DESIGN AND DEVELOPMENT OF HEATED PEBBLES - RICE PADDY PARBOILER

BY

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CERTIFICATION

This is to certify that this project was carried out by Dadi Saraki in the Department of Agricultural Engineering, Federal University of Technology, Minna.

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DEDICATION

This project work is dedicated to my mother Hajiya Fatima and my brother Mallam Issa Mohammed for their moral and financial support. Also to my brother Mallam Ishaku Mohammed.

ACKNOWLEDGEMENT

I am sincerely grateful to the Almighty God the author of life every good thing, who for His sake has seen me through rigour of University education without hitches. I owe my life to Him in every aspect of it.

I also wish to acknowledge the assistance of men and women whom God has used to help me especially during this project. They include such people like;

My project supervisor, Deacon O. Chukwu, for his personal involvement. His scholarly advice, criticism and suggestions have been of a great encouragement to me all through the period of this study.

My parents, Hajiya Fatima Dodo and Alhaji Mohammadu Dadi deserve a heart felt gratitude for all their heart felt support through the duration of my study. May the Almighty reward you with glory in the Hereafter.

Many other relations and friends who are worth mentioning are my uncle Late Lt. Col. Rani (Rtd), my elder brother Mallam Issa Mohammed, and my very good friends Arc. Bala Issa Doko, Eng. Sidiq Hamzat and Mallam Ishaku Mohammed for their moral and financial supports.

I must also mention the man who helped me so much during the construction of this project. He is Tonny Brahama.

May God bless all of you and meet you at the time of your need. Amen.

Dadi Saraki. Minna.

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ABSTRACT

The design and development of a heated pebbles rice paddy parboiler has been carried out in this study. Heating taken place inside the electric oven wherein the pebbles to be heated are placed on the electric oven metal tray where the heater provides the heat.

The study involves the determination of the amount of energy required to parboil a given quantity of rice paddy (20kg) using heated pebbles method for a desired period of time and also bring the temperature of the heated pebbles to a certain level. The design of an electric heater, metal tray, tray support, electric oven casing, insulator and the fabrication and coupling of these different parts are carried out to get the parboiler.

A 30cm size basin to be used for pebble-paddy exposure and a sieve to be used for pebble-paddy exposure separator were also fabricated from iron sheet (gauge 20) and a wooden plank cut to form wooden slab to be used for stirring the mixture.

From the result of the experiment, it was found that stipulated temperature of 200^0c, soaking period (24-36 hours) of moisture content 28% or more and pebbles-paddy ratio of 20 were very important in this system of parboiling for each parboiling operation which will ensure quality parboiled rice.

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CHAPTER ONE

1.0 INTRODUCTION

The cultivation of rice (Oryza sativa) can be traced to the earliest time. Up till this present time, the origin of rice cannot be traced but, it can be said to be first cultivated in Asia and later spread to Africa and America (Kono, 1986).

Rice is taken as a part of the three daily meals in certain areas of the world like India, it tends to be one of the world's economic and political commodities. Rice is a leading cultivated crop for its edible starchy grain.

Rice paddy consists of the husk or hull and the caryopsis or kernel. The husk is formed from the lemma, which covers the dorsal part of the seed and the palea which covers the ventral part. The constituent parts are cellulose and fibrous tissues covered by hard spines. The caryposis consists of the pericap which forms the seed coat. Below this is a thick layer of tissue called aleurone layer or bran. The innermost tissue is the starchy endosperm containing little protein. The presence of void in the starch cells causes breakage during milling. The breakage can be eliminated or reduced by gelatinizing the starch which fills the voids and cements the fissures during the parboiling process (Chukwu, 1999).

Rice is used in the production of starch, alcoholic beverages and soft drinks. Rice meals that include bran layer and the germ are used in pharmaceutical industries for the production of phytin and vitamin B. the germ rich in fats is a good source of butter and rice oil used in the manufacture of soap and candle sticks (Kono, 1986). Rice is used in feeding livestock. Rice is also used for canning and for making beverages and alcoholics. Rice straws when combined with some other cereals such as wheat, millet and corn are used in feeding cattle. Furthermore, rice straws can also be used for mulching on farms or roofing.

1.1. PRIMARY PROCESSING OF RICE

Processing may be defined as any activity done on the farm or by local enterprises that maintains or enhances the quality or changes the form or characteristics of the farm produce. During processing the raw material is subjected to a number of unit operations to produce the designed product e.g bread is the end product of many processes involved in wheat grains. Processing of rice is done after harvesting. It involves threshing, parboiling and milling.

1.1.1. THRESHING

This is the removal of the rice grain from the stalk. It is done by light pounding, beating against a material or tarpaulin. It can also be done by using threshing machine.

1.1.2. PARBOILING

This is a water heating process which involves warm or hot water soaking and steaming of paddy. Parboiling is a hydrothermal treatment given to paddy to improve its qualities and it involves the three basic processes of soaking (or steeping), steaming and drying (Chukwu, 1999).

1.1.2.1 SOAKING/STEEPING

There are two methods of soaking (or steeping) rice namely:

(a) Cold water steeping (Traditional method)

(b) Hot water steeping (Modern method)

Cold water steeping involves soaking paddy in cold water for 3-4 days. This gives rice paddy an unpleasant odour. Hot water steeping is preferred because the offensive odour is eliminated.

Hot water steeping involves washing the paddy in tank to remove dirts and chafts. The washed paddy is then poured into tanks and drums containing warm water, covered up with heavy cloth or jute bags. A temperature of 60-70^{0}c over a period of 18-24 hours is usually suitable for most rice varieties (Chukwu, 1999).

1.1.2.2 STEAMING

Steaming is the process of passing steam through a drained moist soaked paddy for an hour or so until the husks just start splitting and the grains become soft. The duration of steaming depends on the quantity of paddy and steaming is deemed to be completed once splitting of the husk occurs.

1.1.3.3 DRYING

Drying is the last of the three phases of paddy parboiling. Drying is the process of spreading the steamed rice paddy usually in the sun to achieve a moisture content of 13-14% (wb) after which the grains are tempered. It is then allowed to cool for about 2 days before milling.

1.2. PURPOSE OF PARBOILING

The benefits derived from parboiling include:

a) To reduce losses of nutrients during milling.

b) To reduce incidence of breakage during milling.

c) To salvage poor quality or spoiled paddy rice to meet the demand of certain consumers.

d) To improve the milling recovery of rice.

e) To achieve desirable flavour and cooking characteristics.

(Chukwu, 1999).

1.3. OBJECTIVES OF THE STUDY

This study aims at designing of an equipment for parboiling of rice paddy that would use heated pebbles. The heat would be generated from an electric oven. The capacity and efficiency of the equipment would be investigated to determine its performance for a realistic range of parameters.

