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Design and Fabrication of Porridge and Yam Flour Mixing Machine

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Abstract - Porridge and yam flour are perhaps well known by the people all over the part of Nigeria and Africa at large. A portable efficient porridge and flour mixer is a household equipment with the minimum of about 5 and maximum of 7 people could design and fabricate.. The machine consists of a shaft, bearings, electric motor, beaters, bowl and the frame. The machine was developed to enhance the hygienic processing of porridge and flour for domestic consumption, while eliminating the tedious and laborious indigenous process of preparing them. The frame was made of mild angle iron of 2" x 2" (approx. 50mm x 50mm). The frame consists of metal sheet welded to cover the whole frame except the underneath. The frame housed the motor, the gear and the transmission system .The machine was designed to cook yam and turn it to porridge and also to mix flour .The machine was designed to cook 4-5kg of yam within 30minutes and also to turn to porridge within 3-5 minutes which the mass after mixing will reduces to 3.8 – 4.8kg, which make the machine to have 89% efficiency. The machine part consist of 2hp electric motor, driver pulley, V-belt, 20x20x3 ISO angle iron, gear, stainless pot based support, stainless shaft, beater, stainless pot, element (heater),etc. The machine was made to replace the indigenous method and process of mixing porridge and flour for both domestic and commercial uses, this machine is costly because of the materials being used.

Keywords: Gear, Heater, Electric motor, Element, Efficiency

1.0 INTRODUCTION

The term mixing machine is perhaps well known by people over the world, but the exact form and character of dough widely varied among the regions and countries (FAO., 2016).In African countries dough mixer is mainly characterized as the matter created for yam pounding, flour mixing with proper amount of water, with addition of recipe ingredients for flour (yeast, fats and oil, sugar (Agrawal et al.,2017). In Food industries, mixing of flour to form dough has been a major operation in their production process. Even in many homes, mixing of flour for baked foods has become necessary; hence the need for an affordable flour mixing machine is on the increase (Shigley and Mischike,2001). Despite so many mixers in the market, many small and medium scale productions in developing economy still use the traditional method of hands mixing of porridge and dough for economic reasons (Olukunle et al., 2016).Mixer is also a kitchen utensil which uses a gear –driven mechanism to rotate a set of beaters in a bowl containing the food to prepare. It automates the repetitive tasks of stirring, whisking or beating. When the dough hooks are replaced by a beater, a mixer may also be used to knead (Kline and Sagihara., 2014). A stand mixer varies in size from small countertop models for home use to large capacity commercial machines. Stand mixers create the mixing action by rotating the mixing device vertically: planetary mixers, or by rotating the mixing container, spiral mixers(Bot., 2003).Mixers for the kitchen first came into use Midway through the nineteenth century; the earliest were mechanical devices. The demand from commercial bakers for larger - scale uniform mixing resulted in the development of the electric stand mixer(Sluimer., 2005).Mixing machine is an important equipment in bread making, which affects the product quality directly. Most bread use hard wheat flour, which have dense particles that are slow for water to penetrate (Cauvain., 2013). As the mixing action continues, the particles are rubbed against each other, exposing the next layer for hydration, therefore, mixing is not only simply homogenizing the ingredients, but hydrating the ingredients as well. All mixing machines available today are designed to incorporate both the mixing and the kneading processes (Akissoe et al., 2003).

Bread dough mixing requires a method by which the products are homogeneously mixed and hydrated, resulting in a well developed gluten network (Babajide and Atanda,2008). The mixing required could be viewed as the energy necessary to develop the dough. Most bakers use the standard 'stretch to a window pane' test to determine proper development. This requires an extensible dough that would stretch to a thin film, without breaking. In bread dough, both the dough gluten network development and dough temperature are established after mixing. Mixing times are varied depending on the speed of the mixer, mixer design, dough size, dough temperature, water absorption of the flour, etc. Basically, dough mixing needs to meet the following requirements: (Herbert 1980). When discussing about porridge and flour mixing machine, yam which happen to be one of the sources of the porridge must be discuss about. Yam is one of the oldest known recipes to man. It is a tuber crop, which belongs to the class of carbohydrate and has been a part of the African meal for centuries. Yam is the common name for the specie in the genus Dioscorea (family Dioscoreaceae). The sweet potato (Ipomea batatas) has traditionally been referred to as yam in parts of the United States and Canada, but it is not part of the Dioscoreaceae family (en.wikipedia.com/yam).

