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Design and Construction of an Improved Rice Parboiling Machine

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Abstract: ***The rice parboiling machine is used for parboiling of paddy rice before milling. The machine is made to have five main units which includes the water supply tank, boiler, energy unit, steamer and the soaking unit. The existing parboiling machine has a production capacity of 5kg per batch in every five hours and has no provision for soaking the paddy. In the traditional parboiling process, paddy is soaked in water for 3 days, steamed and dried before milling, and the rice usually give off bad odour due to fermentation as a result of prolonged soaking. The modified rice par boiling machine is designed to par boil about 400kg per day which will take not less than 5 days to parboil traditionally.***

Keywords: Rice, parboil, milling, boiler steamer, soaking

1. Introduction

Rice (oryza sativa) is a cereal crop which is cultivated in swampy fields of human/animal consumption. It comes third to wheat and maize in terms of world cereal production, but nevertheless being rated second to wheat in the carbohydrate content and stands as a principal feed crop for over half of the world population. The principal growing areas are in India, Bangladesh, China, Japan, South Africa, but smaller quantities are grown in Africa, Italy, Spain, Brazil, United State and Chile (John.1981).

More than 8,000 botanically different rice varieties are known, but by and large they fall into two main type of group. The Indica varieties mostly long-grained and are harder while the Japonica varieties are shorted grained and are less hard - a variety commonly found in African countries (John, 1981).

When harvested from field, it is threshed and after which the grain is known as paddy rice (sometimes referred to as rough rice) which consist of about 20% hull sand 80% grains. The hull consists of two half leaf like structure i.e. lamina and paleainter locked by enclosing the bran layers which are removed by abrasion and finally, the naked grain known as white rice has been processed (John,1981).

Parboiling of rice paddy involves soaking the paddy in water or hot water to hasten the soaking rate. Thereafter, steamed and later dried to a moisture content of about15% by mass before milling operation.

The poor quality of a locally produced rice is causing a serious draw back in the Nigerian economy.

ForeignriceisoneofthefooditemswhichtheFederalGovernmenthasexpressedseriousconcern for the rate at which it is imported for consumption at the expense of locally produced one. The Government considered that as a threat for our economy and therefore solicit for patriotic citizen or even foreign bodies to come and establish factories to improve the quality of our locally produced rice.

Generally, the two major factors influenced a quality outturn from milling are the degree of ripeness and the parboiling process. A thorough investigation and analysis was carried out and it was discovered that the traditional parboiling process practiced contributed a lot to the poor physical qualities of our indigenous rice. The process involves soaking rough rice or rice paddy over right in water for three (3) days at ambient temperature followed by boiling or steaming the steeped rice at 100°C to gelatinize the starch and then sun dried before milling operation. This result in soul odour due to fermentation for its longer time of soaking period, and greater percentage of broken grain on milling operation for not drying to optimal moisture content before milling operation.

The development is aimed at elimination of unwanted odour and reduction in soaking period by the use of hot water to soak at 60°C below the starch gelatinization temperature, steamed at optimum temperature and pressure; thereafter to be dried under shade to a moisture content of 15% by mass.

The existing traditional parboiling machine has a problem with the control of pressure and temperature generated in the system. This result in subsequent failure of the system while in operation.

The rate of the above problem, we have incorporated an automatic pressure relief valve to operate base on ($10^5 N/m^2$and100°C) at which the hull of the paddy begins to split. Not only that, but also to safeguard the cylinder from failure through explosion.

Another problem encountered with the existing machine is its low capacity and subsequent less production (5kg every 5 hours) compared to the traditional method in place.

These we have tackled by using bigger size cylinder tank, boil energy unit, and also by incorporating a soaking cylinder (40kg per batch) which is four time bigger in size than steamer so as to ensure continuous production of about l0kg/hr of steamed paddy.

The project is aimed at developing an improved rice parboiling machine, the objectives is to produce a rice

parboiling machine that is simple in construction and easy to operate using locally available materials so that it will be affordable to an average farmer.

