DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION OF A STEAMER FOR SMALL-SCALE FOOD PROCESSING INDUSTRIES

BY

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PGD/AGRIC. ENGR./99/2000/88

A PROJECT SUBMITTED IN PARTIAL FULFILMENT OF POST GRADUATE DIPLOMA (AGRIC ENGINEERING) IN THE DEPARTMENT OF AGRICULTURAL ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

MAY, 2000.

CERTIFICATION

This is to certify that the project was carried out by

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DEDICATION

This Project is dedicated to my parents, my wife and children.

ACKNOWLEDGEMENT

I am sincerely grateful to Mr. B.A. Alabadan my Supervisor who had diligently and patiently guided me through the execution of this project. My gratitude also goes to Dr. M.G. Yisa, Head of Department and Dr. N.A. Egharevba, course co-ordinator for their immense contribution offered to me to see to the success of my course. I am also very grateful to all members of staff of Agric. Engineering Department for guiding me in one way or the other throughout the execution of my course.

I will not put down my pen until I express my heartily thanks to my brothers, Umar B, Abubakar Jega, Abdullahi Mohammed Jega, Usman Musa Ilo, Abbas Moh'd Jega, Hassan and Hussaini Usman for their financial support offered to me throughout the execution of my course. I am also grateful to my course mates, Aliyu Muazu, Umar Hussaini Kalgo and Mohammed Garba Jega. My heartily thanks goes to my sponsor, Kebbi Agricultural & Rural Development Authority (KARDA) and it's entire staff. I am also grateful to Abubakar Mohammed Salah Lolo (Small Guy) who contributed a lot to the success of this project. I am also grateful to my wife Zuwaira who contributed in the testing of this steamer, which she used to prepare "WIGLA" for the family, and also tested it to cook sweet potato. Infact she even made me to produce two steamers, one for the family use and the other for my project. Thanks to the entire

members of my family who have contributed to the success of this project and course as a whole. May Almighty Allah continue to reward them "amin".

ABSTRACT

In an attempt to enhance the processing of some agricultural products, a steaming unit, which can be used in rice parboiling process, was designed and constructed.

In this project, the construction was completed tests were carried out to determine the efficiency of the steamer while using firewood and rice husk as a fuel.

Three tests were carried out as a whole and analysis of the results showed a general high efficiency in the last two tests. The first test, which was not successful due to an initial experimentation error. The three tests were analysed in the chapter on results and discussion. In general the test showed that the machine can steam rice paddy in thirty-five minutes and sweet potato in twenty minutes respectively if firewood is used as fuel.

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CHAPTER ONE

1.0 ***INTRODUCTION***

Agriculture which is the main stay of Nigerian economy has suffered a serious neglect and setback for a long time. Apart from the drudgeries of food production, one problem that had remained unresolved for a long time is preservation of the excess food at harvest for the off season. Parboiled rice is traditional processed rice that is produced in many countries. There was report that up to 20% of the 500 million tons of rice produced a year worldwide is processed as parboiled rice. The production and the consumption of parboiled rice have increased in Africa and Central and South America with marked increases in population in recent years. Its importance has been increasing.

Described simply, the rough rice is soaked in water, steamed to gelatinize starchy rice hydrocarbons, and then dried to parboiled rice. It is then milled and is consumed like conventional boiled rice. Geletinization of the hydrocarbons accelerates the hardening of rice grains and inhibits cracks during drying and occurrence of broken rice during milling. It is also confirmed that gelatinization changes the texture of rice grains, decreases viscosity, improves taste for consumers, and enhances nutritional value as vitamins and minerals in the germ and bran layers are transported to milled rice portions.

(Japan, 1995.)

Even though developed economics have invented versatile parboilers which apart from maintaining the quality of rice are also able to accomplish the parboiling process with precision and timeliness. The principal manufacturing method is based upon the hydrothermic process. It is important to supply sufficient water and heat for gelatinizing rice starch. Therefore, any manufacturing method consists of *the following three processes: Soaking to accelerate water absorption of rough rice, steaming (steam is usually used as the heat source to prevent drying), and drying the conventional manufacturing methods adopts the cold water soaking method, whether it is the one used for self-consumption or the one used by a large plant.*

However, the high cost of such machineries make them far from the reach of peasant farmers majority of which constitute the Nigerian farming community. This fabricated steamer essentially designed to be cylindrical in shape and the rice is parboiled in cylinder or tanks. Steam is developed by the heat source at the steam section and passes through pipe to the parboiling section. A variable heat source which can either be gas-cooker, kerosine stove, rice husk, saw dust, animal dung, coal or firewood can be used to parboil paddy rice in order to improve its quality. The heat source is chosen such that cost of production is within the reach of the local farmer. If carefully used and regularly maintained the steamer can serve the owner for a long period of time.

(Ihekeronye etal, 1985.)

1.1 ***AIMS AND OBJECTIVES***

The main aim of constructing Steamer rice Parboiler is to eliminate the problems associated with the old method and at the same time to present a steamer (rice parboiler) to the economic reach of the peasant farmer.

To test the working of equipment as to notice if any difference exist between the equipment and the one being used by the farmer.

a. *To design and construction of a low cost and efficient rice parboiler.*
b. *To evaluate the performance of the fabricated parboiler.*

CHAPTER TWO

*2.0 **LITERATURE REVIEW***

Parboiling is an ancient practice in the rice growing areas of the world. The variability in quality of milled rice can be traced in part to the efficiency of parboiling

(Salako, 1984)

The practice of parboiling improves the dietary and economic values of the rice crop which is becoming more popular not only with traditional rice eating communities but also with urban dwellers.

Rice parboiling involves soaking, steaming and drying. The usual approach to simulate soaking is to consider that water diffusion and starch gelatinization occur in a solid of constant volume. In fact, increase up to 50% in kernel volume at saturation has been observed.

The purpose of this work is to formulate a model to describe the simultaneous processes of diffusion and reaction in a swelling solid and investigate its applicability on rice parboiling.

Assuming that water migrated according to Fick's law and that gelatinization is a first order reaction, the diffusion equation with variable domain of integration was derived assuming volume additivity of solid (rice components) and diffusant (water). The parameters are the diffusion coefficient and the reaction rate constant.

Water absorption curves of long rice grain were measured in the temperature range 35-90^{0}C. the reaction rate constants were measured by dynamic *calorimetric method using PL-D.S.C. equipment. Rice flour were heating at 12^0C/min using water: flour ration of 3:1.*

The diffusion coefficients at different temperatures were found by minimizing the error between the actual and theoretical curves. The Arrhenius plots for both coefficient, water diffusion and reaction rate constant, present a break at 77^0C. Above this temperature there is a more than fourfold increase in the activation energy for diffusion. The present results permit to conclude that for temperatures below 77^0C starch water reaction is the limiting factor for parboiling. Above this temperature water diffusion seems to be the controlling factor.

The proposed mathematical model showed good correlation between observed and predicted values of water uptake. Predicted rates of absorption are higher than those obtained from the classical diffusion equation for nonswelling solid. So, more reliable cooking time could be estimated with the subsequent reduction in the energy input and quality improvement of the final product.

www.confex2.com/1ft/99/annual/abstracts/4582.htm

This steamer is designed to be a versatile machine which cannot only be used in parboiling rice but can also be used for blanching of yams, cooking of potatoes, making "Alele", "Wigila" a native food in Mali Republic, blanch fruits and vegetables and many other food products.

