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Research on Performance Evaluation of Garri Frying, Incorporating an Electro-Mechanical Device

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Abstract- Virtually every average household in Nigeria eats garri. The traditional methods of frying garri pose dangers to both the environment and the person frying the garri. The ever increasing demand for this cassava product necessitates the need for an electro-mechanical device (machine) to alleviate these challenges and more. This research reviews the health hazards faced by most persons using the traditional methods of frying garri. The research examines the mechanical/ chemical properties of Aluminum, Mild Steel and Stainless Steel to determine the best material for the design of a garri frying machine. Hardness, Hot Hardness and Corrosion tests were carried on samples of these materials, using Universal Hardness Testing machine, Muffler Furnace, and Hydrogen Cyanide (corrosive reagent) under approved standard conditions. Mild Steel showed great Hardness and Hot Hardness strength, but low Corrosion resistance. Aluminum showed excellent Corrosion resistance, good Hardness strength but low Hot Hardness strength. Although Stainless Steel is costly compared to the other two materials, it show excellent Hardness and Hot Hardness strength, and great Corrosion resistance. So Stainless Steel is recommended for the design and fabrication of an electro-mechanical garri frying machine because of the safety of the food. This work presents the Computer Aided Design (CAD) of the electro-mechanical device (machine).

Keywords: Cassava, Garri, Health hazards, Meterial Test, Stainless Steel

I. INTRODUCTION

Garri is a fermented product made from processed cassava tubers that is consumed in Brazil, most of the coast of West Africa, and Nigeria. Garri is best defined as a free-flowing particulate product made with dried and gelatinized cassava particles. According to research, cassava (Manihotesculenta), especially among Africans, is the fourth most staple food in the world after rice, wheat, and maize (IFAD/FAO, 2000). Carbohydrates, which indicate that garri is a food that provides energy, are part of its nutritional worth. Garri is prepared using the methods used in the village for processing. Garri is made from peeled cassava tubers, also known as cassava roots, and is characterized as a fine to coarse granular flour with varying textures. Before being grated, the peeled cassava tubers will be thoroughly cleaned to eliminate any remaining stones. Following washing, it will be grated, put into sacks, and have the starch extracted. Depending on the pressing methods used and the amount of tension applied to the sack during the pressing process, it will be allowed to ferment for two to four days. In order to lower the cyanide concentration in the cassava and provide a good aroma to the garri, the fermenting period is crucial. After that, it is cooked, either with or without red oil, which is made from palm oil. Harvesting the cassava tubers from the farm, peeling and cleaning them, grating or grinding them, dewatering (pressing), fermenting, sifting, frying, and cooling the fried garri are the basic steps in the manufacture of garri. In certain regions of sub-Saharan Africa, it is commonly known as gali or garri.

In Nigeria, the Standards Organization of Nigeria (SON) classified garri into four major categories which are (i) extra fine grain garri, where more than 80% of the grain passes through a sieve of less than 350 micrometer aperture; (ii) fine grain garri in which more than 80% of the grains pass through the sieve of less than 1000 micrometer aperture; (iii) coarse grain garri, where not less than 80% of grains passes through a sieve of 1400 micrometer or less than 20% of weight passes through a sieve of 1000 micrometer aperture; and (iv) extra coarse grain gari in which not less than 20% of grain is retained on a sieve of 1400 micrometer aperture (SON, 2000). Traditionally, women cook garri over a wood fire in shallow cast-iron pans called "agbada." When frying, the operator sits sideways by the fireplace, which is uncomfortable because of the heat, the smoke that is packed with carbon, and the

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manner they are seated. To prevent cake formation, the operator presses the sieved mash on the hot frying pan surface using wooden paddles resembling spatulas or half calabash sections, rotating the pan constantly. Due to the paddles' continuous pressing and agitation, the temperature progressively rises and the moisture content decreases, which would have decreased the majority of the tiny lumps that had formed. The product gets fried and dehydrated when the heat applied to the drying surface is increased further.

