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# DESIGN AND CONSTRUCTION OF A DUAL OPERATED GAS-FIRED MEAT ROASTING MACHINE

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***Abstract***
Weirs Food roasting is a technique used for transforming raw food into edible and tasty form, accompanied with change or alteration in the appearance, taste, aroma, shape, or colour of the end product. Thus, this research focuses on the development of a dual operated gas-fired meat roasting machine, with components which include; heating pan, burner, shaft, cover grill, gears, electric motor, power control system and machine frame. The design analysis of machine components was done using appropriate design models. Solidworks CAD software was used to model the design. The simulation of the design was done using ANSYS software. Fabrication of the designed machine was done using appropriate manufacturing techniques. Simulation stress distribution along the structural frame shows that maximum stress experienced on the machine frame is 55.56 MPa. The yield strength of the material for the frame (Plain Carbon Steel) is 220.6 MPa, an indication that the structural beam is capable of bearing the stress imposed on it without failure. Similarly, maximum deformation experienced is 28.23 mm. The maximum deflection from neutral position is negligible in size and cannot cause failure. Simulation results of heat analysis showed that the temperature experienced on the grill is between 340 K (67 ºC), and 350 K (77 ºC), while the temperature at the burner is 451 K (178 ºC). While evaluating the developed meat roasting machine, it was noted that weight of meat sample after roasting 500 g meat was 257 g and the total roasting time was 30 minutes. In order to guarantee the safety of roasted meat produced from the machine, microbial analysis test was done. Two samples were analyzed with sample 1 having a Total Viable Coliform Count of 24 CFU/100 ml and sample 2 with Total Viable Coliform Count of 26 CFU/100 ml. These results indicated that the two samples do not exceed the permissible limit for total viable coliform count in meat, which is typically set at ≤100 CFU/g, thus making the roasted meat safe for consumption..

***Keywords:*** *Design, fabrication, simulation, meat, roasting machine*

## Introduction

Meat is a stable food in many diets. Its taste is satisfying and is an excellent source of high-quality protein and other important nutrients. It is a source of essential amino acids, B-complex vitamins, and minerals (Mishra et al., 2017). Food roasting is a method and technique used for transforming raw food into edible and tasty food accompanied with change or alteration in the appearance, taste, aroma, shape, or colour of the end product. The traditional method of use of open grill in Nigeria as an example, does not produce consistent end products (Ganiyu et al., 2020). Report has it that different cooking methods can affect the quality, taste and healthiness of meat (Franziska, 2020). Raw meat is perishable in nature, hence the need to preserve meat and increase shelve life (Loskota et al., 2023).

Roasting is one of the easiest ways to cook a large cut of meat with minimal effort. Roasting and baking are universal cooking methods which usually involve heating the food inside an oven at a uniform temperature. During oven roasting, hot air circulates around the meat, cooking all sides evenly (Danilo, 2020). Microorganisms grow easily on fresh meat due to high-water content which limits the shelf life of the meat (Ayanwale et al., 2007). The drying process can reduce the water content of meat thereby extend the shelf life of dried meat (Modi, 2007). Dehydrated meat, either cut or ground meat, is widely used as an ingredient in various instant product formulas, such as pasta, noodles, porridge, and soup. The presence of dried meat ingredients in instant food products increases the nutrition and sensory value of these products

(Laopoolkit and Suwannaporn, 2011; Aykın and Erbas, 2016). The drying process should be designed properly so that the dried product satisfied the product standards.

Mediani et al. (2022) posited that the quality of dried meat can be influenced by a variety of factors, such as production conditions and the major biochemical changes that occur during the drying process. Generally, the drying process must consider nutritional and sensory aspects and food safety. The drying process results in significant changes in the physicochemical properties and structure of foods. Some noticeable changes arising from meat drying are; nutritive value (Ayanwale et al., 2007), color, rehydration, texture, and muscular structure (Laopoolkit and Suwannaporn, 2011).

Processed meat products are still in their infancy in some regions. Meat roasting generally has been in existence for ages. However, despite progress being made in engineering and technology, greater percentage of meat being roasted are still being done manually in an unhygienic way. Consideration for intervention into meat roasting machine came to ease the burden of roasting and to get it done in under hygienic condition.