2.1 ***LOCAL METHOD OF PARBOILING***

In parboiling, rice in paddy form is soaked in water for up to a day in accordance with rice variety then, it is subjected to steaming for a short time before drying.

Earthen pots and drums are the equipment used for parboiling. Firewood is used as fuel. The quantity to be parboiled depends on the capacity of the container.

The optimum soaking time varies according to varieties, but usually 7 to 9 hours are used in parboiling.

Atto, 1985 reported that rice was steamed in the olden days using clay pots. Two pots were made with clay, one perforated at the base, containing the rice. This is placed on top of the other containing water, which is placed on fire. When the water boils, the steam moves slowly to the rice through the perforations. In a short period of time the rice or other related grain would be partially cooked.

In a later development, some parts are made from alluminium sheets, the construction are the same with the clay types, although this has the advantage of better heat transfer than the clay type. These are still in used in the rice growing areas of the country. The soaking wets the grain while steaming dextrinizes the kernels and drives the vitamins and other water soluble nutrients from the test and to the starchy endosperm.

2.2 MODERN METHOD OF PARBOILING

In this method, parboiling tanks are filled with a clean water that is heated to a temperature of about 85 °C by passing steam through the coils inside the tank sometimes hot water is prepared in a separate hot water tanks before it is pumped into the parboiling tanks. The second process saves time and increases capacity. In a fully automatic system, the paddy is lifted by an elevator and dumped into the parboiling tanks for soaking. The resulting temperature of the paddy water mixture in the tanks is about 70 °C. After letting the paddy soaked for 3-5 hours *the soaked water is drained and the water discharge valve left open to remove the water that condenses during steaming. The paddy is later removed and dried. Before paddy is fed into parboiling unit, it is desirable to remove the chaff, dirt and other impurities using any appropriate cleaning process.*

(Hendersan and Perry, 1986)

2.4 ***MECHANISM OF SOAKING***

During soaking of paddy, water molecules first adhere to the surface of the hull and penetrates through the micro-spores of the hull into the rice kernel where they may be retained in void or inter granular spaces due to capillary absorption. Some of the molecules will be to the lattice of starch molecules where they will be held as water hydration.

(Francis, 1991)

2.5 ***VOLUME AND ENERGY CHANGES***

There is always a concomitant increases in the volume of paddy with soaking. However, the final volume of soaked paddy is always less than the sum of the initial volume of the paddy and volume of water absorbed. This is due to the fact that some of the absorbed water occupies the minute spaces in paddy grain, and molecules are held with a greater force on the absorbing surface and occupy less space than when in free state. The soaking process always results in the release of heat when water molecules are absorbed a considerable amount of their kinetic energy is lost as heat.

(Titcomb, 1961)

2.6 ***STEAMING OF THE SOAKED PADDY***

The use of steam for gelatinizing the starch in the paddy is preferable to other methods of heating because it does not remove moisture from the soaked paddy, rather it adds moisture by condensation, which increases the total moisture contents of the grain other advantages of use of steam as described by (Mr. Francis C. Ekwu, 1991 includes:-

(I) *It is sterile and can be used to produce power before it can be used to heat the paddy. The total amount of heat applied to the paddy is equal to the heat provided by the soaking and steeping water plus the heat derived from the condensation of steam during operation.*

(ii) *Generally, saturated steam at a pressure of 1- 5 kg/cm is used for steaming the soaked paddy in different methods of parboiling. The duration of steaming is dependent upon the quantity of paddy for small batches 2-3 minutes steaming is adequate whereas for larger batches of 6-8 takes 20-30 minutes. Splitting of the husk can be taken as an index of complete steaming process, although it is not a necessary condition for the paddy can be properly parboiled without splitting.*

(Ihekeronye etal, 1985)

See fig. 1(a) for the diagram of flow chart of parboiling process and Fig. 1(b) for the structure of paddy rice.

ADVANTAGES OF PARBOILING

1. *Shelling of parboiled rice is easier because the husk is split during parboiling.*
2. *The extra strength acquired by the rice kernel during parboiling helps reduce the number of breaks.*

3. *Parboiled rice retain more proteins, vitamins and minerals then raw rice.*
4. *It is more resistant to insect infestation (due to its hardness) during storage than raw rice.*
5. *Parboiled rice withstands over cooking without becoming pasty.*
6. *The loss of solids into the gruel during cooking is less in parboiled rice.*

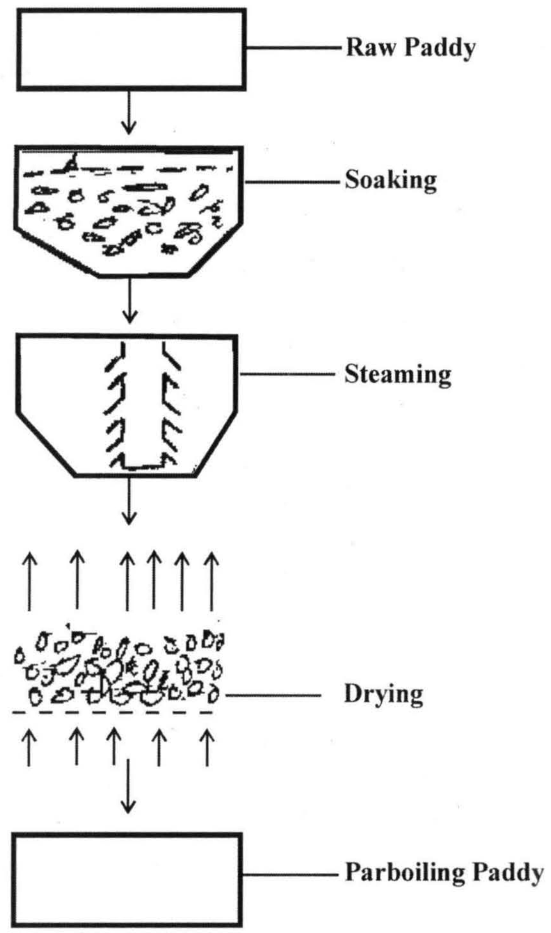


FIG. 1 (a): ***FLOW CHART OF PARBOILING PROCESS***

The grains of rice consist of the endosperm, the main starchy portion, and the embryo or germ, are contained within a hull or husk which comprises an outer pericarp, testa and aleuronic layer. The starch granules themselves are tightly bound to the endosperm protein.