For big or commercial purposes, the conventional method of frying garri is time-consuming, labor-intensive, and prone to health risks and injuries. This study will draw attention to the health risks associated with frying garri using traditional ways and suggest that using a machine that eliminates these risks is necessary. The necessity for such a machine's design stems from the fact that all modern products and equipment are made to fit specific environments, functions, and purposes. Therefore, it is necessary to develop and build a garri frying machine that will both satisfy human needs, particularly for those in rural regions who fry garri for commercial purposes, and lessen or eliminate the problems associated with the traditional method of frying.

This work will be a rationale for knowing much about the engineering materials for such a design concept of an electric garri frying machine so as to handle the challenge of traditional frying. This research will present material analysis of Mild Steel, Stainless Steel and Aluminum. These materials are available, however we will show which material is the best material for food processing at elevated temperature working environment. To this end, we will subject these materials to three tests, namely; Corrosion test, Hardness test and Hot Hardness test. The result of these tests will reveal the best choice of material for an electro-mechanical garri frying machine. There is no doubt that this work will improve the technological level of the nation as well as attract more people to better appreciate agriculture thereby reducing the rate of unemployment in the country.

1.1 STATEMENT OF PROBLEM

The use of hybrid agro seeds and plants has greatly increased food production in the country. At the same it has created a bigger problem; the challenge of processing and preserving these products. The best method to preserve these foods is to dry or fry them, to remove their water content, thus preventing fermentation and wastage.

The use of traditional method of frying of garri over a fire place is time consuming and unsafe as the garri usually get contaminated with carbon gases as the wood burns. This method also poses a danger to safe food.

The traditional method of frying garri has overtime generated more discomfort. Also, the rise in the cost of hydrocarbons has made it difficult to access wood fuel. The use of traditional methods, apart from being time consuming, results in non-homogenous heat distribution and thermal energy losses which resulted to increase in the cost of production, likewise air pollution. Therefore, there is a need for the development of an indigenous electro-mechanical device with thermodynamic fluid (Liquefied petroleum Gas) as fuel, to mitigate these challenges.

1.2 OBJECTIVES OF THE RESEARCH

The following are the objectives of this research:

i. To evaluate the health effects of traditional methods of frying garri
ii. To recommend a frying process to reduce the stress and fatigue incurred in the manual frying of garri.
iii. To analyze the hardness strength of Aluminum, stainless steel and mild steel.
iv. To ascertain the hot hardness strength of Aluminum, stainless steel and mild steel.
v. To ascertain the reaction of Aluminum, stainless steel and mild steel in a corrosive environment.
vi. To ascertain the best materials for the design of garri frying machine.
vii. To recommend based on verified results the best metal material for the design of a garri frying machine.

1.3 PROJECT JUSTIFICATION

In the past years, a lot of research has been carried out to mechanize some aspects of the operation used in garri production, which include peeling and washing of the roots, grating, de-watering, fermentation, sieving, frying and cooling (Akinnuli B. O; Osueke, C. O; Ikubanni P. P; Agboola O.O; & Adediran, A.;

2015). It has been estimated that 52% of cassava output is wasted, as a result of inefficient methods of production and processing. The 43% of the remaining 48% is consumed as food and the rest is used as feed. (Ezedinma et al, 2007) Increasing the production of garri to meet local and international demands has been one of the main reasons for trying to mechanize its production system, as well as to check mate the strenuous labour and human fatigue being experienced in the production process of this product. The result of this research will greatly benefit all who wants to design a garri frying machine and those involved in garri frying process.

II. MATERIAL AND METHODS

Garri is the end product of a very hectic process- Cassava processing. This work examines the process of frying garri. After the cassava have been grinded and compressed, it undergoes sieving to separate the fine grains from the chaff and the uncrushed cassava. This sieved grains are the semi-finished products of cassava, which is fried to produced garri.

