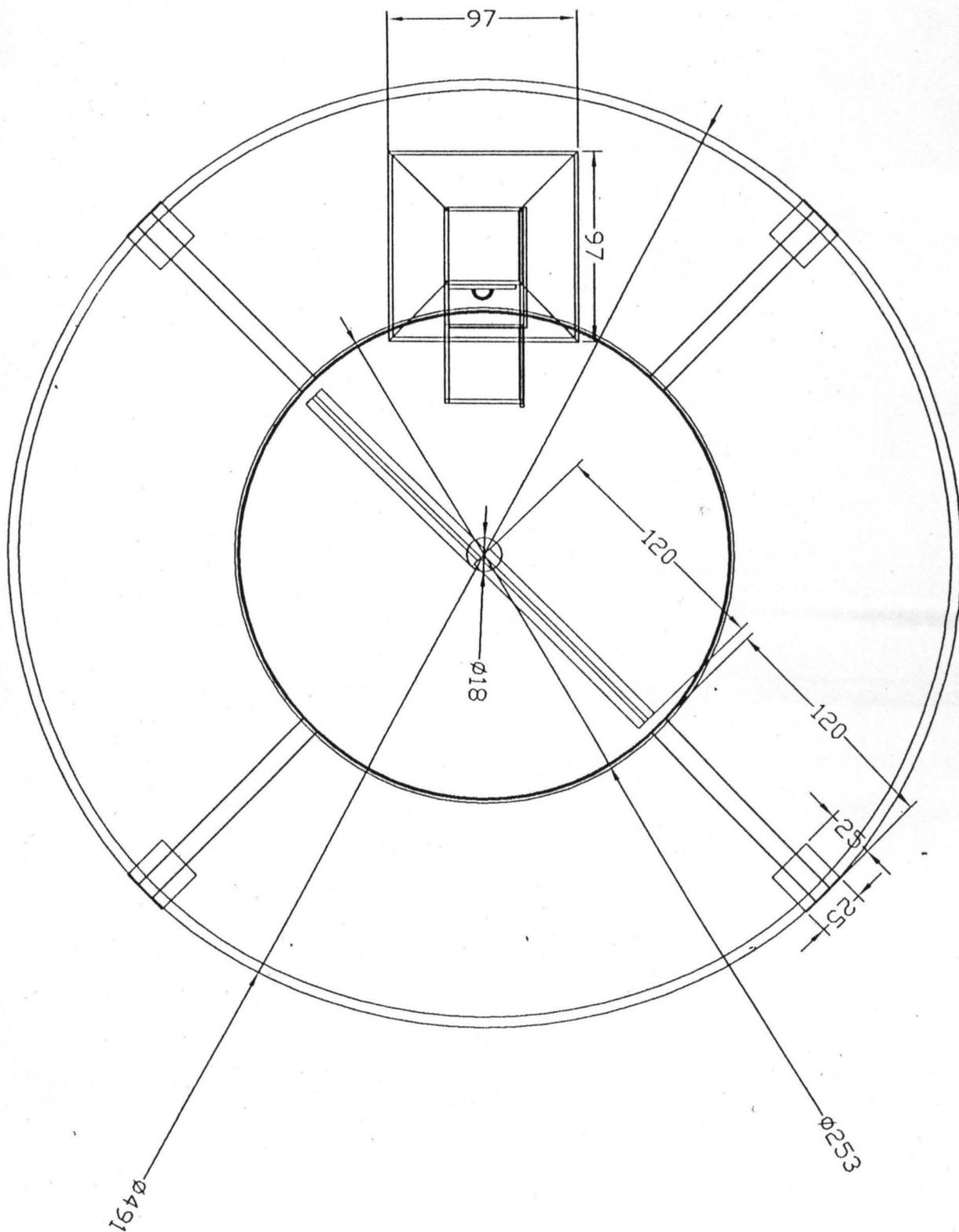