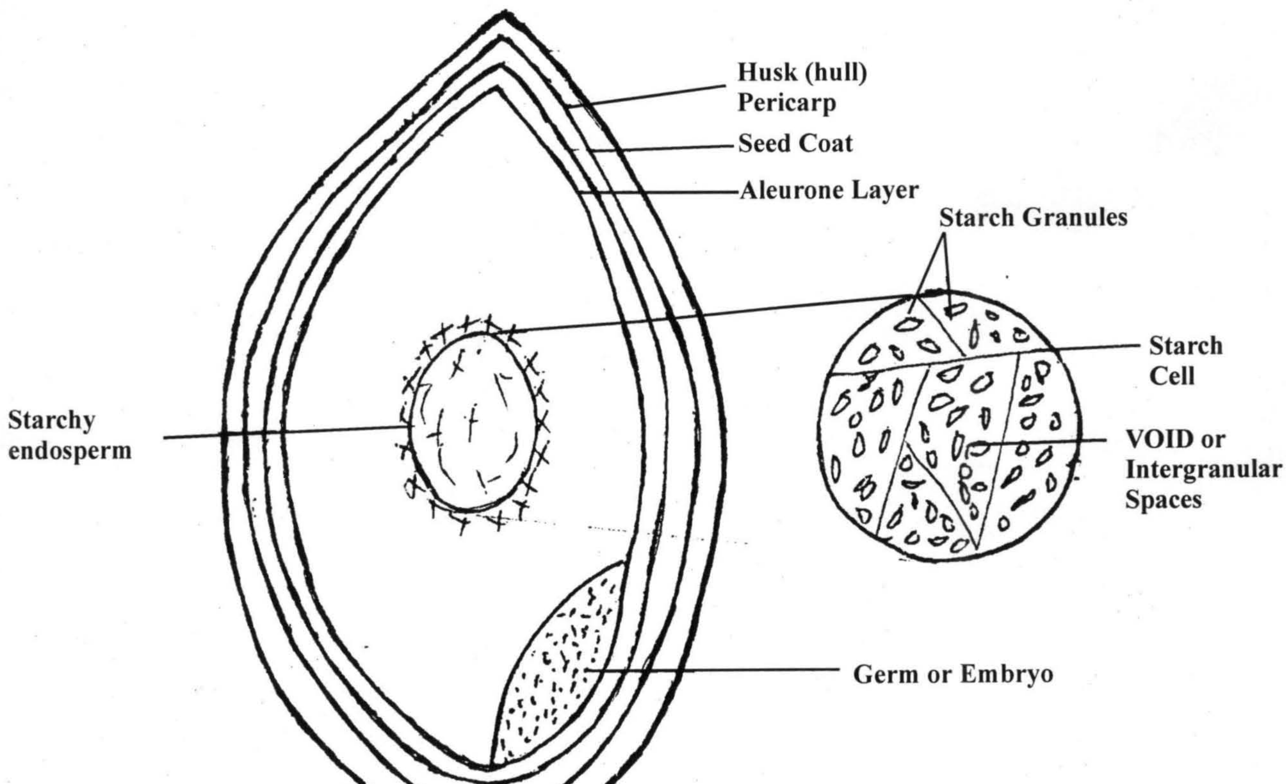


FIG.1 (b): ***STRUCTURE OF PADDY RICE***

CHAPTER THREE

3.0 ***MATERIALS AND METHODS***

All the parts that make up the machine were constructed in the Engineering Workshop.

MATERIALS USED IN THE WORK.

S/NO	***Materials***	***Qty.***	***Specification***
1.	*Sheet metal*	*1*	*1800 x 1200 x 16 mm*
2.	*Galvanised iron pipe*	*1*	*3/4 x 20*
3.	*Elbow*	*7*	*3/4*
4.	*Control valve*	*1*	*3/4*
5.	*Wire Gauge*	*1*	*480 x 260 mm*
6.	*Bolts and nuts*	*8*	*10 mm*
7.	*Paint*	*1 tins*	*50 g*
8.	*Plug & socket (GL)*	*2*	*3/4 inch*
9.	*gas welding*	*2 dozens*	
10.	*Putty*	*1*	*0.5 kg*
11.	*Shearing machine*	*1*	*Edwards 600*
12.	*Folding machine*	*1*	*Edwards True fold 600*
13.	*Rolling machine*	*1*	*F.G. Edwards Ltd London*
14.	*Grinding machine*	*1*	*Gate Mild Ford 250*
15.	*Hand shearer*	*1*	
16.	*Steel rule*	*1*	*10 x 600 mm*
17.	*Compasses*	*1*	
18.	*Screw driver*	*1*	
19.	*Pipe ranch*	*1*	
20.	*Vice and die*	*1*	
21.	*Punch*		
22.	*Hacksaw*		

3.1 ***THE BOILER CAP***

Fig. 2(a) shows the boiler cap. It was cut out from metal sheet 320 mm diameter with a thickness of 1.5 mm. It was perforated with 3/4 inch diameter drill, with three holes for flow of steam and one hole for filling the boiler with water.

The sides of the cap were perforated with 5 mm diameter drill and are 40mm a part for bolts and nuts which could be easily removed and replaced as the case may be for cleaning purposes. The 3/4 inch galvanised iron pipe were welded on top and bent by elbow of 3/4 inch diameter.

3.2 ***THE BOILER***

(Fig. 2(b) *It was constructed from steel metal sheet iron of 1.5mm thickness. The Boiler was cut from this metal sheet and has a diameter of 400mm length, inner diameter 280mm and the outside diameter 320mm and insulating material (Saw dust) between the inner and outer walls.*

The boiler was rolled to have a cylindrical shape, which was done by folding machine and welded to form the effected shape. Drain pipe (Galvanised iron pipe 3/4 inch) was fitted at the bottom of cylinder; Rubber seal was used to prevent steam from escaping. The sides were perforated with 5mm diameter drill and 40mm apart for bolts and nuts.

3.3 ***THE STEAMER COVER***

Fig. 3(a) shows the steamer cover cut to 330mm diameter from metal sheet to form the cover and cut another sheet to make the internal ring of 260mm diameter and outer ring 330mm diameter respectively. Joining was done by riveting. The handle which has a length of 100mm was also joined by means of riveting.

3.4 ***THE STEAMER***

Fig 3(b). Shows the steamer, which the method of construction is the same as the boiler with the same diameter for insulating materials and steamer.

The cylinder is 500mm high and saw dust was used as an insulator sealed between the cylinders. Drain pipe. 1.9mm diameter was fitted at the bottom of the steaming unit for draining the condensed steam. Clips were welded round the cylinder for clipping the steamer cover firmly.

3.5 ***THE BURNING CHAMBER***

Fig 4, shows the burning chamber cut from a metal sheet with 330mm diameter and 140mm height cut from another sheet of the same diameter (330m) and riveted for bottom cover. An opening of 140mm was made for feeding of fuel into the burning chamber.

3.6 ***THE STAND***

Fig. 5, shows the stand constructed from metal sheet with 330mm diameter and 140mm height. Both the steamer and the boiler stands were constructed from metal sheet 1.5mm thickness.

3.7 ***THE BASKET***

Fig. 6, consists of wire mesh. It was cut to measure 460mm height and 260mm diameter to ensure smooth movement in and out of basket as a handle. Another metal was riveted at the bottom to the upper part to strength the basket for holding the required quantity of material.

Another iron metal was cut to make three stands, of 20mm height from the bottom of the steamer so as to allow the condensed water pass through the drainpipe.