As already stated, the traditional method of frying garri is highly stressful and unsafe, for the person frying the garri and the food, as solid carbon often fall into the food. Hence, this paper will examine the need to improve the process of frying garri through the use of an electro-mechanical device (machine). To achieve the best of results- fine products and safe practice, we will carry out corrosion tests, hardness tests and hot hardness tests on Aluminum, mild steel and stainless steel materials, to determine the best material for the design and fabrication of such an electro-mechanical device. Such device will greatly improve performance- garri frying process, increase output and safety of individuals in garri frying business.

2.1 HEALTH HAZARDS ASSOCIATED WITH GARRI FRYING OVER A FIRE STOVE (LOCAL GARRI FRYING)

The traditional method of frying garri exposes the person to severe health dangers that cannot be under estimated. In a study conducted by Ewebiyi, Olawumi, & Adedeji (2015), it shows different health related challenges in cassava processing as well as the severity of these health problems. 98.3% of the respondents experienced severe sight problems, 95.5% experienced chest pains, 93.4% suffer from hotness of the body and 93.3% experienced total body weakness. This could obviously be because of traditional method of frying garri employed by these respondents, which exposes them to severe heat and highly energy sapping procedures. Other health challenges experienced by the respondents include heavy persistent tears (92.5%), high temperature of the body (90.8%), headaches (90.8%), general body pains (75.8%), anemia (81.7%), blurred vision (54.2%), high blood pressure (45.8%) and nose bleeding (46.7%). It is clear from these results that there is need for a better way of frying garri to avoid these health problems.

2.2 CORROSION TESTS OF ALUMINUM, MILD STEEL AND STAINLESS STEEL MATERIALS

The Aluminum, mild steel and stainless steel samples were prepared- fifteen samples for each metal, and their individual weight were measured and recorded as W_0 (initial weight of sample before dipping in corrosive environment for n number of days, where n represent integers). Fresh hydrogen cyanide liquid was deposited in corrosion resistant containers and each sample was deposited in each container, with one sample kept outside the corrosive environment to compare the corrosion rate. The set-up was kept in fairly temperature controlled laboratory. Each 48 hours, one sample of Aluminum, Mild Steel and Stainless Steel is extracted, washed with water, dried and measured to ascertain the weight W_n and apparent weight loss, W_l. (where $W_l = W_0 - W_n$). This procedure was repeated for 720 hours. The experiment was carried following guidelines in ASTM procedure Standard Practice for Laboratory Immersion Corrosion Testing of Metals (G 31). To calculate the corrosion rate, the following expression was used:

$$C.R = \frac{K\ X\ W}{(A\ X\ T\ X\ \rho)} \qquad 2.1$$

Where,

K = a constant for unit convection ($8.76\text{x}10^4$ for unit mm/y),

T = time of exposure in the corrosive medium (in hours),

A = area in cm^2 to the nearest $0.01cm^2$,

W = weight loss in grams (g),

ρ = density in g/cm^3,

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2.3 HARDNESS TESTS OF ALUMINUM, MILD STEEL AND STAINLESS STEEL MATERIALS
The materials were sourced from the local markets and prepared appropriately. The mild steel samples were surface grinded to ensure smooth surface. They were washed, dried, and cleaned using emery cloth until the samples attained fine surfaces. Five (5) samples were prepared for this experiment. The stainless steel samples were washed, dried, and cleaned using soft cotton materials to ensure no surface cracks were initiated. Five (5) samples were also prepared. The same procedures as with the stainless steel were followed for the aluminum samples. Five samples were equally prepared.

Since the experiment is aimed at ascertaining their hardness or strength at room temperature, a uniform thickness of 5mm was maintained for all the samples. Sample loads of 5, 7.5, 10, 15, and 20Kg were prepared the experiment. The tests were carried out on a digital Universal Hardness testing machine.

The mild steel sample was set up on the machine and three indentations were made on it using the 5Kg load, at different points on the plane and the respective hardness for each indentation read off and recorded. The process was repeated for the 7.5, 10, 15, and 20Kg respectively. These processes were repeated for the aluminum and stainless steel samples.