Therearemanyadvantagesinriceparboiling.Itreducesgrainbreakageduringmilling,greatly improve the vitamins and nutritional value of the grain, enhance the cooking and eating qualityof the rice and reduces insect infection during storage. In the traditional parboiling process, due to some problems such as fermentation as a result of prolonged soaking produce soal odour, poor physical quality of milled rice etc. The development is aimed at eliminating of unwanted odour, reduce soaking period, reduction of heat loss and greatly improvement in terms of percentage of breakage during milling operation.

This project is done to parboil our local rice varieties (short grain rice) the construction of the machine was made using locally available materials.

2. Methodology

2.1 Design of the Component

The following show the size, type, shape and material used for each component in this project

2.2.1 Water Tanker

A tank with a capacity almost twice that of boiler is constructed with the pipe outlet at the base and positioned on its stand above the boiler so as to feed the boiler by gravity. Between theboiler and the tank is a non-return valve and a gate valve. When the gate valve is fully opened, the velocity of the flow is proportional to the square roof of the heard producing (Torricelli Cheorem),

$$F = \sqrt{2gHg} \quad (1)$$

The theoretical discharge

$$QTH = AV\sqrt{2gH} \quad (2)$$

The Actual discharge

$$QTH = 0.855\ AV\sqrt{2gH} \quad (3)$$

Where A = The outlet area G = acceleration
H = Head producing the flow

2.2.2 Energy Unit

Wood charcoal is used for its cheapness and safety in terms of hazard. A complete combustion occurs when the stoichoimetric ratio of carbon to air is maintained. The combustion of carbon begins when the ignition capacity i.e 400°c is reached with the presence of oxygen. (Yunus,1992). $C + O_2 + 3.76N_2 \rightarrow CO_2 + 3.7N_2 + Heat$

$$\text{Air-fuel ratio (AF)} = \frac{\text{Mass of fuel } (M_{air\ fuel})}{\text{Mass of fuel } (M_{fuel})} \quad (4)$$

The mass M of a substance is related to the number of moles N through the relation: M = MN (Yunus, 1992). M = molar mass, and N = number of moles Therefore, for the above equation 1 1 .5kg of air is required to burn each kg of carbon during combustion to generate about 19700kj (calorific value) of heat energy to heat the boiler.

Quantity of heat sullied to the boiler Q = MC
Where M = Mass of the charcoal
C = Calorific value of charcoal

2.2.3 The Boiler Design

In engineering field, we usually come across vessels or cylinders of hemispherical ends containing fluids such as boilers. Generally, the walls of such vessels are very chin compared to their diameter. They are considered thin wall thickness to diameter doles not exceed approximately ratio 1:20 (Zhigalla, 2004).

The vessels are subjected to internal pressure due to the steam generated inside it and its walls are subjected to tensile stress. The choice of cylindrical shape with hemispheric end is made for its ability to withstand such high pressure that is liable to cause subsequent failure of the unit. Since the boiler is a cylinder with hemispheric ends and with the fact that the unit experience high stress at the ends than the cylindrical part, the hemispheric ends are made to have thicker materials than the cylindrical part.

Let t 1 be the thickness of the cylindrical portion and t2 be the thickness of the hemispheric end with the internal diameter assumed to be same for both: p be the internal pressure.

1) For cylindrical portion

$$\text{Hopp stress } (T1) = \frac{Pd}{2t1} \quad —(5)$$

$$\text{Longitudinal Stress } (T2) = \frac{Pd}{4t1} \quad —(6)$$

$$\text{Hopp strain } E1\ \frac{Pd}{2t1E}\ 2-V \quad —(7)$$

2) For hemispheric ends
The hoop stress is the same as the longitudinal stress

$$T = \frac{Pd}{2t2} \quad —(8)$$

$$\text{Hoop Stain } E2 = \frac{Pd}{2t2E}(1\text{-}V) \quad —(9)$$

Where
P = intensity of internal pressure
d = diameter of cylinder
V= Poisson's ratio
t1= Thickness of hemispheric ends
t2= Thickness of hemispheric ends
E= Young models of elasticity of material
T_1 = circumferential stress
T_2 = Longitudinal stress
E1= circumferential strain in the cylindrical portion
E2= circumferential strain the hemispheric ends