The word yam comes from Portuguese name or Spanish name, which both ultimately derive from the Wolof word nyam, meaning "to sample" or "taste". In other African languages it can also mean "to eat" e.g. yamyam and nyama in Hausa (Mignouna et al., 2003). Also yam is the common name for some species in the genus and they are perennial herbaceous vines cultivated for the consumption of their starchy tubers in Africa, Asia, Latin America and Oceania. They are used in a fashion similar to potatoes and sweet potatoes, (Brand–Miller et al., 2003). Yam products generally have a lower glycemic index than potato products (Kay, 1987), which means that they will provide a more sustained form of energy, and give better protection against obesity and diabetes (Walsh, 2003). The world production of yam was estimated at 28.1 million tonnes in 1993. Out of this production, 96% came from West Africa, the main producers being Nigeria with 71% of world production; Côte d'Ivoire 8.1%; Benin 4.3% and Ghana 3.5%. In the humid tropical countries of West Africa, yams are one of the most highly regarded food products and are closely integrated into the social, cultural, economic and religious aspects of life. Traditional ceremonies still accompany yam production, indicating the high status given to the plant (Food Information Net, 2008).

Yam is also a daily nutritional food requirement for man and in order to facilitate the processing of yam for consumption, its starchy nature allows yam to form a bond, when it is beaten in a mortar, it forms a starchy drawing semi-solid paste which is then consumed as meal with a choice soup. Yams are economically useful plants belonging to genus Dioscorea (Coursey, 1967). There are many varieties of yam which are differentiated by varying characteristics such as the direction of stem twines (clockwise or counter clockwise), the shape and colour of the leaves, stem and tubers, and the cooking quality of the tubers. The yam tuber is economically the most important part of the plant. The structure is extremely variable, depending on the species. Most yam tubers however are more or less cylindrical in shape and weighs of individual tubers range from 200g to 50kg (Asiedu, 1989). The aim of this project is to work on eliminating the indigenous/crude process of preparing porridge and flour mixing, for domestic consumer and for a better efficiency.

2.0 MATERIALS AND METHODS

Porridge and flour mixing machine consists of a shaft, gear, stainless steel, electric motor, beaters, bowl and the frame. The machine was developed to enhance the hygienic processing of porridge and flour for domestic consumption, while eliminating the tedious and laborious indigenous process of preparing them.

2.1 Material Selection

For the effectiveness of this machine, the following materials were selected and used

1. Stainless steel

Stainless steel is a steel alloy with a minimum of 10.5% to 11% chromium content by mass. Stainless does not readily corrode, rust or stain with water as ordinary steel does, it has high strength and the ability to withstand high temperature. As a result of this property, it is used for the mixing chamber as well as the beater shaft having direct contact with the Porridge (Kline et al,2014).

2. Mild steel

Mild steel also called plain carbon steel is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. It has a relatively low tensile strength but it is cheap and malleable. Therefore, the frame structure was designed using the mild steel (Agrawal et al., 2017).

3. Galvanized Steel

Galvanize sheet metal was selected for the construction of the entire body of the machine because; it has a good surface finish, it is cheap and widely available, it has a good strength and not brittle, it can be drilled and generally machined.

2.2 Design considerations

The following are the factors considered when designing the multipurpose mixing machine;

a. The stresses acting on the loads are both bending, torsional and compressive stresses;

b. The rolling parts of the machine i.e. bearings and coupling system of transmitting power will be considered;

c. The parts use for the design are standard sizes which provides ease for interchange ability of parts;
d. That the quality of the materials selected are good and of high durability;
e. It is ergonomically good and safe to operate.

2.3 Design assumptions

The following are assumed statement and quantities (Ayodeji et al, 2014):
a. The acceleration due to gravity g is 9.81 m/s^2
b. The density of stainless steel is 7880 kg/m^3
c. The density of mild steel is 7850kg/m^3
d. The volume of porridge to be mixed should not be more than $^2/_3$ of the total volume of the mixing chamber;
e. 2horsepower electric motor is equivalent to 1480 Watts;

2.4 Design calculation and analysis

2.4.1 Weight of mixing pot

The volume of the mixing pot is given as:

$$Vp = \pi \frac{(D_b)2 - (d_b)2}{4} \times L_b$$

$$V_p = \pi \times \frac{(0.28)^2 - (0.275)^2}{4} \times 0.25 = 5.449 \times 10^{-4} m^3$$

Since ρ = density of stainless steel = 7880 kg/m^3, then

Wp=Weight of pot = ρ x V x g = $7880 \times 5.449 \times 10^{-4} m^3 \times 9.81 = 42.12$ N

2.4.2 Weight of Beater

Beater dimension:

Length, l= 0.425m, Thickness, t = 5mm = 0.005m, Height, h = 50mm = 0.05m

Volume of each side of the beater, V_b = l x h x t =0.135 x 0.05 x 0.05 = 3.375 $\times 10^{-5}$
The volume of the two sides of the beater = 3.375$\times 10^{-5}$
= 6.75$\times 10^{-5}$
Since ρ = density of stain 30 el = 7880 kg/m^3