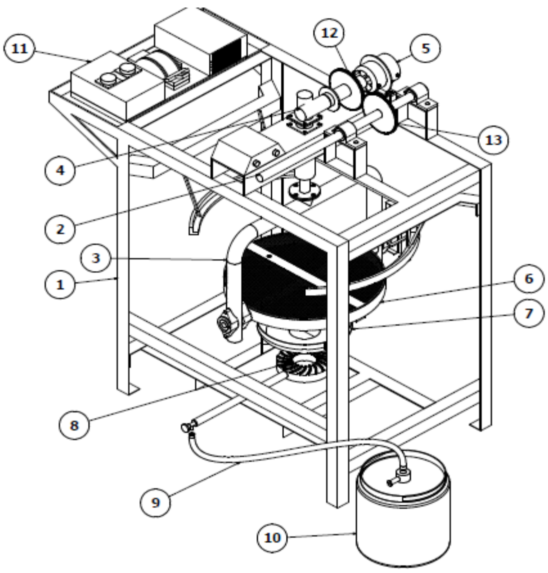
There have been a few products developed in the market that attempted to solve the productivity issues in food roasting. Ezekiel et al. (2012) and Adisa, (2018), developed charcoal fired and electric heated plantain (Musa Paradisiaca) roasting machine respectively. Adegbola et al. (2012) designed and constructed a domestic basic oven, which was tested with varieties of food item like fish, meat and egg. Oke, (2013) developed a manually operated multi-purpose roasting charcoal fired roaster. Awopetu and Aderibigbe (2017), developed a manually operated multi-purpose roasting machine. Kabri et al. (2010) developed a manual groundnut roasting machine. Ahanmisi et al. (2019) and Unguwanrimi et al. (2020) developed similar manually operated machines and were able to achieve a 98 % roasting efficiency.

Traditionally, meat roasting is done by placing the meat to be roasted on a wire mesh platform over burning fire wood or charcoal (Digitemie et al., 2016). This source of heat (charcoal) is a danger to the environment in that the process of acquiring the charcoal promotes deforestation which contribute to global warming (Lawrence, 2012). The process of roasting requires manual control of intensity of the heat and turning of the meat from time to time to ensure the roasting is uniform, a reported in many of the reviewed works. All these require a lot of concentration, intense labour and exposure to heat radiation. Attainment of required temperature at every stage of roasting also takes longer time. Therefore, there is a need to come up with a technology that will minimize these challenges since meat roasting needs to be done in a conducive, hygienic and environmentally friendly way, that is free from pollution due to smoke and heat radiation. Moreover, innovations in food processing and manufacturing support the agenda for sustainable development goal 9 (SDG9) of the United Nations on industry, innovation and infrastructure. In pursuant to this goal, this study aims to achieve this.

## Materials and Method

### Design Criteria and Consideration

The design criteria for the meat roasting machine as presented in Table 1, serves as guide in the implementation of the detailed design analysis and




| PART LIST | | | |
|---|---|---|---|
| S/N | PART NAME | MATERIAL | QTY |
| 1 | STAND | MILD STEEL | 1 |
| 2 | DRIVEN SHAFT | MILD STEEL | 1 |
| 3 | ARM | MILD STEEL | 1 |
| 4 | MOTOR SHAFT | MILD STEEL | 1 |
| 5 | ELECTRIC MOTOR | | 1 |
| 6 | COVER GRILL | MILD STEEL | 2 |
| 7 | HEATING PAN | MILD STEEL | 1 |
| 8 | BURNER | CAST IRON | 1 |
| 9 | HOSE | PVC | 1 |
| 10 | GAS CYLINDER | MILD STEEL | 1 |
| 11 | POWER CONTROL | | 1 |
| 12 | DRIVE GEAR | MILD STEEL | 1 |
| 13 | DRIVEN GEAR | MILD STEEL | 1 |

**Figure 1:** Isometric View of the Gas Fired Meat Roasting Machine

for smooth operation of the machine, which must not be exceeded.

**Table 1: Design Criteria**

| Parameter | Value |
|---|---|
| Weight of meat or product | $\leq 15\ kg$ |
| Height of cabinet | $\leq 1\ m$ |
| Length of cabinet | $\leq 0.9\ m$ |
| Width of cabinet | $\leq 0.7m$ |
| Output Speed | $\leq 12\ rpm$ |
| Overall weight of the machine | $\leq 50$ |

**Design Criteria and Consideration**

The isometric and exploded views of the designed gas fired meat roasting machine are presented in Figures 1 and 2 respectively. The modelling was done using solidworks software.