2.2.4 Steamer

A cylindrical air tight whose top cover in incorporated with a pressure relief valve is constructed. The pressure relief valve is employed to control the optimum pressure and temperature with which the hull of the paddy begins to split. This optimum condition are $10^5 N/m^2$ and $100^0 c$ analysed by food technologist (Magnus Pyke, 1981) using 0.03 m diameter of unknown weight as in figure above.

Area (A) $\pi D^2 = 7.0695 \times 10^4 m^2$
4

F = $10^5 = 7.0695 \times 10^4 m^2$

F = mg

M = $\frac{70.695}{7.2kg} = 9.81$

Where,
m = mass of the relief
g= acceleration due to gravity
A= Bottom area of the relief valve
P = Pressure exerted by the relief valve

The capacity of the targeted production per batch 7.512 x 10 – 2m3 i.e. for 50kg (20 measure) of paddy.

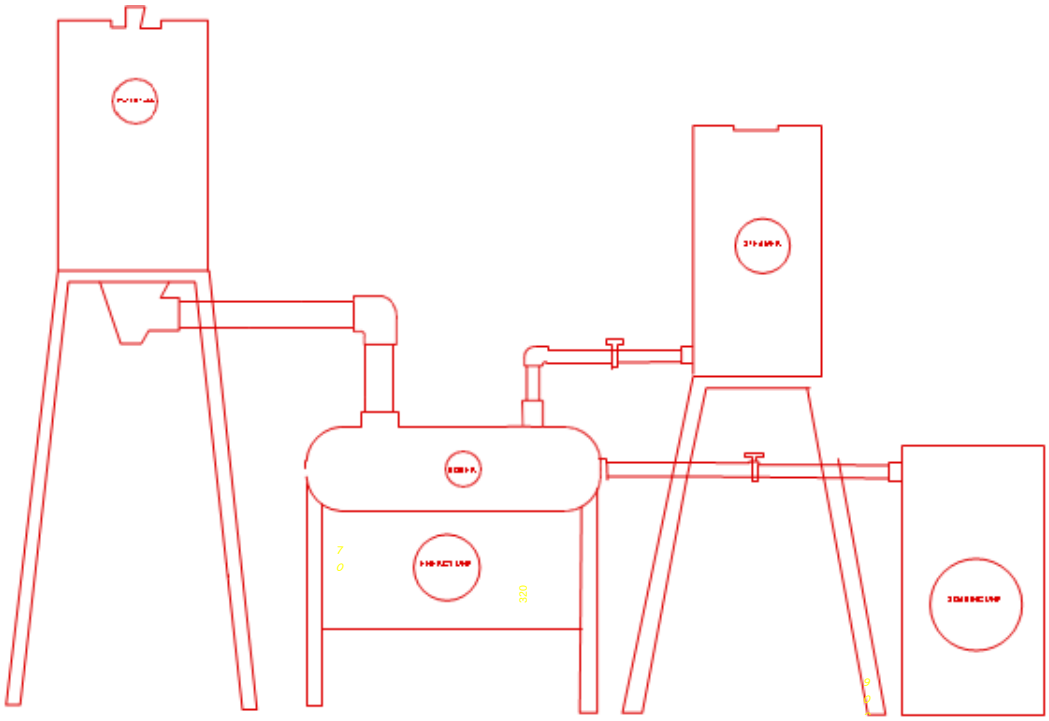

Figure 1: Improved Rice Parboiling machine

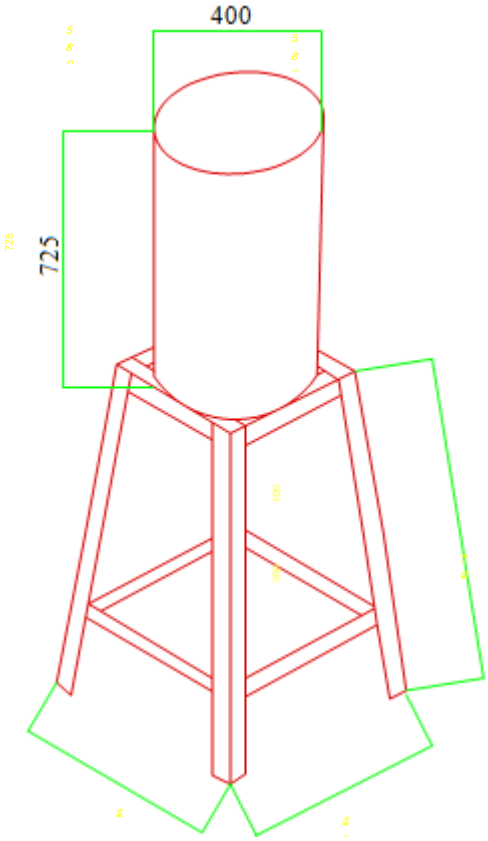

Figure 3: Boiler

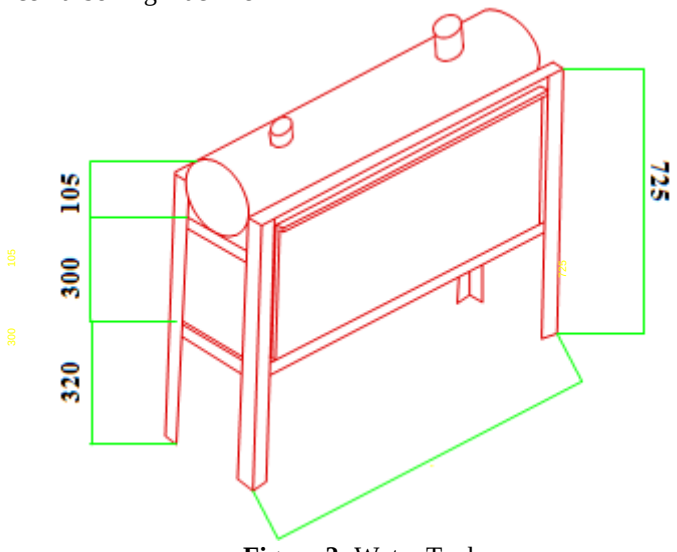

Figure 2: Water Tank

2.2.5 Soaking Cylinder