2.4 HOT HARDNESS TESTS OF ALUMINUM, MILD STEEL AND STAINLESS STEEL MATERIALS
The process of sample preparation for these experiments was similar to the process used in the hardness test experiment. However, there were six (6) samples of mild steel, aluminum and stainless steel. We maintained the same thickness of 5mm for all the samples.

These experiments involved two things, namely; heating the samples, one at a time in a muffler furnace with a digital temperature reading display, to a desired temperature, and then carrying out a hardness test, using a 5Kg weight indenter on the heated sample as quickly as possible to ascertain its strength at that temperature. These involves extracting the heated sample with a tong from the furnace and transferring same to the Universal Hardness testing machine for determination of the sample's strength. These processes were carried out at the following temperature points: 100, 150, 200, 250, 300 and 400℃ respectively. The process of hardness test at elevated temperature was similar to the hardness test earlier reported, as three indentations were made and the readings were recorded accordingly.

III. RESULTS AND DISCUSSION

3.1 CORROSION TEST
At the conclusion of the corrosion tests, W_l was ascertained for each of the metal samples. While Mild Steel showed significant W_l, Aluminum and Stainless Steel showed negligible W_l. Hence, corrosion rate of the Mild Steel was determined using equation 2.1. As shown in table 3.1.1, the corrosion rate (C. R.) was initially high during the first 48 hours. This is likely because of initial exposure to the corrosive media and high concentration of hydrogen cyanide present. As the progresses however, the C.R. declines in value, rises slightly on the 7th test day, and continue to decline in value until the 13th and 14th test days. this agrees with the result of Oladipo, N.O et al (2022) This shows that further exposure of the mild steel sample to the corrosive media will be detrimental to its service life. Refer to figure 3.1.1 for explanatory graphs.

Table 3.1.1: Corrosion test results of mild steel showing the weight loss and corrosion rate

Days of exposure (48hrs apart)	W_0 (g)	W_n (g)	W_l (g)	C.R.
0	16.32	0	0	0.0000
1	15.47	15.38	0.09	2.3723
2	16.29	16.18	0.11	1.3838
3	15.47	15.35	0.13	1.1559
4	15.13	15.00	0.13	0.8806
5	16.72	16.59	0.13	0.6183

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6	16.55	16.44	0.11	0.4575
7	15.27	15.13	0.14	0.5335
8	15.96	15.83	0.13	0.4137
9	15.85	15.70	0.15	0.4500
10	15.77	15.62	0.15	0.3962
11	14.68	14.50	0.18	0.4583
12	16.29	16.13	0.16	0.3478
13	16.01	15.80	0.21	0.4113
14	16.02	15.78	0.24	0.4001

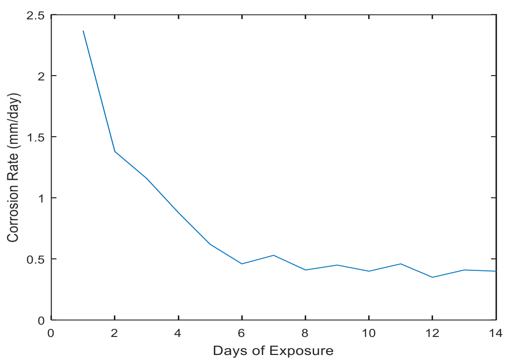

Figure 3.1.1: Corrosion test result of Mild Steel in Corrosive Media

MATLAB CODES FOR THE GRAPH ABOVE

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% Create plot
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% Create xlabel
xlabel({'Days of Exposure'});
% Create ylabel
ylabel({'Corrosion Rate (mm/day)'});
 % end
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For Aluminum and Stainless Steel samples, they showed great resilience in the corrosive media. They exhibited zero to negligible weight lost and so negligible corrosion rate or zero corrosion rates. Of course these characteristics were expected. For stainless steel, the presence of chromium and nickel as alloying element in its microstructure makes it resistant to corrosion. (Khurmi R. S, Gupta J. K, 2011) Aluminum samples were resistant to corrosion. This was expected, as aluminum metal is corrosion resistant. This is because anodized surfaces may be impregnated with corrosion inhibitor by treating the Aluminum with solutions of chromium. The chromate gets absorbed in the coating and protects the metal coating from any corrosion attack. (Jain R. K.; 2011) Table 3.1.2 and 3.1.3 shows the behavior of Aluminum and Stainless Steel in the corrosive media. Refer to figure 3.1.2 and 3.1.3For graphical representation of the data in tables 3.1.2 and 3.1.3.