3.8 THE DELIVERY PIPE

*Fig. 7, consists of galvanised iron pipe 3/4 inch cut to 600mm length threaded both ends and joined them with the same material using elbows of 3/4 inch at each bend. One end of the pipe was joined to the centre of the boiler cylinder by welding to give a height of 100mm and the other end of the pipe to the bottom centre of the steamer to give a height of 500 mm. The vertical pipe of 600mm length was threaded at the centre and fit the control valve (**Stop Cork**).*

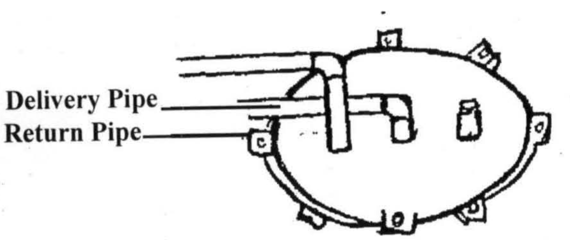


FIG. 2(a): **THE BOILER CAP**

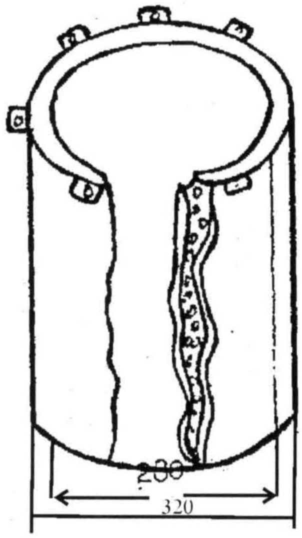


FIG. 2(a): **THE BOILER CUT SECTION**

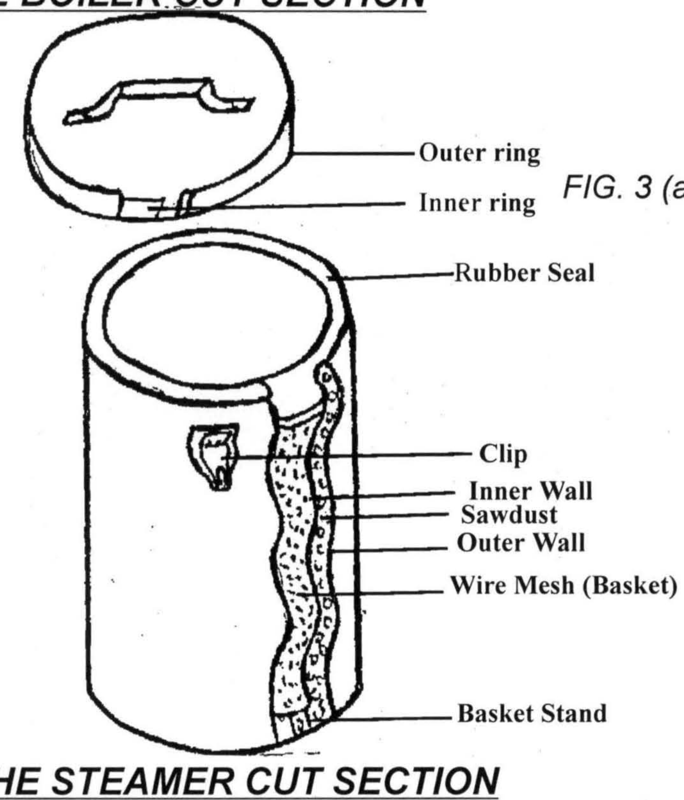


FIG. 3 (a): **THE STEAMER CAP**

FIG. 3(b): **THE STEAMER CUT SECTION**

3.9 <u>THE RETURN PIPE</u>

Fig. 7, shows the return pipe, the construction procedure is the same with that of the delivery pipe and the same material was used. Pieces of galvanised iron pipe 3/4 inch cut according to the dimensions were also joined in the same procedure with that of delivery pipe.

One end of the pipe welded to the steamer of 50mm length from the top, while the other end was welded on to the boiler cap and 50mm to the centre of the cap. This was joined to give 100mm height and 150mm inside the boiler to be submerged into the water.

3.10 <u>DESIGN CALCULATIONS</u>

The thickness for insulating materials between the cylinder walls were chosen from the following calculations:-

Area of boiler is determined as,

h	=	Height of the boiler		
r	=	Radius		
h	=	$0.4m$		
r	=	$0.14m$		
a	=	Area is given by 2□ x rh		
a	=	$2 \times 0.14 \times 0.4$	=	$0.35\ m^2$

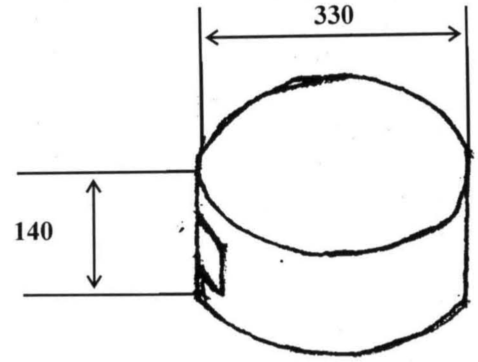


FIG. 4: ***BURNING CHAMBER***

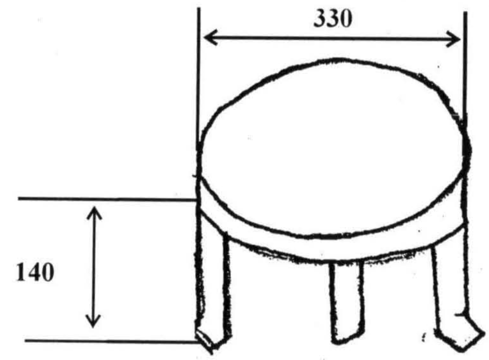


FIG. 5: ***STAND***

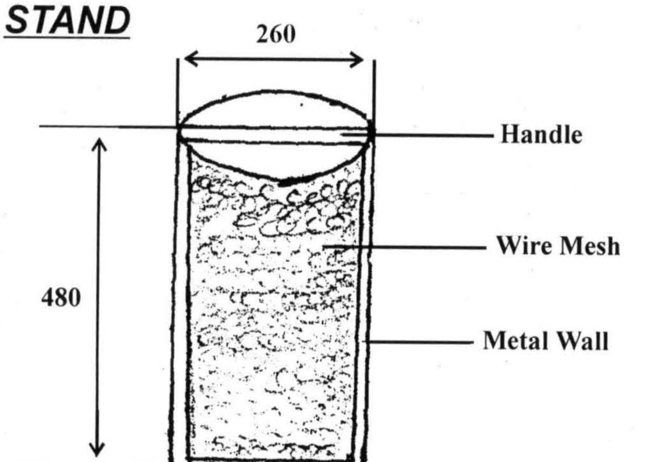


Fig. 6: THE BASKET

SCALE 1:10 (All dimensions are in millimetres)

TABLE 1:

Minimum Allowable Heat Loss in a Steam Power Plant

Plant Element	***Reasons for Losses***	***Availability Loss. KJ/Kg***	***Kcal/Kg***
Boiler Unit	*Boiler Heat Losses*	*288*	*68.9*
	Irreversible heat Exchange	*1305*	*311.7*
Steam main	*Heat losses*	*22*	*5.3*

Boiling point of water = 100^0C

Ambient Temperature = 28^0C *Source(Krillin et-al 1976)*

Temperature of steam = 104^0C

Wood thermal conductivity = *0.15 - 0.2W/mk*

To find the thickness with minimum heat loss in a boiler,

Heat transfer $Q = \frac{A\,Dt\,k}{x}$

where:

Q = *Quantity of heat loss in KJ/Kg)*

A = *Area* (m^2)

Dt = *Change in temperature (c)*

K = *Thermal conductivity of material (Kw/Mk)*

X = *Thickness (m)*

Therefore, for Boiler

$$Q = \frac{A\,Dt\,K}{x}$$

and from table 1

Q = 288

A = 0.35

Dt = (104 - 28) = 76

$K = 0.15$

$X = ?$

$$288 = \frac{0.35 \times 76 \times 0.15}{x}$$

$x = 0.14m$ or $1.44cm$ approximately $\underline{\underline{2cm}}$

For Steamer

$Area = 2\square rh$

$= 2\square\ Q.14 x 0.5$

$= 0.44m^2$

$$Q = \frac{A\,Dt\,K}{x}$$

$$x = \frac{0.44 \times 79 \times 0.15}{288}$$

$= 0.18m = \underline{\underline{20mm}}$

Saw dust was chosen as insulating material and was sealed in a thickness of 20mm for both the steamer unit and boiler respectively.