1. It was intended that the result would stimulate the interest of designers towards the development of other systems that could use electricity as their basic source of power, thereby giving room for the country's technological advancement
2. It would also help to combine the gelatinization (steaming) and drying operations from three basic processes of rice paddy parboiling operations- (soaking or steeping, steaming and drying). This would result in considerable savings of energy.
3. The study aims at low energy consumption for parboiling of rice paddy using heated pebbles method as compared to modern methods, which require high energy.
4. It was also aimed that this method of rice paddy parboiling would be suitable for small-scale operations where modern methods are quite capital and energy intensive.

1.4 JUSTIFICATION OF THE OBJECTIVES

The above objectives when achieved would have shown the potentials of parboiling of rice paddy with heated pebbles as a way of combining the gelatinization (steaming) and dry operations, thereby saving energy. Further more, farmers would now be able to produce as much as they can afford without the fear of failure due to over dependence on sun-drying. That is, an alternative cheap and portable means of parboiling rice paddy would have been produced and this would contribute to the "self-sufficiency in food production" which is our national goal.

CHAPTER TWO

2.0 LITERATURE REVIEW

Braddom (1907) was struck by the fact that the China immigrants in Malaya who consumed milled raw rice, suffered severely from beriberi, whereas the Tamil immigrants who preferred rice in the Indian fashion i.e. parboiled escaped the disease. Starting from this observation, Braddom showed by a painstaking epidemologic survey that throughout South East Asia, the consumption of raw milled rice was associated with beri-beri, whereas the consumption of parboiled rice was usually associated with immunity from it. Fletcher (1907) found that beriberi in a mental asylum in Kuala Lumphur boll was almost completely eradicated when parboiled rice was substituted for highly milled raw rice (Bienvenido, 1972).

Various bodies, manufacturers, and research institutes have made numerous efforts in the fabrication of rice parboilers. Central Food Technological Research Institute (CFTRI) established hot water soaking equipment. Researchers however realized that its adoption required certain minimum changes in the technology. The (CFTRI) equipment (1969) consists of upright conical-bottomed, over ground, mild steel tanks, each holding 3-4 tonnes of raw rice. It was fitted with steaming manifolds.

Jadaupur University, Calcutta carried out similar studies and developed a process more or less along the same lines as CFTRI (Magunder et al; 1960).

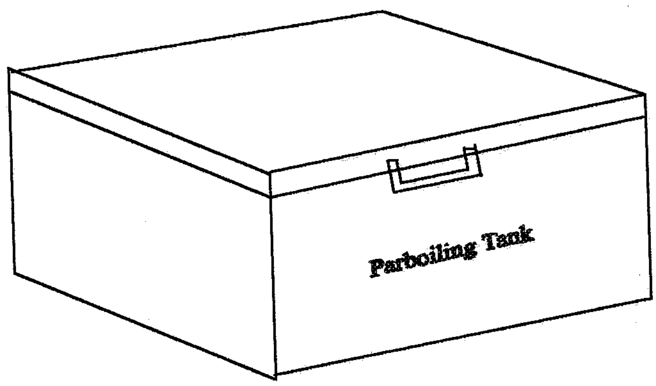
circulated in a jacket to maintain the internal temperature at around 75^0c. The speed of the travel is so adjusted that the rice reaches the end of the soaking area and put into a steaming chamber, where it is exposed to leave steam for a few minutes.

2.1. TYPES OF RICE PADDY PARBOILERS

In an industry so diversified and extensive as the rice industry, it would be expected that a great number of different types of rice parboiling equipment would be in use. This is the case and the wide range of equipment may not be described in this study. Common parboiling equipment are:

2.1.1. DIRECT HEATING PARBOILER

This consists of a rectangular tank and a hoist. The rice inside a tied bag is soaked in tank with water (80^0c hot) for 4-5 hours. The water is then drained to the false bottom level and the content of the tank steamed. Heat is applied directly at the bottom (Grist, 1983). The figure 1 below shows direct heating parboiler.



· Fig. 1. Direct Heating Parboiler.

2.1.2. INDIRECT HEATING PARBOILER

This parboiler has a separate boiler and a tank for soaking and steaming sections linked with pipes. Water for soaking in the boiler is heated by firewood and released to this tank through the pipes. After soaking the rice paddy in this tank to one quarter (¼) of its volume for 4-6 hours, the water in the boiler is drained to one quarter of its volume and heated up to 100^0c to generate steam. The steam is released with the aid of gate valve along the pipe network connecting the boiler and the tank for the soaking and steaming and this then completes the parboiling operation (Grist, 1983). The figure 2 below shows indirect heating parboiler.

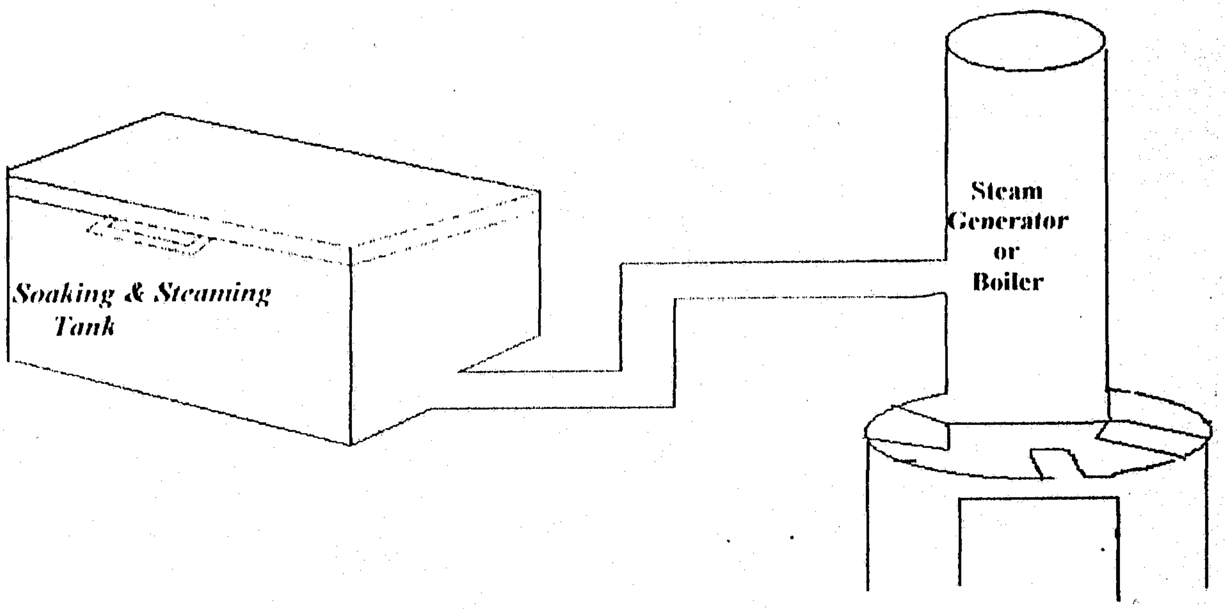


Fig.2. Indirect Heating Parboiler.