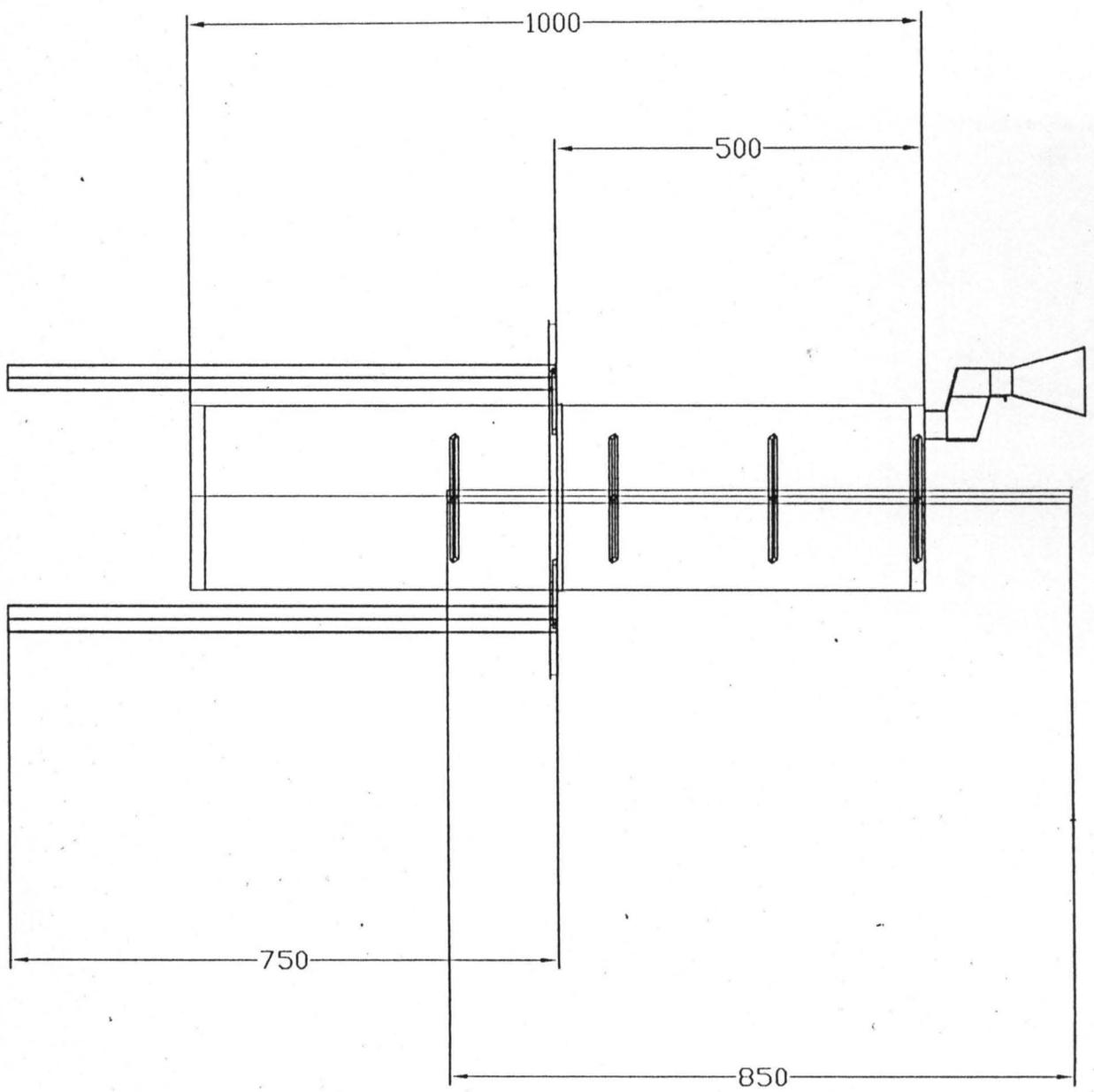Let,