Mass of beater, $m_{bl} = \rho\ V$
= 7880 x 3.375 $\times 10^{-3}$ = 0.266kg

Weight = mg where g = 9.81kg/m^2
= 0.266 x 9.81 = 2.61N
Ring dimension:
D = 19mm = 0.019m, d = 17.5mm = 0.0175m, width, w = 50mm = 0.05m

Weight of each ring, W_r = $\rho \times A \times w \times g$

= $7880 \times \pi \times \frac{(0.019)^2 - (0.0175)^2}{4} \times 0.05 \times 9.81 = 0.166$ N

Total weight of beaters = 3(2 x weight of each side of the beater + weight of each ring)
= 3(2 x 2.51 + 0.166) = 15 558 N

1.3.3 Weight of Shaft

$$w_s = \rho \times \frac{\pi D^2}{4} \times h \times g$$

$$= 7880 \times \frac{\pi(0.02)^2}{4} \times 0.089 + 0.015^2 \times 0.003 + 0.01^2 \times 0.038 \times 9.81 = 2.983 \text{ N}$$

=7880 x π/4 (4.0075) x 9.81
=2.433 N

2.4.3 Weight of Transmission shaft or Connecting rod, (referred to the diagram)

$V_1 = \pi(HR_1^2 - hr_1^2)$
$V_1 = \pi H (0.015^2 - 0.008^2)$

$= \pi \times 0.003\ (0.015^2 - 0.008^2)$
$= 1.517 \times 10^{-5}\ m^3$

$V_2 = \pi H\ (R_2^2 - hr_2^2)$
$= \pi \times 0.055 \times 0.015^2$
$= 3.888 \times 10^{-5}\ m^3$

$V_3 = \pi H\ (R_3^2 - hr_3^2)$
$= \pi \times 0.04 \times (0.015^2 - 0.008^2)$
$= 2.023 \times 10^{-5}\ m^3$

Total volume of shaft = $1.517 \times 10^{-5} + 3.888 \times 10^{-5} + 2.023 \times 10^{-5}$
$= 7.428 \times 10^{-5} m^3$

Weight of shaft $= \rho \times V \times g$
$= 7880 \times 7.428 \times 10^{-5} \times 9.81 = 5.742\ N$

2.4.4 Design of Thrust Bearing

$P = W/A = w/\pi R^2$
Where;
W = load transmitted over the bearing surface
R = Radius of the bearing surface (or shaft)
A = cross – sectional area of the bearing surface
P = bearing pressure per unit area of the bearing surface between rubbing surface
N = speed of the shaft in rpm
W = Total load = Wb+Wbl+Ws
= 42.12+16.158+2.433
= 60.711 N
R = Radius of bending surface = radius of shaft = 30 mm = 0.03 m
$P = 60.711/\pi\ (0.03)^2 = 21472.124\ Nm^2$
$= 21.47\ KNm^2$

2.5 Fabrication and welding method

Plate1: The Frame Diagram

The marking out was carefully done on the angle metal and sheet metal in accordance with the design specification (Sluimer., 2005). The frame was made of mild angle iron of 2" x 2" (approx. 50mm x 50mm). The frame consists of metal sheet welded to cover the whole frame except the underneath. The frame housed the motor, the gear and the transmission system(Spotts et al, 2004) . A metal plate of 5mm height ,50mm long was folded and welded to create the pot chamber and to hold the pot when work commenced on it(Varriano et al.,1980). The metal sheets were folded according to the specification of the design and the welding processes were carried out accordingly. Thereafter, all the machine parts were assembled.