2.1.3. ELECTRIC PARBOILER

This is a compact (rectangular) system which uses electricity as its source of heat. It has a thermometer and a safety device (pressure relief) on the cover. A drainage pipe is also incorporated at the false bottom level to drain water and leave a predetermined volume of water for steaming (Grist, 1983). The figure 3 below shows electric parboiler.

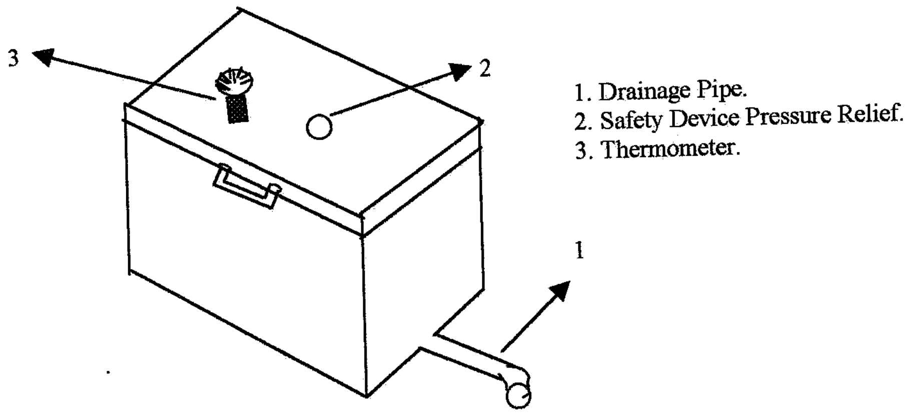


Fig. 3. Electric Parboiler

2.1.4. GAS PARBOILER

This parboiling equipment is similar to the indirect firewood system. The only difference is that gas is used as the source of heat instead of firewood.

2.2. IMPROVED RICE PADDY PARBOILER BY NCRI BADEGGI

National Cereal Research Institute (NCRI), Badeggi, Niger State also made some developments of rice parboilers such as the improved traditional firewood rice parboiler, improved steam rice parboiler, electric parboiler and the gas parboiler (NCRI, 1992).

The improved traditional firewood rice parboiler facilitates the removal of foreign materials such as sand, pebbles, straw and also defective and empty grains. It is operated by first soaking the rice paddy in water and later the soaked paddy is transferred into the parboiling tank which is allowed to boil for about 20 minutes. When the husk begins to split, the paddy is then removed and spread on a concrete floor. The capacity of the NCRI improved traditional firewood rice parboiler is only 50kg although this could be made to any capacity (NCRI, 1992).

The improved steam rice parboiler comprises two tanks made of galvanized iron sheets. One serves as the boiler and the other serves as the steam generator. The source of heat is firewood. The rice paddy is put into perforated crates in the steamer. The steamer is tightly closed. The water in the boiler is heated to about 30-60^{0}c depending on the variety of rice. The hot water control valve is opened so as to allow it flow into the steamer. It is left closed for about 5-6 hours. The furnace is fed back with firewood. The remaining water in the boiler is fired so as to generate the required steam (NCRI, 1992).

The electric parboiler is made up of galvanized iron sheet with a lid. It comprises water heating element, thermometer, thermostat, pipe network, insulator, electric cables e.t.c.

The cleaned rice is packed into the perforated crates. Cold water is poured above the rice paddy in the crates and the equipment is switched on. When the water is heated to about 60-70^{0}c, the equipment is switched off and left for about 3 hours (NCRI, 1992).

The gas parboiler is made up of black plates while the steamer is of galvanized iron sheet. It comprises gas combustion chamber, steamer cylinder, high pressure regulator, pressure release valve e.t.c. The water inside the boiler is heated to about 60-80^{0}c, after which the burner is turned off. The hot water valve is opened to allow it to flow into the steamer. This is closed after it has completely covered the rice paddy crates in the steamer. The equipment is left closed for about 5-6 hours before draining off the water from the steamer (NCRI, 1992).

CHAPTER THREE

3.0 DESIGN OF HEATED PEBBLES RICE PADDY PABOILER

3.1. DESIGN OF ELECTRIC HEATER.

On the basis of the parameters (ideal) established in the experiment of rice paddy parboiling using heated pebbles method (Chukwu, 1991, 1999), it was calculated that about 0.64GJ of energy would be utilized in parboiling 1 tonne of paddy in 1 hour with heated pebbles process.

Therefore, let the energy used for parboiling rice paddy per tonne per hour using heated pebbles method be ε_c.

$\varepsilon_c = 0.64 \times 10^9 \, Jt^{-1}h^{-1}$

1 tonne = 1000kg

$\varepsilon_c = 0.64 \times 10^6$ KJ/1000kg/hour

$\varepsilon_c = 0.64 \times 10^3$ KJ/kg/hour

$= 6.4. \times 10^5$ J/kg/hr.

This value represent the energy in Joules required to parboil 1kg of rice paddy in 1hour.

For the purpose of this design, the maximum amount of rice paddy chosen to be parboiled using heated pebbles method was 20kg. This quantity of paddy was simply chosen based on the fact that the heaters to handle large quantity of rice paddy are not easily available.

Now, the energy required to parboil 20kg of rice paddy using heated pebbles method in 1 hour will be

$\varepsilon_q = Q \times \varepsilon_c$ ________ (1)

Where Q = Quantity of paddy to be parboiled.

$\varepsilon_q = 20 \times 6.4 \times 10^5$.

$= 1.28 \times 10^7$ J/hr.

= 12.8 MJ/hr.

Therefore, the heater element that can produce this energy under 1hour is then designed for as follows:

Let the energy heater element produces per second be ε_q, so that in 1hour will produce 12.8 MJ.

$$\therefore \varepsilon_p = \frac{12.8 \times 10^6}{60 \times 60} \text{ J/s}$$

$$= \frac{1.28 \times 10^7}{60 \times 60} \text{ J/s}$$

= 3555.5556W

$\simeq$ 3556W

To take care of loss(es) during the heating process, a 3600W heater is selected.

A 3600W heater generates 3600J per second.

In 1 hour it will generate 3600J x 3600J = 1.296×10^7J.

Let the energy loss in Joules during the heating process be ε_L.

Then $\varepsilon_h = \varepsilon_q + \varepsilon_L$ ________ (2)

Where ε_h = Required energy to parboil 20kg in 1hour in (J).

ε_L = Energy loss during heating process in (J). It is energy assumed to be lost.