Air density   =

Product quantity to be = 50kg
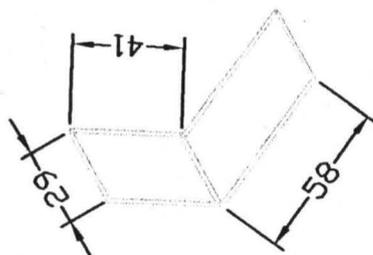
Enzymes % = $\frac{6.7}{50}$ x 100   = 13.4%

$\frac{6.17}{50}$ x 100   = 12.34%

11.35 kg/m^0 + 50kg +13.4 + 0 $\implies$ 50kg + 12.34 + 0

= 74.9 $\implies$ 62.34

Since the materials is dehydrating there is likely hood of losses of up to 12.6% may be partly due to incubation material, temperature or moisture constant.
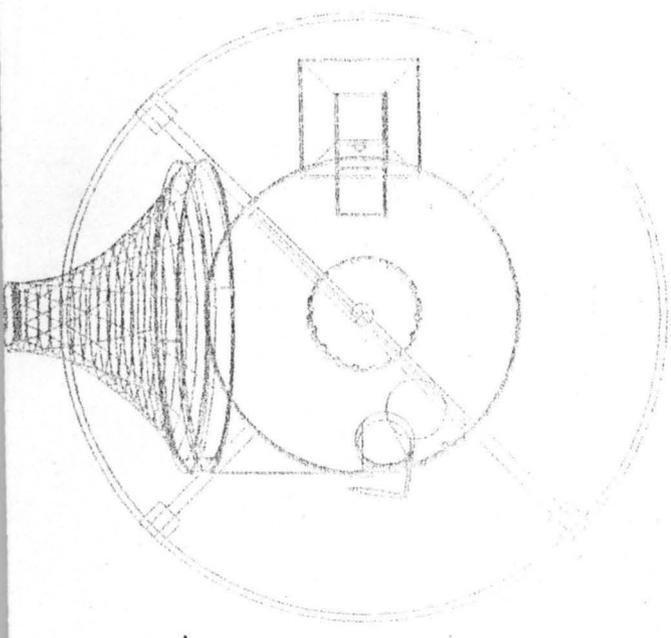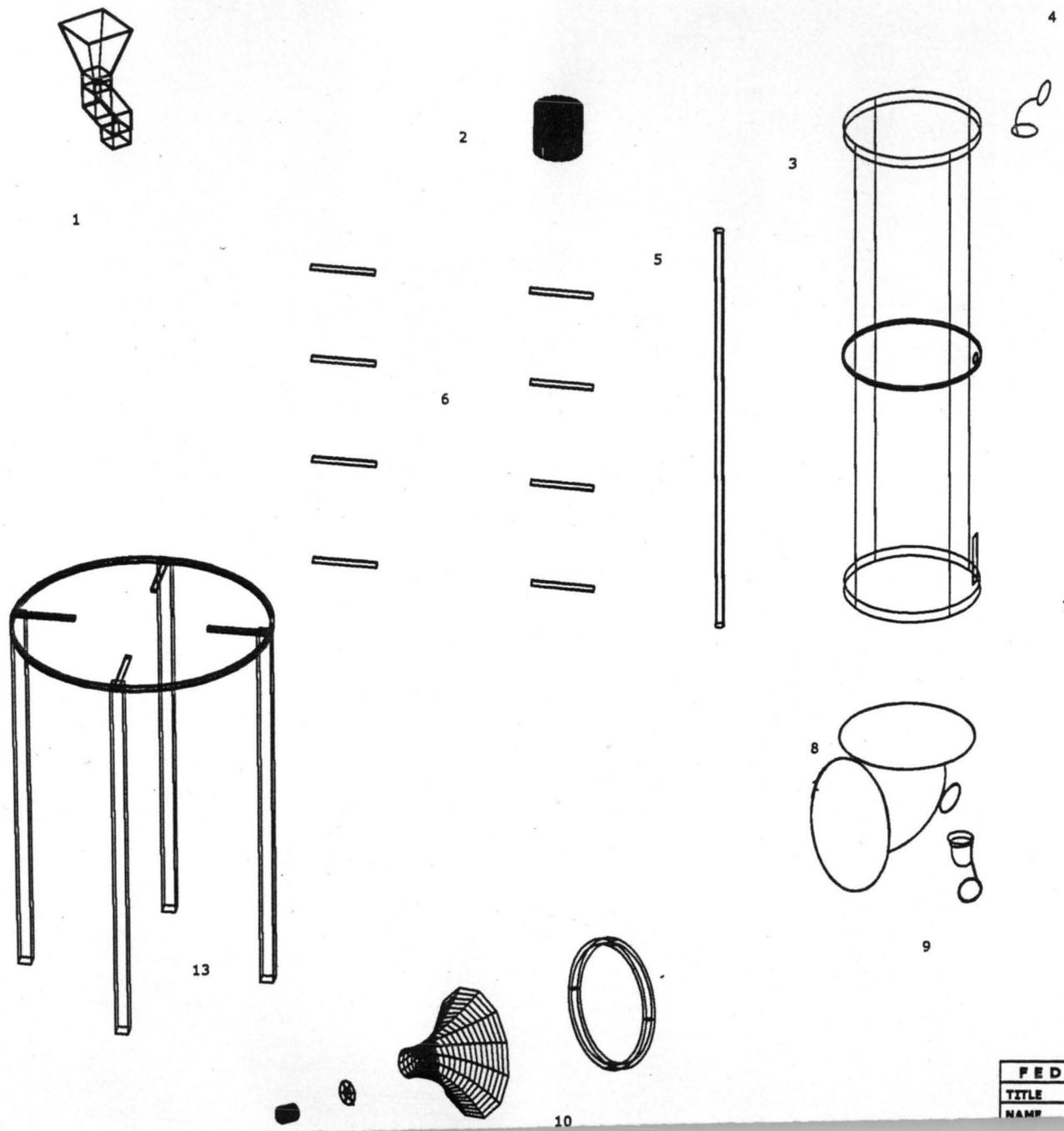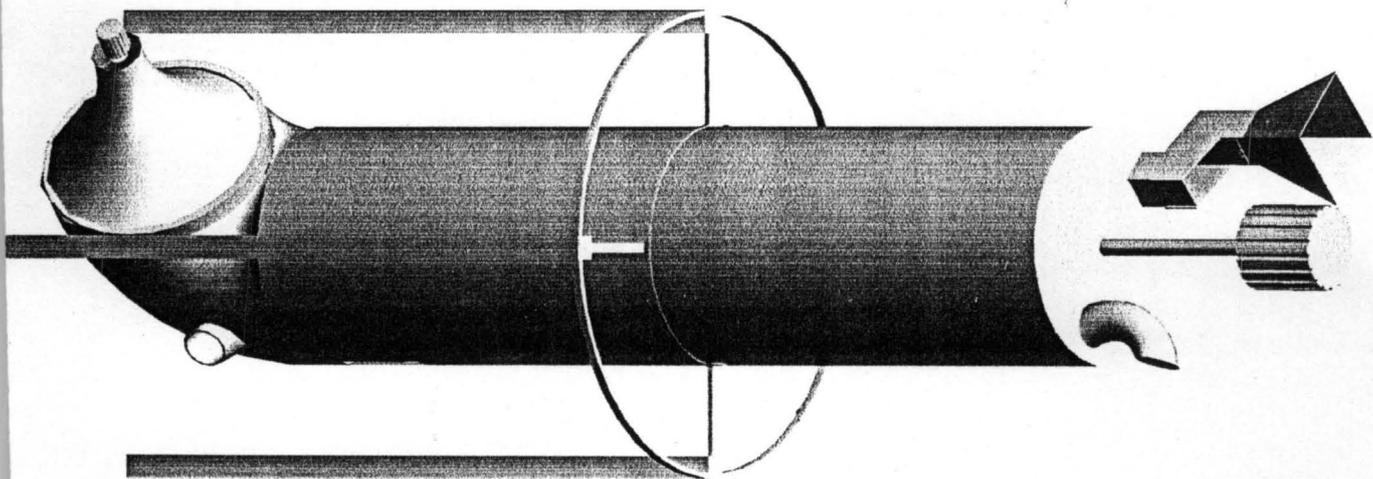
97