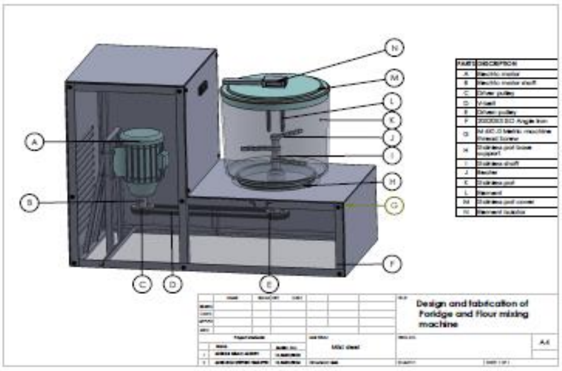

Figure 1: Assembly Drawing

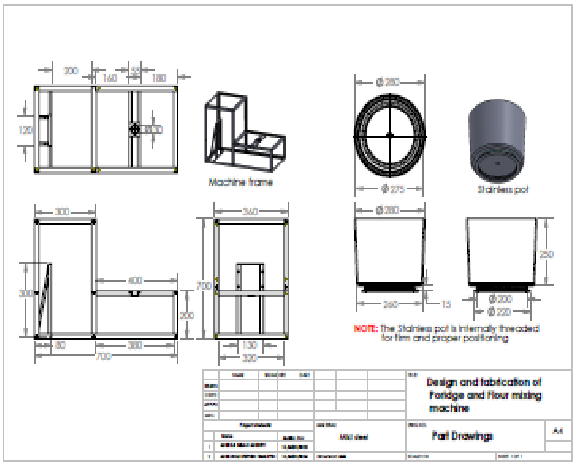

Figure 2: Orthographic Design of the Mixer

3.0 RESULTS AND DISCUSSION

3.1. Tests and results

The fabricated flour and porridge mixing machine was tested and compared to the indigenous method of mixing porridge. In order to achieve the desired texture, test for hardness was carried out to know if it is necessary to add water to the mixed flour or porridge.
The result show in table 1and 2 below

TABLE 1: Test of the Efficiency of the Machine through Mixing of Porridge

S/N	Method	Mass of yam cooked (kg)	Cooking time(min)	Mixing time(min)	Mass after mixing
1	Porridge	4-5	30	3-5	4.5-5.8

TABLE 2 Test of the Efficiency of the Machine through Mixing of Yam Flour

S/N	Method	Volume of water boiled	Water boiled time (min)	Mass of Flour to mix	Mixing time (min)	Mass after mixing
1	Yam Flour	2 L	10	4-5	2-4	5.5-6.5

It was observed that the fabricated machine eliminates the tedious and laborious indigenous process of preparing porridge. More so the capacity was increased;

3.2 Determination of Functional Efficiency (£)

This is a measure of the mass in kg porridge as output to the mass of the yam loaded into the mixing chamber.

Machine Method Functional Efficiency

For Porridge

If M_a = Mass of yam cooked

M_b = Mass of mixed porridge pack

Hence, ,$\epsilon = \frac{Ma}{Mb} X \frac{100}{1} = \frac{4.0}{4.5} X100$=89%

For Yam Flour

If Ma= Mass of yam flour to mix

Mb== Mass of yam flour after mixing

Hence, $\epsilon = \frac{Ma}{Mb} \times \frac{100}{1} = \frac{4}{5.5} \times 100 = 73\%$

3.3 **Discussion**

The machine was well evaluated to suit its usage. That is, the components parts. The make up of the machine was duly selected to carrying out its purpose and making it easily operational to the users.

The factor considered and evaluated are as follows:

- Weight of motor.
- Weight of metallic base.
- Thickness of beater.
- Total weight of the machine.

Repair / maintenance schedule

Repairs are affected when a machine fails to function effectively and efficiently as required. The machine parts likely to fail which could have a great effect on this machine are electric motor, electric switches, shaft and blades.

The machine is economically fabricated to aid replacement of damaged parts as well as periodic inspection.

The maintenance system or process includes

- Cleaning of the pots before and after operation.
- Greasing of motor bearings.
- Storing the machine in a cool and dry place.
- General inspection and cleaning of the worn out parts.

As a matter of fact, the maintenance requirements are categorized into:

1. Breakdown maintenance.
2. Overhaul maintenance.
3. Planned preventive maintenance/ Corrective maintenance

Unlike the other method of mixing yam flour, this newly designed machine makes the work easier, efficient and much faster than the indigenous way of mixing porridge and yam flour which also has the ability to cook the yam before turning it to porridge with 89% efficiency. It was however observed that the rate of mixing porridge in this machine was faster. This research work has successfully presented a functional and highly efficient low cost porridge and yam flour machine by minimizing traditional technique of mixing and health condition of individual, this machine is design for home and restaurant usage, in other to improve a healthy and hygienic condition of an individual. It is expected that an average home in Nigeria can afford the machine.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

A mechanical porridge and flour mixing machine is developed for the domestic consumers for better efficiency. In addition to the fact that this machine gives more hygienic mixed porridge, it also eliminates the indigenous process of preparing porridge. The improvement of flour mixing machine which is able to cook yam and turn it to porridge demonstrates that the fact that such food processing equipment helps in producing large quantities and keeps cost under control. The flour and porridge mixing machine is fast and reduce wastage in mixing porridge and flour. This machine is design for home and restaurant usage, in other to improve a healthy and hygienic condition of an individual. It is expected that an average home in Nigeria can afford the machine.

4.2 Recommendations

From this research, we recommend that some chemical analysis of the end product should be carried out to determine the degree of contamination of the mixed porridge or yam flour by the material employed in the machine construction. Also, there is room for improvement in the efficiency and physical outlook of the machine. We also recommend that this write up in design and fabrication of this project should serve as a stepping stone for further and well defined fabrication.

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