CAPACITY OF BOILER AND STEAMER

Capacity of the Boiler was measured with the volume of water it can hold.

Volume of Boiler	=	$\pi r^2 \times h$
	=	$\pi \times (0.14)^2 \times 0.4$
	=	$\pi \times 0.196 \times 0.4$
Volume	=	$0.0246 m^3$

Capacity of the steam was measured by the volume of the basket inserted into the steamer. Thus it was calculated as:-

Volume of basket	=	$\pi r^2 \times h$
	=	$\pi \times (0.13)^2 \times 0.46$
	=	$\pi \times 0.0169 \times 0.46$
Volume	=	$0.0244 m^3$

3.11 METHOD OF TESTING II

Three tests were carried out with the machine:-

1. *Steaming of soaked rice paddy using sawdust as fuel*
2. *Cooking of root crop (Sweet potato) by steaming using firewood as fuel.*
3. *Steaming of soaked rice paddy using firewood as fuel*

3.12 STEAMING TEST USING SAWDUST TO PARBOIL RICE PADDY

In this experiment, sawdust is used as fuel and was not successful because it was experienced that there was problem with the heat source, it was constructed to be very small and there was leaking at the drain pipe of the boiler unit, and also the fuel used was not a compacted saw dust, it was just put into the heat source. Moreover, the ambient temperature of the water before soaking was not recorded.

Above are the experimental errors encountered. The errors were corrected before undertaking the second and the last test.

3.13 <u>COOKING OF ROOT CROP (SWEET POTATO) BY STEAMING</u>

In this test, the product was cut into 30mm sizes for uniform treatment.

The following were used during the testing:

Volume of water used	*16 litres*
Quantity of fuel used (firewood)	*4.5 kg*
Weight of Sweet Potato	*2kg*
Initial temperature of the steam	70^0c
Initial water temperature	29.5^0c

Temperature of steam that cooked the material 102^0c

Panel of judges determine the level of heat treatment of sweet potato steamed.

<u>INSTRUMENTS USED</u>

The instruments used in the course of this thesis includes Glass mercury thermometer, Penetrometer, Weighing Balance, Knife, Ruler, Firewood and Sweet potato.

<u>PROCEEDURE</u>

16 litres of water was fed in to the boiler using a funnel. The firewood was placed and allowed to burn. The temperature of the steam was taken using a glass mercury thermometer. The basket containing the 30mm potatoes was placed into the steamer and then the steamer was closed. The reading of different samples were taken after the material was steamed at different time intervals. Penetrometer was used to measure the softness of the potato. The more soft it is and hence the higher level of heat treatment.

3.14 COOKING OF ROOT CROP (SWEET POTATO) WITH BOILING WATER

A test was conducted at home to determine the level of heat treatment using local materials. Initially the materials provided for the test are firewood, cooking pot,16 litres of water, 2kg of Sweet Potatoes cut into pieces of 30mm sizes and glass mercury thermometer.

PROCEDURES

16 litres was fed into the cooking pot, the firewood was placed and lighted. The initial water temperature was taken to be 59.5^0c using glass mercury thermometer. The 2kg potato was placed into the water and the pot was closed.

It was observed that the potato was cooked at 30 minutes. And some friends determined this. In every 10 minutes a sample was taken until it was observed that at 30 minutes the sweet potato was very soft. It was then left for further 10 minutes making it to be 40 minutes and in this stage it was watery.

3.15 STEAMING OF SOAKED RICE - PADDY

2.5kg of soaked rice paddy was soaked for 17 hours and steamed to give a good quality parboiled rice. The instruments used includes; 2.5kg of soaked rice paddy, 5.5kg of fuel (firewood), glass mercury thermometer. 16 litres of water having ambient temperature of 29.5^oc and final temperature after soaking 28.2^oc, weighing balance, stop cork, steamer.

PROCEDURE

The soaked paddy was placed in the basket and inserted into the steamer when the steam was reduced at a temperature of 90^oC and the time taken for the steam to be produced was 45 minutes. The steamer was closed to avoid loss of steam.

Different steamed samples were taken at different intervals and analysed in the chapter on results and discussion.