Table 3.1.2: Corrosion test results of Aluminum sample showing the weight loss

Days/Sample Number (48 hrs apart)	W_0 (g)	W_n (g)	W_l (g)
0	6.98	0	0
1	6.26	6.26	0.00
2	5.33	5.33	0.00
3	6.86	6.86	0.00
4	5.87	5.87	0.00
5	6.84	6.83	0.01
6	6.37	6.37	0.00
7	6.42	6.52	0.12
8	5.04	5.19	0.15
9	6.26	6.36	0.10
10	7.10	7.10	0.00
11	6.43	6.43	0.00
12	5.66	5.65	0.10
13	5.60	5.50	0.10
14	6.45	6.44	0.10

Figure 3.1.2: Behavior of Aluminum in the corrosive media

Weight of Stainless Steel (g)

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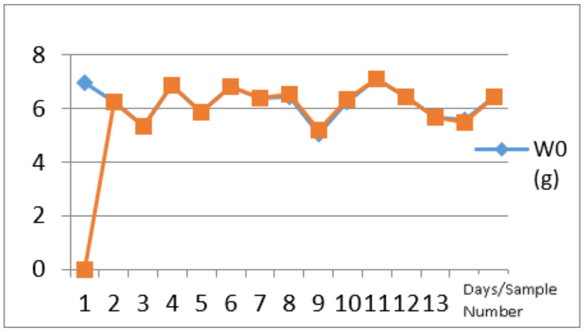

Table 3.1.3: Corrosion test results of Stainless Steel Sample showing Weight Loss

Days/Sample Number (48 hrs apart)	W_0 (g)	W_n (g)	W_l (g)
0	14.64	0	0
1	14.99	14.99	0.00
2	14.59	14.59	0.00
3	14.42	14.42	0.00
4	14.44	14.44	0.00
5	14.68	14.68	0.01
6	14.75	14.75	0.01
7	13.64	13.63	0.01
8	13.30	13.29	0.00
9	14.11	14.10	0.01
10	13.86	13.86	0.00
11	13.67	13.67	0.00
12	13.65	13.64	0.01
13	13.59	13.59	0.00
14	13.55	13.55	0.00

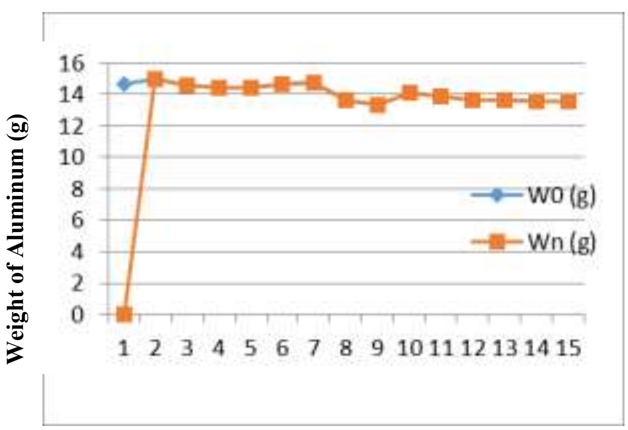

Figure 3.1.3: Behavior of Stainless Steel in the corrosive media

3.2 HARDNESS TESTS

The results of the tests show the hardness of the sample materials at different loads. The aluminum samples showed good strength under loads of 5, 15 and 20Kg and better strength under 7.5 and 10 Kg. This makes it difficult for it to be used in the design and fabrication of a machine that will regularly come under torque. Practically the machine would be loaded while at rest. This is showed in table 3.2.1 and figure 3.2.1. (where BHA is Brinell Hardness Average)