The torque transmitted by the driven gear of the gearbox can be gotten from Equations 3 and 4 respectively, according to Khurmi and Gupta (2005);

For the driver (worm);

$$P_1 = \tau_1 \times \frac{2\pi N_1}{60} \quad (3)$$

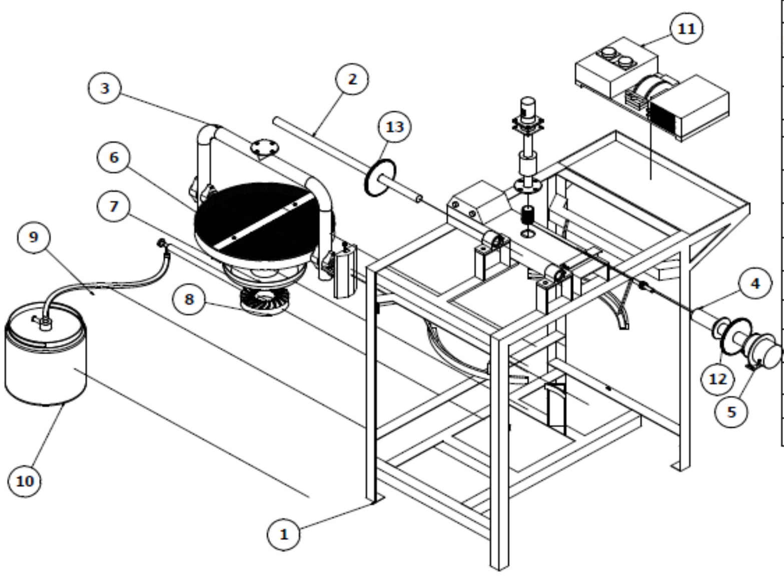
For the driven (wheel);

$$P_2 = \tau_2 \times \frac{2\pi N_2}{60} \quad (4)$$

Equation 3 can be re-written as presented in Equation 5

$$P_1 = \tau_1 \times \frac{2\pi N_1}{60 N_2} \times N_2 \quad (5)$$

Let $a = \frac{N_1}{N_2}$ (Khurmi and Gupta, 2005)

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| 8 | BURNER | CAST IRON | 1 |
| 9 | HOSE | PVC | 1 |
| 10 | GAS CYLINDER | MILD STEEL | 1 |
| 11 | POWER CONTROL | | 1 |
| 12 | DRIVE GEAR | MILD STEEL | 1 |
| 13 | DRIVEN GEAR | MILD STEEL | 1 |

**Figure 2:** Exploded View of the Gas Fired Meat Roasting Machine

**Design Analysis of Some Machine Components**

**Mechanical Power**

Recall according to Khurmi and Gupta (2005), the mechanical power is given by Equations 1-2;

$$P = \tau\omega \quad (1)$$

and $\omega = \frac{2\pi N}{60}$ (2)

where; $P$ is mechanical power,

$\tau$ is the torque produced,

$\omega$ is the angular velocity,

$N$ is the rotational speed of the shaft.

Thus, substituting $a$ into Equation 5 gives Equation 6

Then, $P_1 = \tau_1 \times \frac{2\pi N_2 \times a}{60}$ (6)

By making $a$ in Equation 6 the subject of formular, Equation 7 is derived

$$a = \frac{60 P_1}{\tau_1 \times 2\pi N_2} \quad (7)$$

Similarly, Equation 4 can be re-written as shown in Equation 8;

$$P_2 = \tau_2 \times \frac{2\pi N_2}{60 N_1} \times N_1 \quad (8)$$

Let $\frac{1}{a} = \frac{N_2}{N_1}$. Hence, by substituting $\frac{1}{a}$ into Equation 8, Equation 9 is derived;

$$P_2 = \tau_2 \times \frac{2\pi N_1}{60 \times a} \quad (9)$$

Therefore, making $a$ in Equation 9 the subject of formula, Equation 10 is derived;

$$a = \frac{\tau_2 \times 2\pi N_1}{60 P_2} \quad (10)$$

Thus, equating Equations (7) and (10) produces Equation 11

$$\frac{60 P_1}{\tau_1 \times 2\pi N_2} = \frac{\tau_2 \times 2\pi N_1}{60 P_2} \quad (11)$$

Making $\tau_2$ in Equation 11 the subject will give Equation 12

$$\tau_2 = \frac{900 P_1 P_2}{\pi^2 N_1 N_2 \tau_1} \quad (12)$$

Where $P_1$ and $P_2$ are the power delivered to the gearbox (input) and power delivered by the gearbox (output) respectively**,** $\tau_1$ and $\tau_2$ are the input torque and output torque respectively.