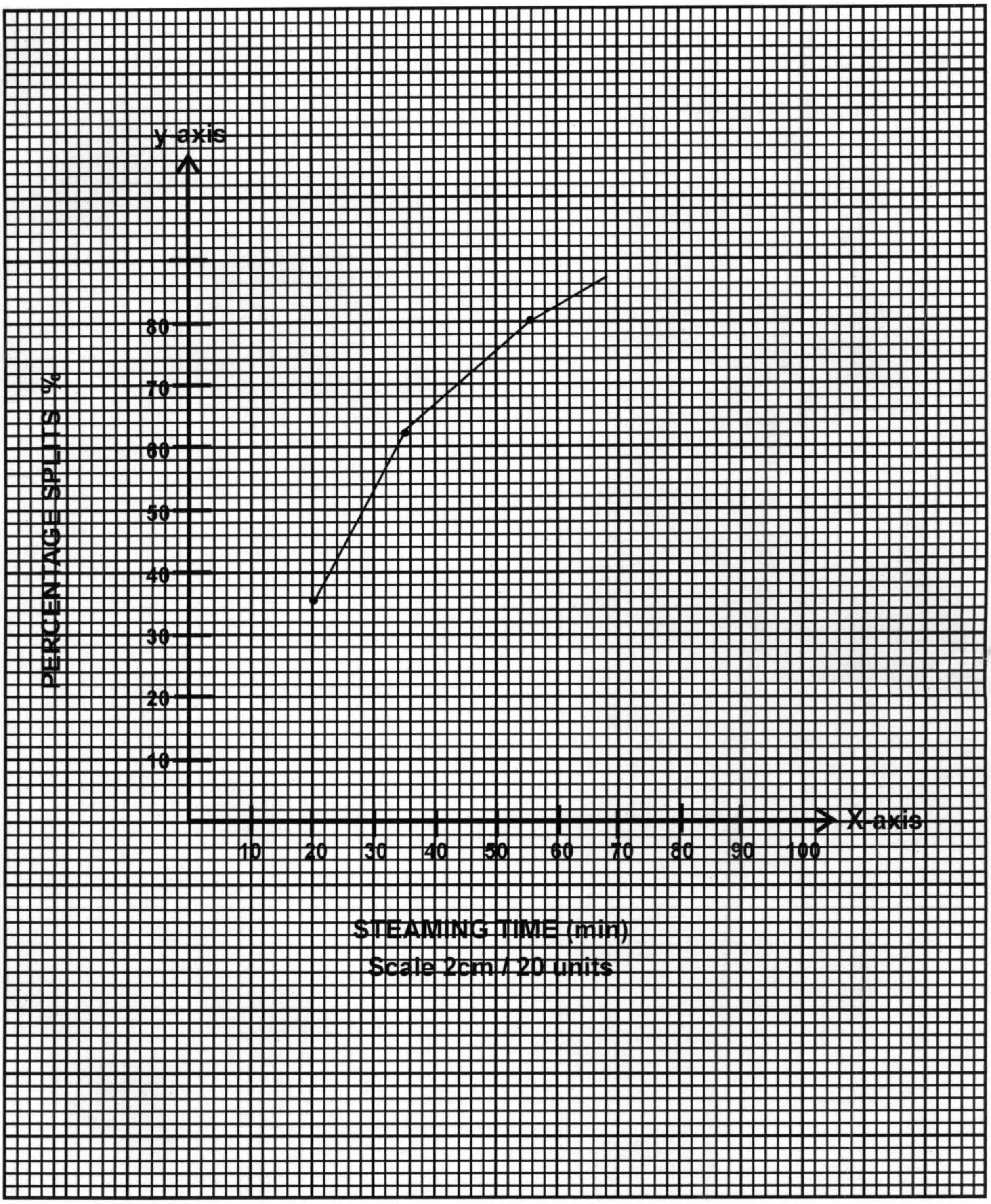


FIG. 7: DEGREE OF PARBOILING WITH TIME

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION:

Cooking of Root Crop (Sweet Potato) by Steaming

Table 2, shows the depth of penetration which indicates the level of heat treatment at different time intervals the more the penetration of the penotrometer the more soft it is and hence the higher level of heat treatment.

Table 2: ***SAMPLE ANALYSIS***

samples (30mm sizes)	*Time (minutes)*	*Average depth Of penetration (mm)*
1	*10*	*12*
2	*15*	*13*
3	*20*	*20*
4	*30*	*25*

Fig 8: shows the relationship between time of heat treatment and depth of penetration.

It could be seen that from the graph, that the higher the time, the more the depth of penetration. They are directly proportional to each other. The graph is divided into segments as follows:-

X-A:- *The product was observed to be hard, there was less penetration- the product was not soft.*

A-B:- *The product began to soften and the penetrometre entered into the product with little depth.*

B-C:- *The product was observed to be soft, there was more depth of penetration of the penetrometer.*

C-D:- *At this point the penetrometer penetrates through the product to the other end. The product was observed to be soft, weak and watery.The optimum time of cooking root crops (sweet potatoes) with the generated steam is 20 minutes from the graph, since this is where it was well cooked and the material was not watery. Different time of cooking may be determined for different tuber crops as the texture and appearance are different according to the varieties.*

4.1 ***COOKING ROOT CROP (SWEET POTATO) WITH BOILING WATER***

From the experiment, it was observed that cooking sweet potato by steaming is better than cooking in water. The advantages of cooking with steam are that less time was taken to cook the product as compared to cooking with boiling water. Steamed cook material was observed to be more nutritious as no loss of nutrients is incurred through leaching. It was observed that steaming is better than cooking in water because of the advantages discussed.

4.2 ***STEAMING OF RICE PADDY***

Table 4 shows the different samples taken at different time intervals of steaming and observations were made.

TABLE 4 ***SAMPLE ANALYSES***

SAMPLE	*TIME*	*OBSERVATION*
1	*20*	*It was observed here that paddy rice was still hard and there were very few splits.*
2	*35*	*The bran weakens and there were many splits less unsplits. The grain turned reddish in colour.*
3	*55*	*Many grains were exposed and only few good splits were seen. The grains were very soft wet and easily crushed, because the aleuronic layer and the starchy part of the grains were exposed.*

TABLE 5 ***THE SUMMARY OF PERCENTAGE SAMPLE FARMERS***

AV. QUANTITY(g.)	*TIME (Min.)*	*AVERAGE SPLIT*	*PERCENTAGE SPLIT*
45	*20*	*15.5*	*34.4*
45	*35*	*28.17*	*62.6*
45	*45*	*36*	*80*

Figure 9 is a graph showing the relationship between the percentage splits, and the steaming time. In the graph it can be seen that there is direct relationship between number of splits of the rice after steaming and the steaming time.

4.3 ***EVALUATION OF THE STEAMED AND DRIED PADDY***

The three different samples steamed at different time intervals were dried for 24 hours under the same atmospheric conditions and the following observations were made. Rice steamed at 35 minutes was found to have more splits without exposing the aleuronic layer and hard enough to withstand milling and the grains turned to reddish in colour.

Rice steamed for 55 minutes was found to be soft and loose and most of the starchy parts of the grains were exposed due to excessive steaming.