Table 3.2.1: Brinell Hardness Value for Aluminum Sample

S/N	Load (kg)	BHA
1	5	60.66
2	7.5	71.21
3	10	74.98
4	15	68.35
5	20	64.48

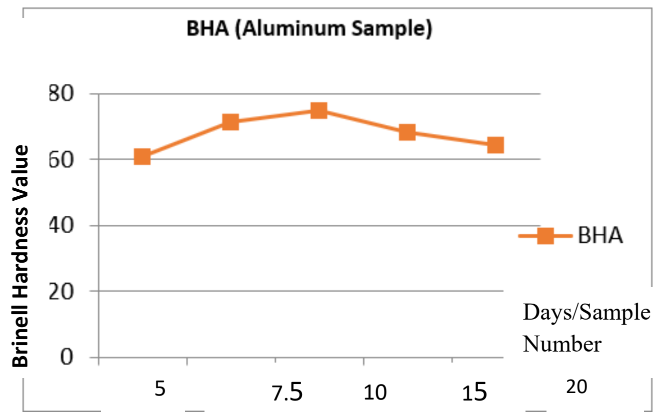

FIGURE 3.2.1: Brinell Hardness Value for Aluminum Sample

The Mild Steel samples showed better strength than Aluminum samples. This was expected as steel has higher tensile strength that aluminum, 400 to 550MPa and 90 to 150MPa. It was noticed that the strength decrease with increase in the magnitude of the load. This means that caution is needed when loading the machine, if mild steel is ever used to design the machine. The behavior of mild steel during the test is shown in Table 3.2.2 and Figure 3.2.2 respectively.

Table 3.2.2: Brinell Hardness Value for Mild Steel Sample

S/N	Load (kg)	BHA

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1	5	122.46
2	7.5	140.52
3	10	116.12
4	15	95.81
5	20	93.87

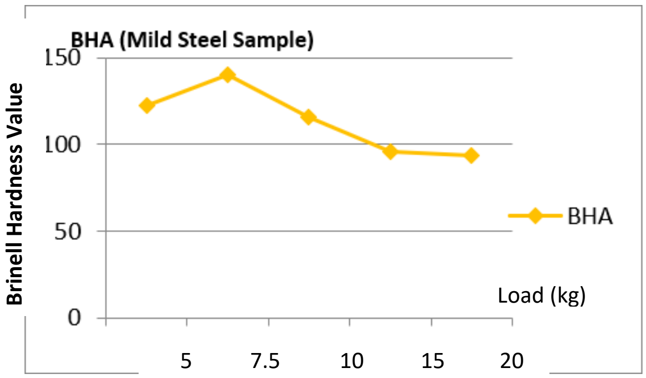

FIGURE 3.2.2: Brinell Hardness Value for Mild Steel Sample

The stainless steel samples had very good strength. It was observed that with increased load the strength increases also. This no doubt was encouraging considering its behavior in the corrosion test. At higher loads, stainless steel showed greater strength than mild steel and aluminum. This is illustrated in Table 3.2.3 and Figure 3.2.3 respectively

Table 3.2.3: Brinell Hardness Value for Stainless Steel Sample

S/N	Load (kg)	BHA
1	5	92.84
2	7.5	87.43
3	10	83.50
4	15	101.60
5	20	113.71

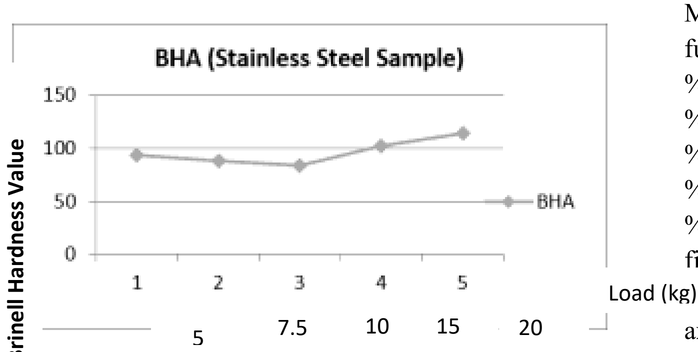

Figure 3.2.3: Brinell Hardness Value for Stainless Steel Sample

3.3 HOT HARDNESS TESTS

At the end of the processes, the hot hardness test values were recorded after each test. As stated in section 2.4, three indentations were made. The average values determined and recorded accordingly.