Given that:

$\varepsilon_q = 1.28 \times 10^7 J$

$\varepsilon_h = 1.296 \times 10^7 J$

From equation 2,

$\varepsilon_L = 1.296 \times 10^7 - 1.28 \times 10^7$

$= 1.6 \times 10^5 J$

Percentage of energy assumed to be lost during heating process (PhL) is then calculated as follows:

$$PhL = \frac{\varepsilon_L}{\varepsilon_h} \times 100 \quad \text{\_\_\_\_\_\_\_\_(3)}$$

$$PhL = \frac{1.6 \times 10^5}{1.296 \times 10^7} \times 100\%$$

$$= 1.23457\%$$

Let's derive simple equations so that the heater rating to be selected can be easily known when parboiling time is to be reduced.

Let:

ε = The energy required to parboil a given quantity of rice paddy using heated pebbles method.

Q = The quantity of rice paddy for parboiling.

t = Parboiling time.

(i) Hence, for a given quantity of rice to be parboiled,

if ε increases, parboiling time t decreases and if ε decreases, parboiling time t increases.

(ii) Also, for a given constant ε (energy required for parboiling),

if Q increases, parboiling time t increases and if Q decreases, parboiling time t decreases.

From the above, the following can be concluded:

(i) ε (Energy required for parboiling) is inversely proportional to the parboiling time t, ($\varepsilon \propto {}^{1}/_{t}$).

(ii) Q (quantity of rice paddy for parboiling) is directly proportional to the parboiling time t, ($Q \propto t$).

Hence, combining these two variations together gives a joint variation.

$$\varepsilon \propto \frac{Q}{t}$$

$$\varepsilon = K\frac{Q}{t}$$

Where K = constant of proportionality.

Now, on the basis of the parameters (ideal) established in the experiment of rice paddy parboiling using heated pebbles method (Chukwu 1991, 1999), it was calculated that about 0.64 GJ of energy would be utilized in parboiling 1 tonne of paddy in 1hour with heated pebbles process. Hence, based on this, the constant of proportionality (K) could be determined.

$$\varepsilon = K \frac{Q}{t}$$

Where K = constant of proportionality

Given that $\varepsilon = 0.64GJ$.

$= 064 \times 10^9 J$

$Q = 1$ tonne

$= 1000kg$

$t = 1hour$

Substituting these values into the equation above gives:

$$0.64 \times 10^9 = K \times \frac{1000}{1}$$

$$K = \frac{0.64 \times 10^9}{1000}$$

$$= 6.4 \times 10^5 \text{ Jhr/kg}$$

$$\therefore \varepsilon = 6.4 \times 10^5 \frac{Q}{t} \quad \text{\_\_\_\_\_\_\_\_(4)}$$

Where ε = Energy required to parboil a given quantity of rice paddy in (J).

Q = Quantity of rice paddy to be parboiled using heated pebbles method in (kg).

t = Parboiling time in (hours)

K = Constant (Jhr/kg).

If Q = 1 tonne = 1000kg and t = 1hour then ε = ?

From equation (4),

$$\varepsilon = 6.4 \times 10^5 \times \frac{1000}{1}$$

$= 0.64 \times 10^9 J$

$= 0.64$ GJ

Also, If Q = 20kg and t = 1hour then ε = ?

From equation (4),

$$\varepsilon = 6.4 \times 10^5 \times \frac{20}{1}$$

$= 1.28 \times 10^7 J$

(i) Given Q = 1000kg and t = 1hour, then from the equation 4 above ε = 0.64 GJ. The power of the heater to be selected to deliver the required energy is then calculated using equation (5).

$\varepsilon = Pt$ ________ (5)

When ε = Required energy in (J)

P = Power of the heater in (W)

t = Operating time of heater in (sec.)

Given that $\varepsilon = 0.64 \times 10^9 J$ and t = 1hour = 3600sec.

From equation (5),

$$P = \frac{0.64 \times 10^9}{3600}$$

$= 1.777777 \times 10^5 W$

$= 177.777$ KW

(ii) Given Q = 20kg and t = 1hour, then from the equation (4) above $\varepsilon = 1.28 \times 10^7$J. The power of the heater to be selected for this energy required is then calculated using equation (5).

Given that $\varepsilon = 1.28 \times 10^7$J and t = 1hour = 3600 sec.

$$\therefore P = \frac{1.28 \times 10^7}{3600}$$

$$= 3555.5556W$$

$$\simeq 3556\ W$$

(iii) If Q = 20kg and t = 30 min = ½ hour, then from the equation 4 above

$$\varepsilon = 6.4 \times 10^5 \times \frac{20}{0.5}$$

$$= 2.56 \times 10^7 J.$$

The power of the heater to be selected for this energy required is then calculated using equation (5)

$$\therefore P = \frac{2.56 \times 10^7}{1800}$$

$$= 14222.2222W$$

$$\simeq 14.222KW$$

Hence, a heater of power approximately 14.222KW cannot be selected because it is not easily available. Therefore, a heater of power approximately 3556W obtained in (ii) above is then selected.

3.2. DESIGN OF METAL TRAYS

For the purpose of this design, the total mass of rice paddy to be parboiled (M_c) is 20kg.

On the basis of the data obtained (Chukwu 1991, 1999), "a heated-pebble temperature of 200^0c, pebble-paddy ratio of 20 and a paddy pebble exposure of 10 seconds were found to produce optimum results with 20% increase of head rice yield (recovery) over the control (paddy parboiled by the traditional method)".

Hence, a pebble-paddy ratio of 20 will be used in this design.

As denoted above $M_c = 20$kg

Bulk density of rice paddy $\rho_c = 320.37$ kg/m^3 (Mohsenin, 1978)

Therefore, the volume of rice paddy to be parboiled denoted as V_c is given as:

$$V_c = \frac{M_c}{\rho_c} \quad \text{\_\_\_\_\_\_\_\_(6)}$$

$$= \frac{20 \text{ kg}}{320.37 \text{kg/m}^3}$$

$$\therefore \quad V_c = 0.062427817 \text{m}^3$$

The electric oven is designed to be a tray loading type. Therefore the volume of pebbles to be heated denoted as V_p is then given as:

$$V_p = \frac{V_c}{20} \quad \text{\_\_\_\_\_\_\_\_(7)}$$

$$= \frac{0.062427817}{20}$$

$= 0.00312139m^3$

$= 3.12139 \times 10^{-3}m^3$

Let the length of the tray L= 350 mm

Breadth of the tray B= 250mm

Area of tray A = L x B

$= 0.35m \times 0.25m$

$= 0.0875m^2$.

The pebbles are to be loaded to a thickness of 20mm and denoted as x.

We can calculate for the volume of each tray denoted as V.

$V = A x$ ________(8)

Where x = Thickness of the pebbles.

A = Area of tray.

$V = 0.0875m^2 \times 0.02m$.

$= 0.00175m^3$/tray.

$= 1.75 \times 10^{-3}$ m_3/tray.

Therefore, the dimensions of the metal tray are:

Length L = 350mm.