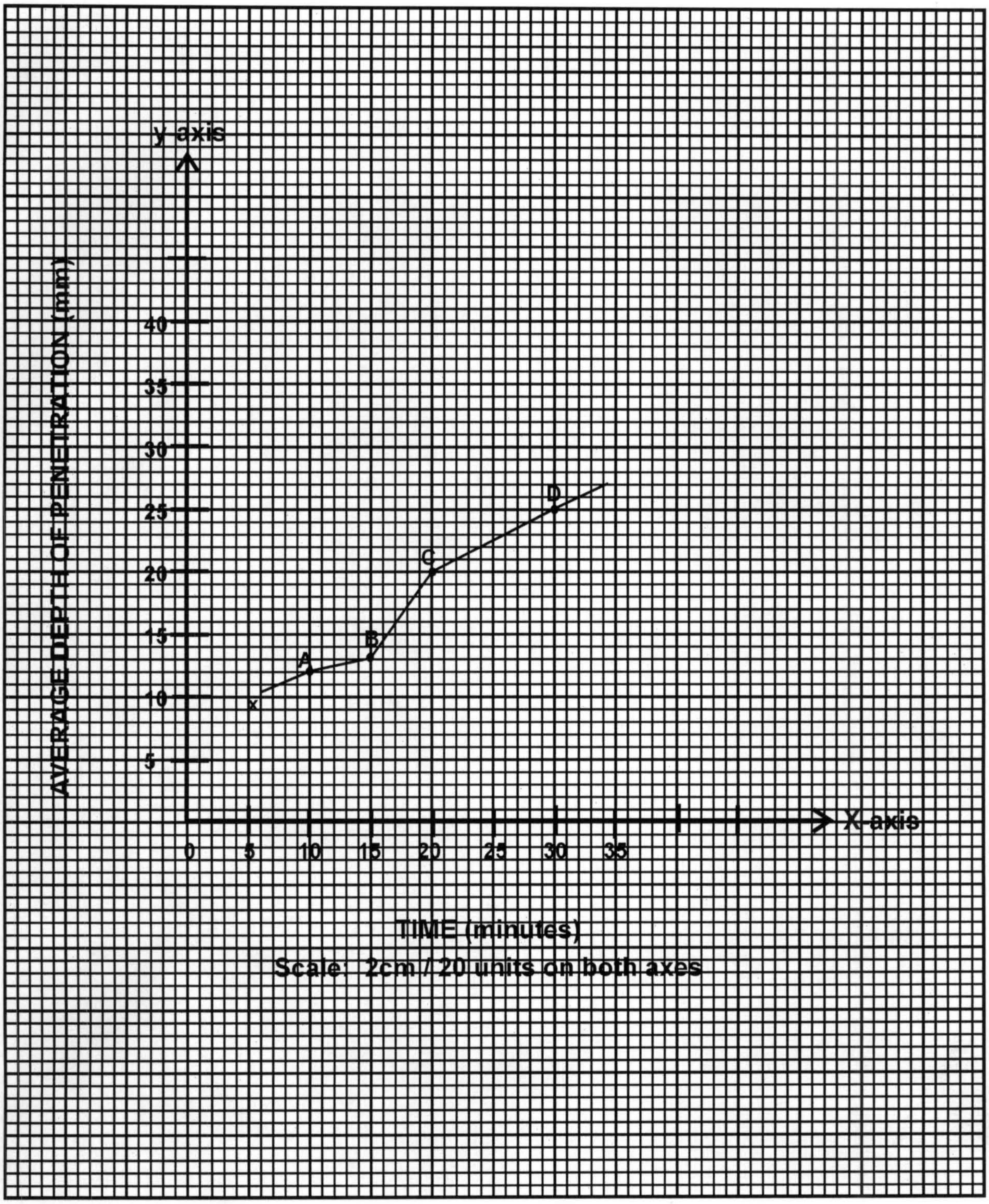


FIG. 8: ***AVERAGE DEPTH OF PENETRATION WITH TIME***

It is concluded that the optimum steaming time for parboiling soaked rice paddy with this particular machine is 36 minutes and as the time exceeds this limit the grains can not be milled successfully, thus it will result in crushing and some steamed grains will stick into the crushing rolls of rice milling machine due to its high moisture content and due to the exposure of the starchy part of bran. Another method of determining the steaming efficiency is by milling the steamed rice to find the percentage of broken over the unbroken rice. This was not done due to time and financial constrain.

4.4 ***ASSEMBLAGE:-***

Fig. 9 shows a fully labeled diagram of the whole assembly and the relative positioning of components. All the components described above when connected together form the main machine (steamer). All the cylinders were insulated with saw dust to prevent loss of heat. At the end of the steaming operation the water can be drained through draining pipe before storage.

Joining is made by means of 3/4 inch elbows (galvanised iron) and 3/4 union (galvanised iron) that makes it easier for the dismantling of the machine, transportation, repairs, etc. the overall area of the steaming unit is (600x320) mm and the boiling unit is (600 x 280mm) and the weight of the whole machine is 24.7 kg.

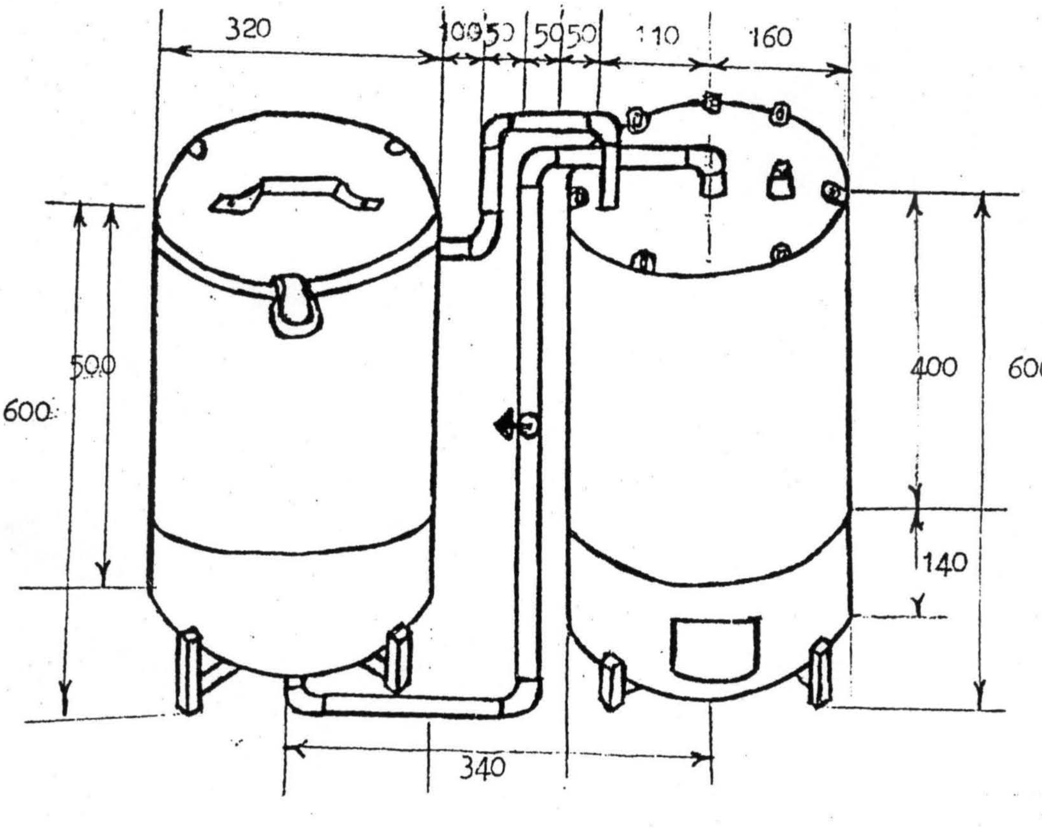
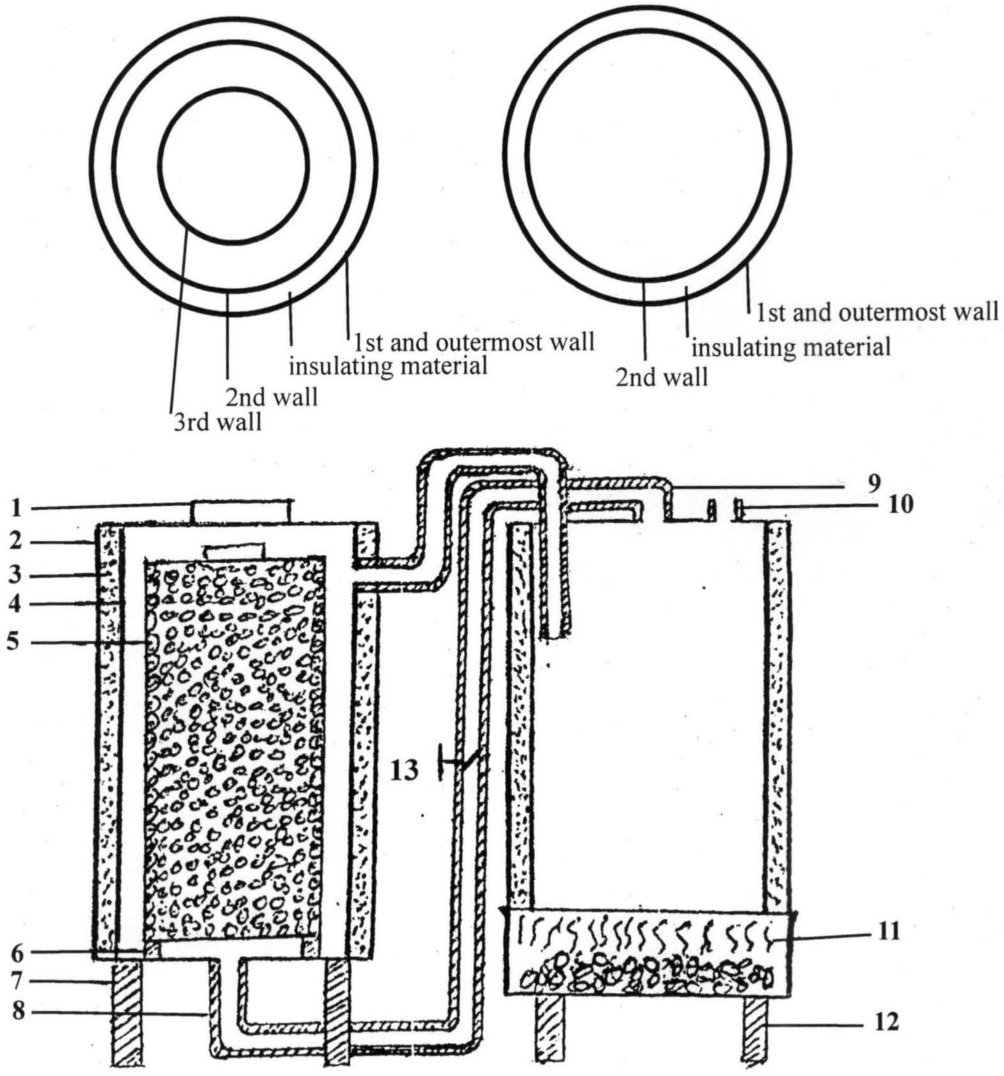