Aluminum sample showed good hot hardness strength at 100℃ . The strength decreased, however with increase in temperature. From the data, the aluminum samples happened to have the least hot hardness strength when compared to mild steel and stainless steel. The behavior of the aluminum sample is shown in Table 3.3.1 and Figure 3.3.1

Table 3.3.1: Hot Hardness Test for Aluminum Sample

S/N	Temp(^{0}C)	BHA
1	100	57.48
2	150	50.20
3	200	45.37
4	250	42.30
5	300	40.74
6	400	34.73

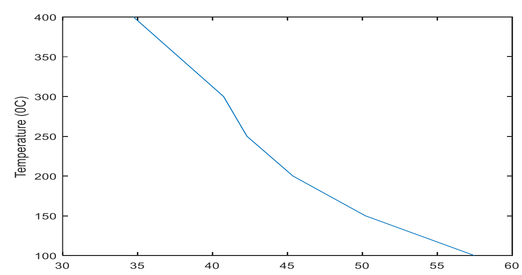

Figure 3.3.1: Hot Hardness Test for Aluminum Sample

MATLAB CODES FOR THE GRAPH ABOVE

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Create axes
axes1 = axes('Parent',figure1);
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box(axes1,'on');
hold(axes1,'on');
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The mild steel sample showed better hot hardness strength than the aluminum sample. It was noticed that at 100℃, the sample showed great hot hardness strength. Of course due consistent raise in temperature, the strength reduced at a almost at a steady rate. Comparing the samples of aluminum and mild steel performance on these tests, mild steel was better to withstand the increased temperature. The behavior of mild steel in the hot hardness tests are shown in Table 3.3.2 and Figure 3.3.2 respectively.

Table 3.3.2: Hot Hardness Test for Mild Steel Sample

S/N	Temp(^{0}C)	BHA
1	100	98.11
2	150	83.18
3	200	77.68
4	250	64.57
5	300	59.77
6	400	48.31

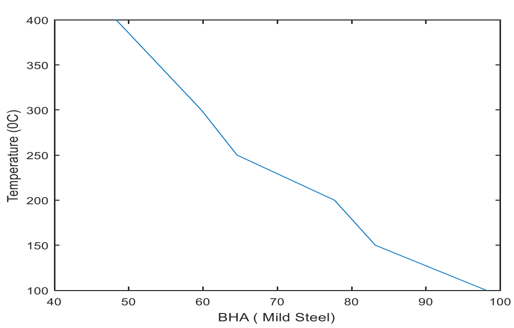

Figure 3.3.2: Hot Hardness Test for Mild Steel Sample

MATLAB CODES FOR THE GRAPH ABOVE

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```

The stainless steel sample showed the best hot hardness strength, when compared to mild steel and aluminum samples. The result shows that stainless steel sample will more readily retain hardness at temperatures above 300℃ than the aluminum and mild steel samples. The behavior of stainless steel at elevated temperatures are shown in Table 3.3.3 and Figure 3.3.3, respectively.