Breadth B = 250mm

Depth H = 20mm (Fig. 4).

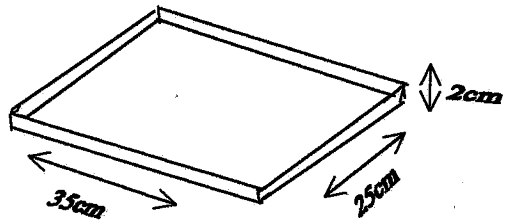


Fig. 4. Diagram showing the dimensions of the metal tray.

The number of sets of trays (n) that are to be mounted in the electric oven is determined from equation (9).

$$n = \frac{\text{Total volume of pebbles loaded in the oven}}{\text{volume of pebbles/tray}} \quad \frac{V_p}{V} \qquad (9)$$

From the above calculations,

$V_p = 0.00312139m^3$

$V = 0.00175m^3/tray$

$$\therefore n = \frac{0.00312139m^3}{0.00175m^3/tray}$$

$= 1.783651429$

$\simeq 2$

For this design, 2 sets of trays are to be mounted in the electric oven.

The capacity of the electric oven is calculated from equation (10).

That is the total volume of pebbles that can be loaded in the electric oven denoted as V_T is given as:

$$V_T = n \times L \times B \times H \qquad (10)$$

Where n = No. of sets of trays in the electric oven

L = Length of metal tray (m)

B = Breadth of metal tray (m)

H = Depth of metal tray (m)

$V_T = 2 \times 0.35 \times 0.25 \times 0.02$

$= 0.0035 m^3$.

Total mass $M_T = V_T \times \rho_p$ __________(11)

Where ρ_p = Density of pebbles

3.3. DESIGN OF BASIN FOR PEBBLES-PADDY EXPOSURE

Since the heated pebbles and rice paddy are to be transferred into this basin for exposure, its volume denoted as V_b will be the summation of capacity of electric oven V_T and total volume of rice paddy to be parboiled V_c.

$V_b = V_T + V_c$ ___________ (12).

From the above calculations; $V_T = 0.0035 m^3$.

$V_c = 0.062427817 m^3$

$\therefore V_b = 0.0035 + 0.062427817$

$= 0.065927817 m^3$.

As specified, the basin for pebbles-paddy exposure has a base of 30cm size and shall have the volume as calculated above to be $0.065927817 m^3$.

3.4. DESIGN OF OVEN CASING

The electric oven casing consists of walls, which enclosed the entire system. For the purpose of this design the length (L), width (B) and the height (H) of the oven casing wall are expressed as follows:

$L = S_i + L_t + S_r$ ____________ (13)

Where L = Length of the oven casing (mm).

S_i = Length of the space between the tray and left of the oven casing wall (mm).

L_t = Length of the tray

= 350mm.

S_r = Length of the space between the tray and right of the oven casing wall (mm).

In this case, $S_i = S_r$

$\therefore\ L = 2S_i + L_t$ _________ (14)

$B = S_f + B_t + S_b$ ________ (15).

Where B = Width of the oven casing (mm).

S_f = Length of the space between the tray and front of the oven casing wall (mm).

B_t = Breadth of the tray

= 250mm.

S_b = Length of the space between the tray and back of the oven casing wall (mm).

In this case, $S_f = S_b$.

$\therefore\ B = 2S_f + B_t$ ___________ (16)

$H = S_t + nh_t + xS + S_o$ __________(17)

Where H = Height of the oven casing (mm).

S_t = Length of the space between the first tray and top of the oven casing

wall (mm).

n = No. of sets of trays in the electric oven.

= 2

h_t = Depth of tray.

= 20mm.

S = Equal distance between trays.

x = No. of equal distance between trays.

S_o = Length of the space between the last tray and oven casing bottom wall (mm).

But x = (n-1) and in this case, $S_t = S_o$.

$\therefore H = 2S_t + nh_t + (n-1) S$ ______________(18).

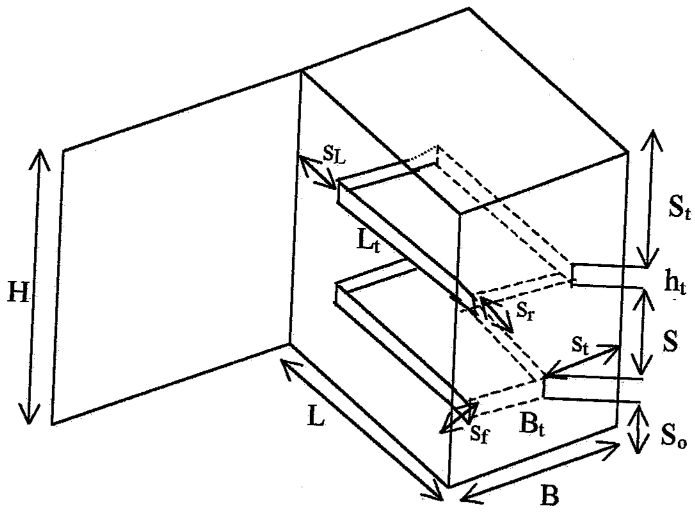


Fig. 5. Diagram showing the dimensions of the oven casing.

From equation (14),

$L = 2S_i + L_t$.

Let S_i be equal to 25mm to enable slot-in of length of metal tray in the oven casing.

$\therefore\ L = 2 \times 25 + 350$

$= 400mm$.

From equation (16),

$B = 2S_f + B_t$

Let S_f be equal to 75mm to enable slot-in of breadth of metal tray in the oven casing.

$\therefore\ B = 2 \times 75 + 250$

$= 400mm$

From equation (18),

$H = 2S_t + nh_t + (n-1)\ S$.

Let S_t be equal to 130mm to enable heat flow at the top and bottom of the electric oven and let S be equal to 150mm.

$\therefore\ H = 2 \times 130 + 2 \times 20 + (2-1) \times 150$

$= 450mm$.

Length L = 400mm.

Width B = 400mm.

Height H = 450mm.

3.5. DESIGN OF INSULATOR

The thickness of the insulation wall is a major factor to be considered in the control of heat loss in any heat production chamber. Depending on the thermal conductivity of the insulating material, the heat loss from a chamber can be controlled by varying the thickness of the insulating material.

The insulating material to be used in this design is particle board (fibre board) with thermal conductivity of 0.052 $JM^{-1} S^{-1} C^{-1}$ (Earle, 1992). The rate of heat loss here is to be maintained at less than 1.2%. The rate of heat loss is given by Forgers equation.

$$q = UA\Delta t \qquad (19)$$

When q = Rate of heat loss, Js^{-1}

A = Area of insulation wall, m^2.

Δt = The temperature difference between the medium.