FIG. 9: ***ASSEMBLED MACHINE (PICTORIAL VIEW)***

SCALE 1:10 (All dimensions in mm)

THE CUT SECTION OF THE MACHINE:

FIG. 10. This shows the cut section of the whole system, fully labeled all the cutting section of the components described above can be seen in the diagram below.



1- Handle
2- 1st and outermost wall
3- Insulating material (Saw dust)
4- 2nd wall
5- 3rd wall (Basket
6- Basket stand
7- Steamer stand
8-Delivery Pipe

9- Return Pipe
10- Water
11- Heat Source
12- Boiler Stand
13- Control Valve

FIG. 10 ***CUT SECTION OF THE STEAMER***

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 ***CONCLUSION***

This work is a method by which agricultural products (rice) could be parboiled gainfully by the peasant farmer. The design is by itself not an end but a means to an end; subsequent storage under good conditions will ensure a continuous availability of food for the masses both during harvest and off seasons.

It must be noted here that as a result of limited time and financial constraints, the design could not be tested with some other fuels such as animal dungs, kerosene stove, or cooking gas, thus allowing for logical conclusion.

The design is by itself not for parboiling rice only but the machine could be used for blanching fruits and vegetables cooking yam, potatoes, prejelling of starchy foods for instant food formulation.

5.2 ***RECOMMENDATIONS***

The followings are recommended for further work,

(1) Animal dungs, cooking gas, kerosene, should be tried as an alternative fuel.

(2) A compacted saw dust, rice husk, millet husk and other agricultural waste should be evaluated as fuel.

(3) A means of pressure gauge should be provided and a pressure relief valve should be corporated in to the system.

The machine should be evaluated in the following food processing unit operations:

(i) Blanching of fruits and vegetables

(ii) Prejelling of starchy foods for instant food formulation

5.3 REFERENCES

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5.4 APPENDIX I

TABLE 6: SAMPLE ANALYSIS (SPLIT AND UNSPLIT)

	Qty. Taken (g)	***Split Time***	***Sample (min)***		***Unsplit Time***	***Sample (min)***	
		20	*35*	*55*	*20*	*35*	*55*
	45	*15*	*30*	*25*	*30*	*15*	*10*
	43	*18.5*	*31*	*40*	*28.5*	*16*	*7*
	47	*13*	*23.5*	*33*	*30*	*19.5*	*9*
Total	*135*	*46.5*	*84.5*	*108*	*88.5*	*50.5*	*26*
Average	*45*	*15.5*	*28.17*	*36*	*29.5*	*16.33*	*8.67*

Therefore, percentage splits with respect to time intervals is determined as follows:-

At 20 minutes % Split $= \frac{15.5x100}{45} = 34.4\%$

At 35 minutes % Split $= \frac{28.17}{45} \times \frac{100}{1} = 63\%$

At 55 minutes % Split $= \frac{36}{45} \times \frac{100}{1} = 80\%$

5.5 APPENDIX II: COST ANALYSIS

The cost incurred with the construction of this machine will include the cost of materials and labour. However, as labour cost varies with time, the cost of materials will be dealt with here basing estimation on current market situation.

The table below shows the breakdown of the materials cost analysis incurred in the construction of the machine.

TABLE 7: ***MATERIAL COST ANALYSIS***

S/No.	Materials	Qty.Required	Specification	U/Price(Naira)	T/Price (Naira)
1.	Sheet Metal	1	1800x200x16m	900	900
2.	G.I. Pipe	6'	m	120	120
3.	Elbows	7	3/4"	30	210
4.	Control Valve	1	3/4"	300	300
5.	Drain Plug	2	3/4"	20	40
6.	Wire Gauge	1	3/4"	100	100
7.	Bolts and Nuts	8	380x260	10	80
8.	Paint	1 tin	-	100	100
9.	Socket	2	50 mil	20	40
10.	Putty	1	3/4"	20	20
11.	Rice Paddy	2.5 kg	0.5 kilo	40	90
12.	Fuel	4kg	2.5 kilo	5	20
13.	Sweet Potatoes	5kg	4kg 5kg	10	100
TOTAL					2,120

LABOUR COST

There are costs incurred or wages paid to workers on construction. These are estimated at an assumed cost of 100.00 per day at two people working for five days. Therefore labour cost is calculated to be 100x2x5 = 1000.00.

PERSONAL COSTS

These are minor costs incurred by the owner that are often not included in the total cost. These include cost of transportation, cost of minor items such as, razor blade, needle, machetes, kerosene etc. They are assembled to be 5% of the material costs.

P.C. = Personal Cost.

M.C. = Material Cost

L.C. = Labour Cost

Therefore:-

(i) $PC = \frac{5}{100} \times M.C.$

$= 0.05 \times 2120$

$= 106.00$

(ii) $\text{Total Cost} = MC + LC + PC$

$= 2120 + 1000 + 106 = \underline{\underline{3226}}$

The cost of construction this approximate to about 3,226.00 per unit, compared to available mechanical and electrical steamer. This machine could thus be seen as an economically reasonable alternative for the peasant farmer. The advantages for underwrite this amount, the farmer will be able to increase his production and will definitely get higher economic value for his products.

APPENDIX III PROTECTION

The whole machine is painted black to prevent the machine from rust and corrosion. The black colour was chosen due to the fact that the heat source of the machine is by burning fuel such as firewood, rice-husk, animal dungs etc which provide smoke.

The appearance of the machine is kept neat after cleaning the body with a piece of loth.

AINTENANCE

fter the Operation:

- *The water in the boiler should be drained through a drain pipe beneath the cylinders to avoid rusting.*
- *Inspect the machine after the days operation for any deposit or condensed water. Remove and clean thoroughly with water.*

- *Clean both inside and outside of the machine before storing*
- *Flush water inside the pipe to remove the deposits as deposits contaminates the materials.*

Before Operations:

- *Tighten the bolts and nuts firmly to protect steam loss.*
- *Tighten the control valve (stop cork) and elbows to avoid steam loss*
- *Inspect for leakages and repairs.*

Before Starting:

- *Dismantle the system and clean thoroughly*
- *Store under cover, use tarpaulin to prevent rain, light intensity to the machine*
- *Keep out of the reach of children not to damage the threaded part of the machine and the rubber seals.*
- *Apply oil to the threaded parts to prevent damage and rust.*