97

120

120

25

25

⌀18

⌀253

⌀491
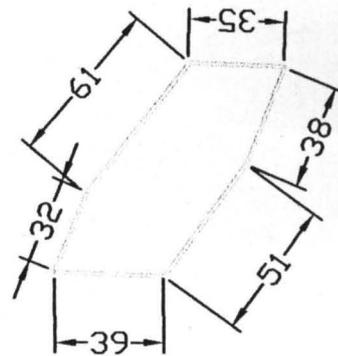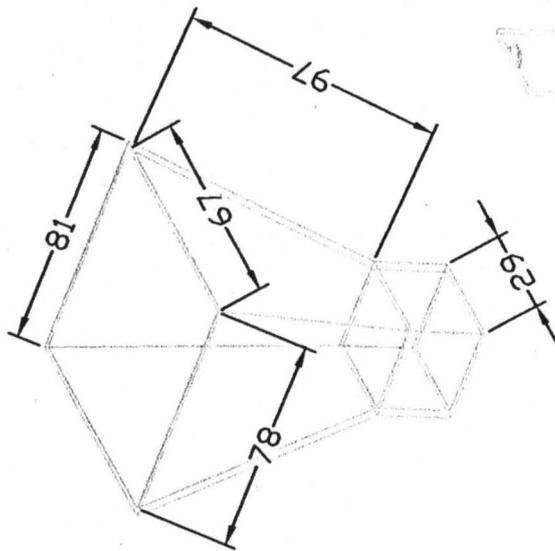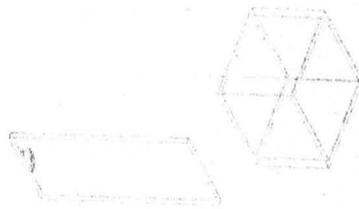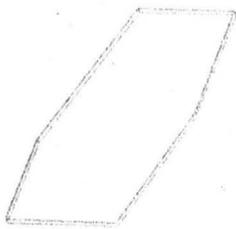
FRONT ELEVATION

SIDE ELEVATION

13	MAIN FRAME/ STAND	1	M. STEEL
12	ELECTRIC MOTOR	1	M. STEEL
11	BLOWER	1	M. STEEL
10	AIR INLET CHANNEL	1	M. STEEL
9	WASTE OUTLET	1	M. STEEL
8	AIR INLET	1	M. STEEL
7	THERMOMETER	1	M. STEEL
6	TURNERS	8	M. STEEL
5	MAIN SHAFT	1	M. STEEL
4	GASEOUS OUTLET	1	M. STEEL
3	TANK	1	M. STEEL
2	ELECTRIC MOTOR	1	M. STEEL
1	HOPPER	1	M. STEEL
S/N	PART	QTY	MATERIAL

PART LIST

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

TITLE	WORKING DRAWING OF A LOCUSTBEAN DIGESTER
NAME	MOHAMMED BIDNI

CHAPTER FOUR

4.0   Description of the Bio Digester

The digester is cylindrical in shape made from a galvanized Iron sheet of 18mm thick, 1.0m height and 0.252m in diameter. The capacity of the vessel is meant to ferment 50kg beans per batch, air is allowed into the system to aid the growth of the micro organisms which facilitated the fermentation.

Inside the cylinder is located the stirrer which is mounted on a shaft and deep inside the cylinder to encourage the intimetent mixing required for uniform air in the system. The stirrers are made of flat-blade impellers which rotated inside the cylinder. At the bottom of the vessel is the outlet, which allowed the fermented product to be collected. All gaseous product are expelled at the top cover plate.

4.1.0   Testing and Evaluation

A 50kg weight of cooked beans were packed into the cylindrical vessel they were than completely covered. The beans were then allowanced to ferment under controlled conditions at a temperature of 30^0C and 25^0C (inside the vessel) for 72 hours, from where samples were taken for analysis.