U = The overall heat transfer coefficient otherwise called overall conductance of the combined layers.

$$A(\Delta t) = q\left(^{1}/_{u}\right) \qquad (20)$$

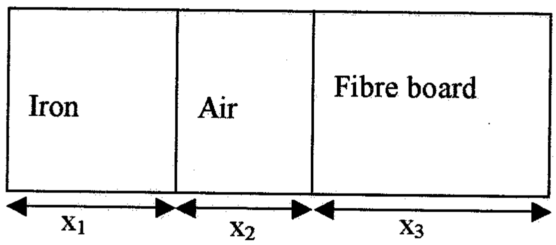


Fig. 6. Electric oven wall thickness.

$$\frac{1}{u} = \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3}. \qquad (21)$$

x_1, x_2 and x_3 represent the thickness of the layers making the insulation wall, that is inner iron sheet, air and fibre board respectively. k_1, k_2 and k_3 are the corresponding thermal conductivities of the layers.

$k_1 = 45\ JM^{-1}\ S^{-1}\ {}^0C^{-1}$.

$k_2 = 0.0260\ JM^{-1}\ S^{-1}\ {}^0C^{-1}$.

$k_3 = 0.052\ JM^{-1}\ S^{-1}\ {}^0C^{-1}$.

Let x_1 = 3mm thick = 0.003m

x_2 = 20mm thick = 0.02m

x_3 = 10mm thick = 0.01m

From equation (21),

$$\frac{1}{u} = \frac{0.003}{45.00} + \frac{0.02}{0.0260} + \frac{0.010}{0.052}$$

$$\frac{1}{u} = 0.961605128$$

$u = 1.03927898$

∴ A = Area of grate wall facing the furnace.

$= 0.4 \times 0.45 = 0.18m^2$

$\Delta t = t_1 - t_2$.

Where t_1 = Inside temperature = 205^0c

t_2 = Outside temperature = 24^0c.

$\Delta t = (205 - 24)^0c = 181^0c$.

From equation (19),

$q = 1.03927898 \times 0.18 \times 181$

$q = 33.85970917 \ Js^{-1}$

$= \frac{33.85976917}{1000} \times 3600$

$= 121.894953$ KJ/h.

The percent heat loss (PhL) can be calculated from equation (16).

$$PhL = \frac{q}{\varepsilon_q} \times 100 \qquad (22)$$

But from the above $\varepsilon_q = 1.28 \times 10^4$ KJ/h

$= 3555.555556 \ Js^{-1}$.

From equation (22),

Percentage heat loss (PhL)

$= \frac{33.85970917}{3555.555556} \times 100$

$= 0.95230432\%$

or

$PhL = \frac{121.894953}{1.28 \times 10^4} \times 100$

$= 0.95230432\%$

$\simeq 0.95\%$

∴ The insulation material to be use is 10mm thick of fibre board since the heat loss is less than 1.2%.

3.6. SELECTION OF THERMOMETER

The selection of thermometer in this design is based on the inside temperature of the electric oven; maximum of 205^{0}c. Therefore, the selected thermometer will have the range of 0-250^{0}c for reading.

3.7. SELECTION OF WOODEN SLAB

To control uniform mixing of paddy and pebbles by turning action, wooden slab is used and is chosen based on the depth of the basin where the mixing takes place.

3.8. DESIGN OF HEATED PEBBLES-PADDY EXPOSURE SEPARATOR.

The design of the heated pebble-paddy exposure separator was motivated by the use of graded pebbles for parboiling of rice paddy which was obtained by passing the pebbles through a set screens. As specified, the graded pebbles have the sizes as the U.S sieve number between 25 and 35 (Chukwu, 1999).

The heated pebble-paddy exposure separator is designed to be made up of the following components.

(i) The screen base.

(ii) The basin bowl.

The screen base shall be made of wire mesh with the holes of 5mm diameter as the U.S. sieve number between 25 and 35.

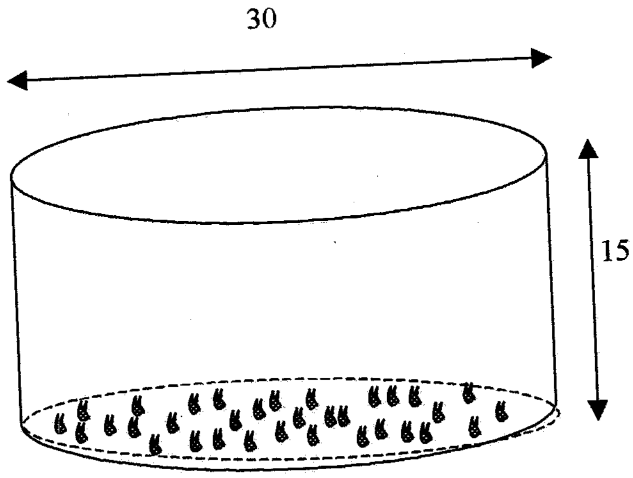


Fig. 7. Diagram showing the dimensions of the heated pebbles-paddy exposure separator

CHAPTER FOUR

4.0. TESTING PROCEDURES, RESULTS AND DISCUSSION

The design and development of the heated pebbles rice paddy parbroiler was carried out in this study. The testing was carried out in order to verify the design claims, such as developing an equipment for parboiling of paddy that uses heated pebbles with temperature of 200^0c, pebbles-paddy ratio of 20 and the achievement of the overall objectives.

4.1 TESTING PROCEDURES

It is very important to have the sequential order of how to carries out the testing of the developed rice paddy parboiler and these are as follows.

IR-8 paddy, which was previously cleaned and dried to 12-13% mc level was use in all the experiments. Paddy was soaked in tap water at room temperature (28-31^0c) for specific experimental durations as presented in Table 1.

In this experiment, 6kg of IR-8 paddy was divided into 6 equal parts, each with mass of 1kg. Each mass of 1kg was oven dried using International Standard of temperature (105^0c) for 24hours. The final mass after oven dried was 0.85kg.

$$\% \text{ of water removed} = \frac{1.00 - 0.85}{1.00} \times 100$$
$$= 15\% \text{ (wb)}$$

Each 1kg of paddy was dried to m.c of 15% (wb) (control).

Table 1. Soaking time increase in Mc of IR-8 variety at room temperature.