Since the production for soaking a paddy at 60°c is four hours per batch, while that of steamer is one hour to ensure a continues production, the capacity of the soaking cylinder is made at least twice bigger in capacity than the targeted steamer production per batch. A cylinder whose diameter is 0.57m and length of 0.78m will conveniently be used for soaking. The total capacity of the soaking cylinder is 1.99 x $10^{-1}m^3$ out of which 1.1024 x $10^{-}m^3$ will be occupied by the targeted production per batch of soaking which is 100kg of

paddy while the remaining 4.87 x $10^2 m^3$ will be occupied by the water used for soaking.

2.2.6 Drying Process

The steamed is to be dried to an optimum moisture content of between 13% - 15% by mass under shade on a clear concrete floor or mat let the initial weight of 10 No. of paddy = W,

Then weight of equal number of the soaked paddy=W_S Let the final weight of some number while drying = W_f Moisture content

1) Material Selection

S/No	Description	Material	Size
1	Boiler	Galvanized Steel	0.01995M^3
2	Water Tanker	Galvanized Steel	0.0321M^3
3	Soaking Cylinder	Galvanized Steel	0.087978M^3
4	Steamer	Galvanized Steel	0.0321M^3
5	Distribution Pipe	Mild Steel Coated with Zinc	160mm and 140mm
8	Elbow Joint	Galvanized Steel	¾ Inch and 1½
9	Socket	Galvanized Steel	¾ Inch