4.1.1   Measurement of Fermentation Rate

Rate of fermentation was determined by measuring the P_H of the samples every 72 hours and comparing to the P_H of the fresh unfermented beans. About 20g of beans collected from vessel and fermenting batch was milled and mixed well in 400ml distilled water. The P_H of the solution was then measured using a digital P_H meter model CD 60.

4.1.2 Sensory Evaluation

Those who are familiar with the product were asked to organoleptically evaluate the quality of the traditional fermented locust bean samples alongside one fresh samples from vessel with respect to smile (aroma), colour (appearance), texture and general acceptability using a five-point Hedonic scale as reported by Ihekoronye and Ngoddy (1985).

4.2 Result and Discussion

There was a general increase in P_H during fermentation, Table 5. the range of P_H, however, varied with increase temperature and heat. An increase of P_H from 7.98 to 8.3 at 30^0C and 8.3-9. 2 at 35^0C respectively. These observed ranges of increase is in

Table 5. Means scores for overall acceptability of 'Daddawa' fermented in a modern incubation material

MATERIAL	FERMENTATION AT 30^0C FOR 48 HOURS	FERMENTATION AT 35^0C FOR 72 HOURS
Galvanized Iron Sheet	7.98 – 8.3	8.3 – 9.2

32

accordance with that obtained by Antai and Ibrahim (1986). Odunfa (1981), also recorded PH increase of 8.3 during the first 48 hours of fermentation. This increase in PH could be due to the production of ammonia due to the activity of proteolytic enzymes produced by Baccilus subtilis (the main fermenting organism), which makes the condition of the "dawa dawa" alkaline (Soundhagul, 1972; Antai and Ibrahim, 1986, Steinkraus, 1966; Aderihigbe and Odunfa, 1988; Sarker et al, 1994).

Ammonia production has also been reported as a common feature associated with the fermentation of vegetable protein e.g. in the fermentation of soya beans to produce 'tempe' (Owens et al, 1997).

Since locust beans fermentation is carried out by aerobic bacilli (Washen and Steinkraus, 1980) the more porous the system was allowed for air to enter thus supporting growth of the fermenting organisms and encouraging fermentation the better since dawa dawa is produced by moist solid-state fermentation (Akinrele, 1964). Temperature usually affects microbial growth and activity, the increase in temperature to 35^0C could also have contributed to the higher fermentation rate observed at this temperature as against 30^0C.

The proximate composition of raw and fermented samples of locust beans indicated that the protein content increase from 30.8% in raw bean to 3.5.5% at 30^0C and 35^0C respectively. This trend agrees with that of Campbell-Platt (1980) who reported an increase from 30% to 38% and attributed it to the organism Bacillus subtilis with the fermentation. Sarker et al, (1993), and Odunfa (1983), also reported that during fermentation, the inedible legumes are made edible by extensive hydrolysis of nitrogenous compounds into amino acids.

The moisture content increase also with increase in PH, since fermentation rate increase from 25.7% to 36.3% at 35^0C. This trend of increase in moisture content was also reported by Antai and Ibrahim (1986) though the value of 59.6% which was reported was much lower than the value obtained in this study. This could be due to difference in processing method as well as processing materials used.

CHAPTER FIVE

5.0   Conclusion

The result of the study gives an indication that fermentation of locust bean can be done effectively, without deterioration of the seed while inside the processing vessel, which was produced using local materials. The PH was determined to be 8.3 at 30^0C and 9.2 at 35^0C respectively.

The capacity of the digester was determined to be 50kg / batch.

5.1   Recommendation

In this research work it is recommended that the following should be considered in any subsequent development.

1.   Proper Instrumentation should be a priority for temperature reading

2.   Need for a compressor for air delivery into the system

3.   An electric motor to power the stirrer at intermittent period of time.

4.   The whole process of fermentation of locust bean could be achieved more effectively if a hydraulic ram principle is in corporation into cylinder to press the material and eject it out.

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