Soaking Time (hr)	Initial Mass Of Rice Paddy (M_0) Kg	Final Mass Of Rice Paddy (M) Kg	Mc % (wb)
6	1.00	1.29	22.50
12	1.00	1.33	25.00
18	1.00	1.39	28.00
24	1.00	1.43	29.50
30	1.00	1.43	30.00
36	1.00	1.45	31.00

Note: $MC = \frac{(M - M_0)}{M} \times 100\%$

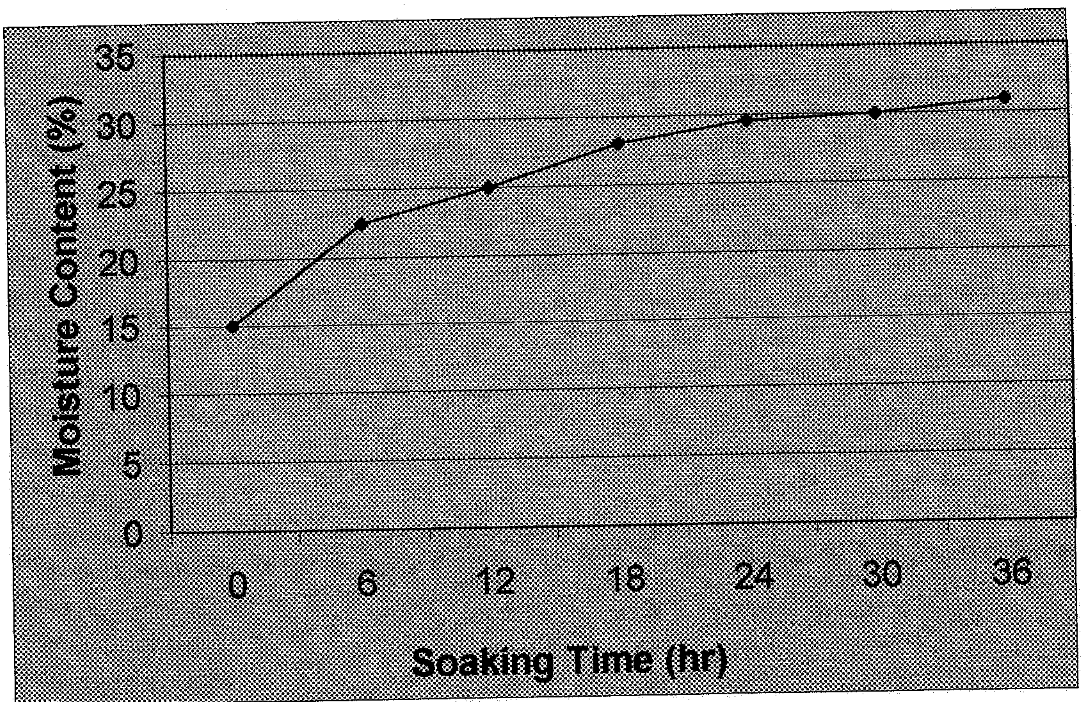


Fig. 8. Soaking time and increase in mc graph (IR-8 variety, at room temp.).

Figure 8 indicates that water intake capacity of the IR-8 paddy tapers off after 24 hours of soaking at room temperature. Further soaking does not increase moisture level substantially. Soaking at higher than ambient temperature was not investigated in this study, as it would increase energy requirements and therefore costs. Results of the soaking experiment indicate that a 24h soaking period at ambient temperature is adequate for heated pebble parboiling Fig 8. The 24h soaking period is also convenient as it involves an overnight soaking.

After soaking, the surface water was removed by spreading paddy on jute bags for 10-20 minutes at room temperature.

The pebbles used were washed with water to remove dirt and dust particles and was then dried in the sun. The pebbles were also passed through a set of screens to retain particles. Hot, washed and graded pebbles were easy to separate during experiments from paddy grain by simple screening.

The required amount of pebbles was heated to a desired temperature in an electric over in metal trays. Hot pebbles were quickly transferred into a 30cm size basis. After the heated pebbles were transferred to the basin, a specific quantity of soaked paddy was quickly poured into the basin and allowed to mix with pebbles for the desired experimental duration. The paddy and pebbles were uniformly mixed by turning action with a wooden slab.

A drop of 20^0c in pebble temperature was observed when heated pebbles were to be transferred from metal trays to the basin. To compensate for any errors resulting from this temperature drop during the experiments, the basin was placed on a sheet of bedding form to reduce heat loss through the bottom to a minimum. Moreso, pebbles were heated to 20^0c higher than the required experimental temperature. This enables the required temperature range to be achieved after some drop in the pebble temperature.

As soon as the splinting of the paddy occurs after the required paddy and pebbles exposure time was achieved, the paddy grains were separated from the hot pebbles by manual shaking in the traditional sieve. The still-hot pebbles were placed back into the oven for the next experiment. The temperature of the heated pebble grain temperature was recorded at the end of each exposure. The exposed paddy sample was immediately placed in a bottle and the grain temperature was recorded. The mc of the exposed grain was determined after it had cooled for 10-20 minutes at room temperature. The treated paddy samples were spread for 24hrs for tempering in a room at 24-26^0c temperatures and a humidity of about 60-65%. At the end of the tempering period the mc of the paddy was again recorded.

Treated paddy samples of each 1kg were hulled and the number of the total milled rice (mixture of brokens and head rice) was recorded. The brokens are the kernels that are less than ¾ full size. The head rice and brokens were separated by manual picking and the number of brokens and head rice were separately recorded. The head rice sample and the number of the total milled rice sample were used to determine the head rice recovery.

4.2. RESULTS AND DISCUSSION

TABLE 2: Head Rice Recovery at Different Heated Pebble Exposure Time (at pebble temperature of 200^{0}c and pebble-paddy ratio of 20)

NOTE: $$HRR = \frac{HR}{TMR} \times 100\ \%$$

Soaking Duration (hr)	Exposure Time (s)	Head Rice Recovery
0	0	(%) 77 (control)

Soaking Duration (hr)	Exposure Time (Min)	Heated Pebbles-Grains Exposure Temperature (^{0}c)	Exposure grains Temperature (^{0}c)	Number of Total Milled Rice (TMR) (grains)	Head Rice (HR) (grains)	Head Rice Recovery (HRR) (%)
6	2	32	28	800	176	22
	3	33	28	800	144	18
12	2	32	28	800	280	35
	3	30	28	800	240	30
18	2	30	28	800	456	57
	3	31	29	800	320	40
24	2	33	29	800	544	68
	3	34	29	800	576	72
30	2	31	29	800	608	76
	3	30	29	800	520	65
36	2	32	30	800	576	72
	3	30	28	800	632	79

It appears that the difference in head rice yields, when paddy is soaked for 24 or 36 hours is small. Paddy soaked for less than 12h however, results in a substantially lower head rice yield than 77% recovery of the control sample. It seems that whenever paddy was soaked for 18h or more, higher head yields were obtained by exposing it to the heated-pebbles process. It can be concluded that 30% paddy moisture is the minimum for parboiling with the heated pebbles method. This is somewhat higher than the results obtained by Khan et al (1970) and Arboleda (1973) at IRRI. Perhaps varietal difference may be the reason for the difference in the results obtained in the two studies. Khan et al (1970) and Arboleda (1973) used IR-36 variety while IR-8 paddy variety was used in this study.

One could safely conclude that to achieve the 30% grain mc level a 24h soaking period is sufficient. When paddy was soaked for 24 hours or more and was exposed to 200^0c heated pebble for 2minutes, highest head rice yield were obtained. When paddy was soaked for 36 hours and was exposed to 200^0c heated pebbles for 2mins, highest head rice yield of 79% was obtained. This is 2% greater than that obtained for the control sample which is 77%.