2) Result

Table 1: Parboiling Time of the Rice

Weight of Rice (Kg)	Time To Parboil(Hr.)
5	1
10	2
25	4
50	8

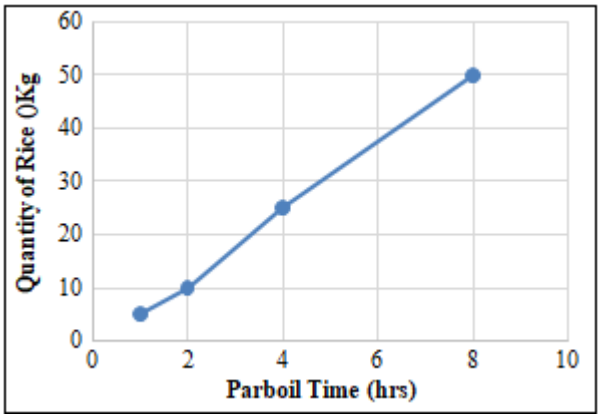

Figure 4: Variation of Time to the Quantity of Rice Parboiled.

The rice parboiling machine after construction was tested with 5kg (20measure of paddy rice and the following are processes and facts obtained.

1) **Soaking Process:** Paddy was soaked at 60°C temperature inside a soaking cylinder for the period of four hours to reduce the incidence of a flatoxin contamination during the soaking. Separation of chaff and offer foreign material from the good paddy was made by floatation.
2) **SteamingProcess:**duringsteaming,Slitresofwaterwassup pliedintotheboiler.7.5kg of charcoal was supplied into the energy unit. The were burned for the period of about 80 minutes from which it took about 20minutes before the water attained its saturation temperature (boiling point). At the end of steaming process about 1 litre of water was left unevaporated, unbound; thus 5.5kg of charcoal was expanded to convert 71itresof water into steam under atmosphere pressure.
3) **Drying Process:** After 60minutes of steaming, the steamed paddy was discharged for tempering under shade and it took about 24hours to attain 15% moisture content by mass.

3. Conclusion

Design processes are sometimes very heavy work. At times they are measure and the results obtained are not good enough, redesign are made over and over until the task is accomplished. The difficulties encountered along the run, however. Are always well rewarded with clear success attained.

It is important to note that the change design to facilitate ease of manufacture, low cost and good output in both quantity and quality and not easy to go by. Some of the problems encountered was that of the construction of a boiler with a capacity of about 371itre that will be able to steam about 200kg (80 measure) of soaked paddy i.e. steaming about 50kg per batch. The rice parboiling machine has been tested and found to be more effective with over 60% of material constituting the construction are locally contained. The machine being designed and constructed is able to increase the capacity output of parboiling about 400kg (3bags) per day which would make not less than 3days to parboil it traditionally. Not only in the area of capacity but also use less energy cost i.e. charcoal in place of firewood.

Other areas of improvement include

- Elimination of bad odour due to fermentation
- Less breakage of rice during milling operation
- Improvement of nutritional value as it retains more protein and vitamin

4. Recommendation

The parboiling machine construction was incomplete because the following parts could not be found in the market:

- Temperature gauge (metal type)
- Pressure gauge
- Water gauge

These gauges give accurate pressure and temperature dairy parboiling process for accurate result. Since they are absent in our construction, the result of the parboiling will be accurate when the machine is tested. We therefore recommend that those who wish to carry on from where we stop can get these items and fit them for efficient performance of the machine. Also to hasten the rate of water heating, a blower should be incorporated because the average atmospheric air velocity of 2.5 m/s is not enough to provide 111 5kg of air which is the stiochiometric value of the air per kg of charcoal, otherwise firewood may be used. While installing the machine of soaking cylinder with a

capacity of about 0.2m be incorporated to guarantee continues production without storage.

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