Table 3.3.3: Hot Hardness Test for Stainless Steel Sample

S/N	Temp(^{0}C)	BHA
1	100	74.60
2	150	70.40
3	200	63.64
4	250	60.40
5	300	59.01
6	400	56.94

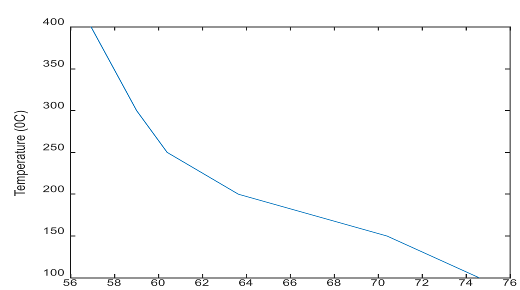

Figure 3.3.3: Hot Hardness Test for Stainless Steel Sample

MATLAB CODES FOR THE GRAPH ABOVE

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```

IV. CONCLUSION

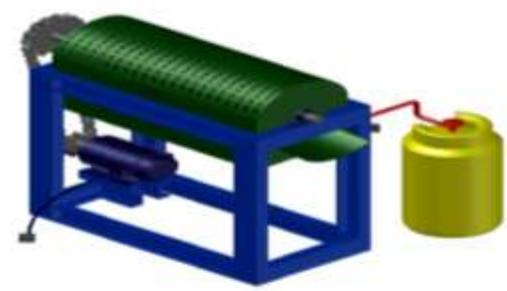
It is very clear that the traditional method of frying garri is neither safe for the product nor the person frying the garri. Hence, there is a need for a mechanical machine or device to help maximize product and reduce waste.

At end of the corrosion, hardness and hot hardness tests, we conclude as follows based on the observations made:

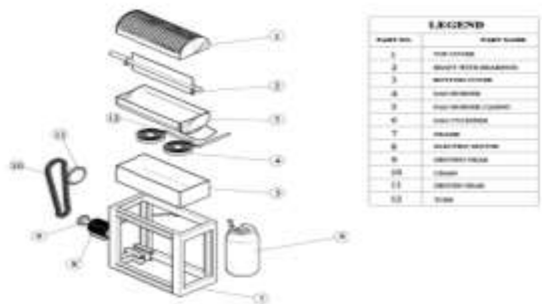
- Based on the corrosion test, Aluminum and stainless steel are the safest material for the design and fabrication of a garri frying machine (food processing machine). This is because of these samples possess better chemical stability in a corrosive environment than mild steel.
- Based on these tests, one of the samples stands tall above the others. Thus, stainless steel would be the best material for the design and fabrication of a garri frying machine. This is because it possesses excellent strength (hardness and hot hardness) and chemical stability.

APPENDIX

ISOMETRIC VIEW

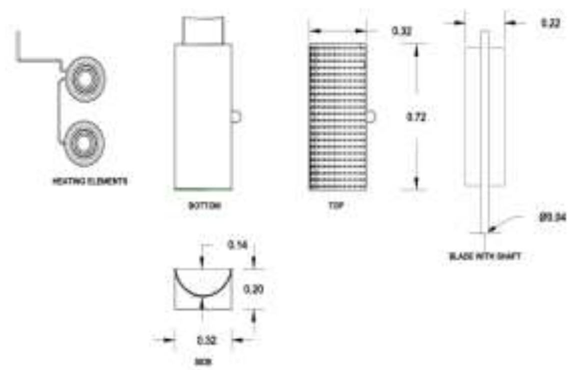


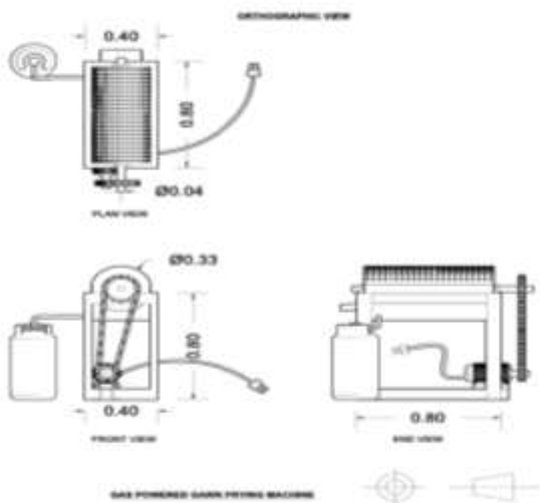
GAS POWERED GARRI FRYING MACHINE



EXPLODED VIEW

COMPONENTS





ACKNOWLEDGEMENT

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