For the model above, the input parameters of the gearbox is the same as the rating (output) of the prime mover (electric motor in this case) employed.

**Speed Control**

Due to limited availability of range gearboxes suitable for this purpose, a $20:1$ worm and wheel reduction gearbox was obtained. Therefore, the output speed can be obtained as shown in Equation 14, according to Khurmi and Gupta, (2005);

$$\frac{N_1}{N_2} = 20 \quad (14)$$

Where $N_1$ is $1800\ rpm$ (gotten from the nameplate of the electric motor)

$$\therefore \frac{1800}{N_2} = 20$$

$$N_2 = 90\ rpm$$

The module has to be used with the gearbox (i.e. the module cannot be used alone to control the speed) for the reasons that a low speed but high torque form of output power is required.

**Burner Design**

Due to The control and burner assembly in the combustion chamber are designed to control the fuel (gas) flow and mix the fuel gas with an appropriate amount of air, within the flammability limits, such that the mixture can be easily ignited and completely burned in safety. According to Hein, 2015, the combustion equation of propane is given by

$$C_3H_8 + 5(O_2 + 3.76N_2) \rightarrow 3CO_2 + 4H_2O + 18.8N_2 + Heat$$

**Burners and Flame Characteristics**

A burner is a device which enables a chemical reaction of fuel gas (such as acetylene, natural gas or propane) and oxidizer (usually oxygen from air) to produce heat in a controlled way. Domestic/cooking gas burners are normally designed in such a way that complete combustion is achieved. Burners are sometimes categorized according to the mode of formation of the flame (Lorenzo, 2008), which are; non-aerated burner and aerated burner

**Mode of Heating**

Since the barbecue (meat) is required to be of high quality, an indirect mode of heating is employed in this research. This is conceived in order to prevent burning of the meat on the surface and to eliminate pollution due to gas combustion on the meat. This is achieved with the help of a hollow truncated dome introduced between the burner and the grill. Also, provision is made for the dropping juice from the meat to be channeled away, through the use of hollow pipes attached to the truncated dome. The heat transfer from the flame of the combustion process to the meat in the grill can be summarized as follows: Radiative heat transfer from the flame; Radiative heat transfer from the internal surface of the truncated dome to the grill and consequently directly to the meat (product); Convective heat transfer from the burner through the centre of the truncated dome to the meat; Convective heat transfer from the burner through the holes on the side of the truncated dome to the meat; Heat conduction from the grill's external surface to its internal surface and consecutively to the meat.

**Grill Handling Capacity**

Average density of cow, sheep, goat, chicken and pork meat ranges from $1068\ kg/m^3$-$1041\ kg/m^3$ (Adam *et al.,* 2017). Equations 15-16 gave the expression for the volume and density.

Density taken to be 1041 $kg/m^3$,

Volume of the meat keeper, $V = \pi r^2 h = \pi \times 0.15^2 \times 0.07 = 0.005\ m^3$ (15)

According to Khurmi and Gupta, 2005, recall that

density= $\frac{Mass}{Volume}$ (16)

Mass $= 1041 \times 0.005 = 5.15\ kg$

Therefore, the mass of meat that can be handled by the grill can be taken to be 5 kg. When meat is cooked, it will be subjected to shrinkage.

According to Julia (2021), beef meat loses 37% of its mass when you barbecue it. Thus, it is expected that a raw beef meat of 5 kg will shrink to about 3.15 kg after roasting.

## Results and Discussion

### Load Analysis on the Frame of the Meat Roasting Machine

The purpose of this analysis is to simulate the static forces and load acting on the structural stand that carries the parts of a meat roasting machine. This analysis is done with a view to ensure that the structure is sufficiently designed to carry the weight of the parts of the roasting machine being placed on the members of the structure without permanent deformation or failure. The stand is made of plain carbon steel, normalized at 870ºC.

This analysis was carried out using the Solidworks 2021 Simulation CAD software.

### Stress Analysis Results

The simulation result for machine stress analysis is presented in Figure 3.

Figure 3 shows the stress distribution along the structural frame. The maximum stress experienced on the structure is 55.56 MPa. The yield strength of the material for the frame (Plain Carbon Steel) is 220.6 MPa. This shows that the structural beam is capable of bearing the stress without failure. Secondly, from the table above, we also see a high measure of stability of the structure at the legs.