As explained by Arboleda (1973), the two factors in this process of parboiling the high rate of heat transfer into the grain and the presence of a critical level of moisture in paddy are essential for gelatinization of starch in rice kernel. It was however, not verified whether, with pebble temperature of less than 200^0c and paddy moisture level of less than 25%, proper gelatinization of starch may still occur. From Table 2, it can be concluded that the optimum soaking time, exposure, duration and heated pebble temperature to achieve maximum head rice yield with this method are 36 hours, 3mins and 200^{0}c respectively.

The pebble paddy ratio was not adequately investigated in this study as all experiments were performed with a pebble-paddy ratio of 20. The experimental basin used to turn the paddy-pebble mixture was not insulated and a considerable amount of heat was controlled during the experiments. During the 2mins. exposure at 200^{0}c heated pebbles, paddy moisture was reduced by about 10-13% from the initial 30% level. The samples were subsequently kept in a room at 24-26^{0}c for about 24h tempering. At the end of the tempering period, paddy had reached the 12-14% equilibrium moisture level which is the optimum level for milling. Thus there is no need for any hot air drying of paddy, after the paddy has been parboiled with the heated pebbles method.

It seems that there is considerable scope for developing a continuous parboiling heated pebbles operation based on a 48hr cycle, i.e 24hr for soaking and 24hr for tempering. This method offers considerable possibilities for an energy-efficient and reduced-cost method for small scale parboiling process.

4.3. EFFICIENCY OF HEATED PEBBLES-RICE PADDY PARBOILER

The efficiency of this parboiler depends on the following factors:-

1. The moisture level of the soaked grain or soaking duration.
2. The pebble-paddy exposure time.

Efficiency of the parboiler is therefore given as

$$\eta = \frac{\text{Output (0)}}{\text{Input (I)}} \times 100$$

O = Quantity of rice paddy parboiled

I = Total quantity of rice paddy feed into parboiler.

For 24hours soaking of 1kg of paddy which was exposed to 200^{0}c heated pebbles for 3mins. about 504 grammes of paddy was parboiled.

$$\eta = \frac{504}{800} \times 100 = 72.0\%$$

Also, for 36 hours soaking of 1kg of paddy which was exposed to 200^{0}c heated pebbles for 3mins. about 632 grammes of paddy was parboiled.

$$\eta = \frac{632}{800} \times 100 = 79.0\%$$

CHAPTER FIVE

5.0 COST ANALYSIS OF THE HEATED PEBBLES - RICE PADDY PARBOILER.

In this chapter, the cost analysis of the equipment is carried out. It is based on the present market value of the materials used for the development of the equipment since from conception. The availability of materials used were available locally, though better quality of work could be achieved with precise machine or certain parts. Therefore, the availability of the materials for development of the equipment, cheap electricity and the fact it is an equipment that would meet one of the most important needs of our local farmers, have made the belief that is quite economical acceptable.

The table below shown the consisting of the materials at their present market value.

Part List Chart for Costing the Heated Pebbles Rice Paddy Parboiler

Part No	Description	Quantity	Unit Cost ₦ K	Total Cost ₦ K
1.	3mm thickness sheet metal (gauge 20).	1	1600.00	1600.00
2.	10mm thickness particle board (gauge 20).	1	900.00	900.00
3.	20mm x 20mm square pipe	1	400.00	400.00
4.	3600W electric heater	1	800.00	800.00
5.	5mm diameter wire gaze (½ yard)	1	800.00	800.00
6.	Thermometer.	1	500.00	500.00
7.	Thermostat	1	100.00	100.00
				5100.00

LABOUR COST

Part No	Description of Work	Quantity	Unit Cost ₦ K	Total Cost ₦ K
1	Production of electric oven casing	1	600.00	600.00
2	Production of metal trays	2	100.00	200.00
3	Production of separator	1	200.00	200.00
4	Production of Basin	1	200.00	200.00
5	Insulating the electric oven casing	1	900.00	900.00
6	Insulating the basin with ceramic		700.00	700.00
7	Electrical fittings e.g cables & fuses		200.00	200.00
				3,000.00

Total material and Labour cost = ₦5,100.00 + ₦3,000.00

= ₦8,100.00

Total Cost of the Heated Pebbles Rice Paddy Parboiler = ₦8,100.00

5.1. ECONOMIC ANALYSIS OF THE RICE PADDY PARBOILER.

In analyzing any investment economically, the true worth of the investment is regarded as how mush income it will generate and how soon after the original capital outlay (Chukwu, 1987).

Therefore it is desirable that an investment generates large share of total income in the early years of its life. For the Heated Pebble Rice Paddy Parboiler the income is viewed as saving, accruing from;

1. Choosing electricity as a source of energy instead of other conventional energy sources.
2. The opportunity offered farmers to produce rice crops at the time when maximum yield is possible without considering the problem associated with high cost of parboiling after harvest.

To completely analyse the Heated Pebble Rice Paddy Parboiler economically therefore, data are to be collected for at least a period of one year to know what savings could be made using this type of parboiler or any other type in a farm for wide variety of crops grown within the period of maximum production (agronomical period). Morever, the efficiency of the parboiler is a major factor especially when calculating the pay back period.

Therefore, within the limit of time and the completion time of this project, a full economic analysis could not be made.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

With only welding of a few parts left, the design and development of a heated pebbles rice paddy parboiler has been made. As could be seen in this report, it involved;

1. The consideration of electricity as a source of energy.
2. The design of electric heater.
3. The design of metal trays.
4. The design of oven casing.
5. The design of basin
6. The design of insulator

The rice paddy has a capacity of parboiling 20kg of rice paddy per batch and uses electricity as a source of energy at a rate of 3600 Joules/sec and rise the temperature of pebbles to 200^0c for period of about 45minutes.

The development of this project is cheap, low energy consumption in parboiling and combined the gelatinization (steaming) and drying operations in the three basic operations of parboiling and hence it is recommendable to local farmers because the cost of its construction is within their reach.

Strict compliance to the stipulated temperature (200^0c), soaking period (24-36 hours) of moisture content 28% or more and pebbles-paddy ratio of 20 are very important in this system of parboiling for each parboiling operation will ensure quality parboiled rice.

Finally, parboiling of rice is very important because the broken grains are eliminated during milling and make change in cooking quality.

6.2 RECOMMENDATIONS

If required funds and materials could be provided, more improvement can be made on this project and can be made to parboil large scale of rice paddy. The construction of this project needs multiplication, such that those in rural areas who have been encouraged into mechanized large-scale rice production, can have a device that can parboil their rice with less effort, low cost and energy consumption and high efficiency. This can only be achieved through governmental support either financially or otherwise.

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