### Machine Frame Displacement Simulation Result

The simulation result for machine frame displacement analysis is presented in Figure 4.

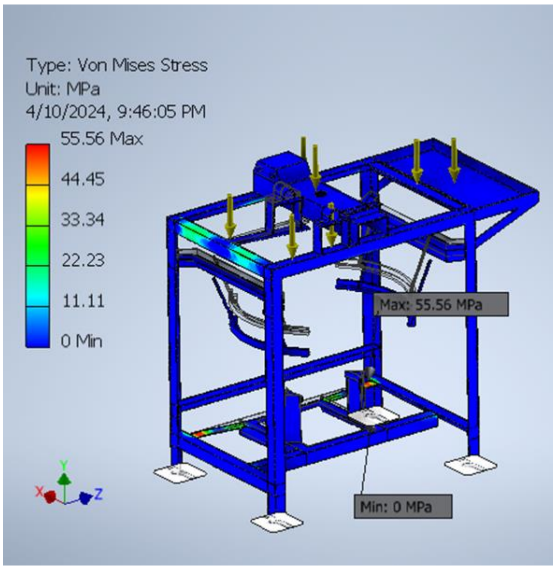


**Figure 3:** Machine Frame Stress Distribution Simulation Result

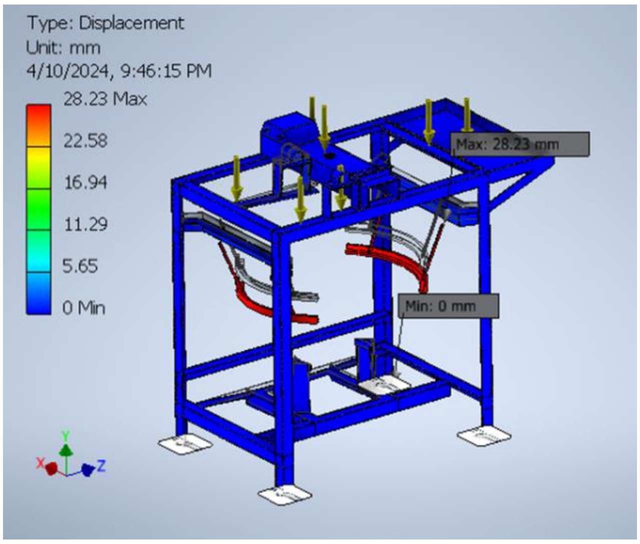


**Figure 4:** Frame Deformation Simulation Result

Figure 4 shows the amount of deformation experienced by the structural stand. From the data above, it shows that the maximum deformation experienced by the chair is 28.23 mm. This maximum deformation is experienced at the side curved members of the frame. This maximum deflection from neutral position is very negligible in size and cannot cause failure. It can also be reduced by improving the amount of reinforcement on the two frame members, so as to cushion the effect of gravitational forces on it, and prevent a slow but permanent deformation of the two side members.

**Heat Analysis Simulation Results for the Meat Roasting Machine**

**Gas Burner**

Machine parts simulated for heat analysis include; the grill, heating pan, and gas burner.

The simulation was carried out using the ANSYS Fluent 2022 software environment and the results are presented in Figures 5-7 respectively.

Figure 5 shows the parts considered for the thermal analysis. The surrounding medium (represented by the box) is air. The air flows from the heater at the bottom to the grill at the top, thus carrying the heat as it flows. The Boundary conditions and simulation parameters are shown in Table 2.

**Heat Analysis Simulation Result**

Figure 6 shows a view of how the heat flows from the gas burner to the meat grill.

The figure also shows that the temperature being experienced on the grill is between 340 K (67 ºC), and 350 K (77 ºC), while the temperature at the burner is 451 K (178 ºC).

According to Bengtsson et al (1976), the required maximum temperature for roasting beef is 70 ºC, while the temperature required to roast chicken is 75 ºC. This required temperature is well achieved by the design as shown by the temperature scale.

From the results obtained from the conjugate heat transfer simulation, the temperature range of the design shows that it can operate within the standard required temperature range for roasting meat. The inclusion of a heating pan into the system helps to evenly spread the heat generated by the burner, before it is then transferred to the grill. This spread of the heat helps to prevent high concentration of heat within a region that will cause the meat to get burnt. The design of the system is well arranged to suit its deigned intentions.

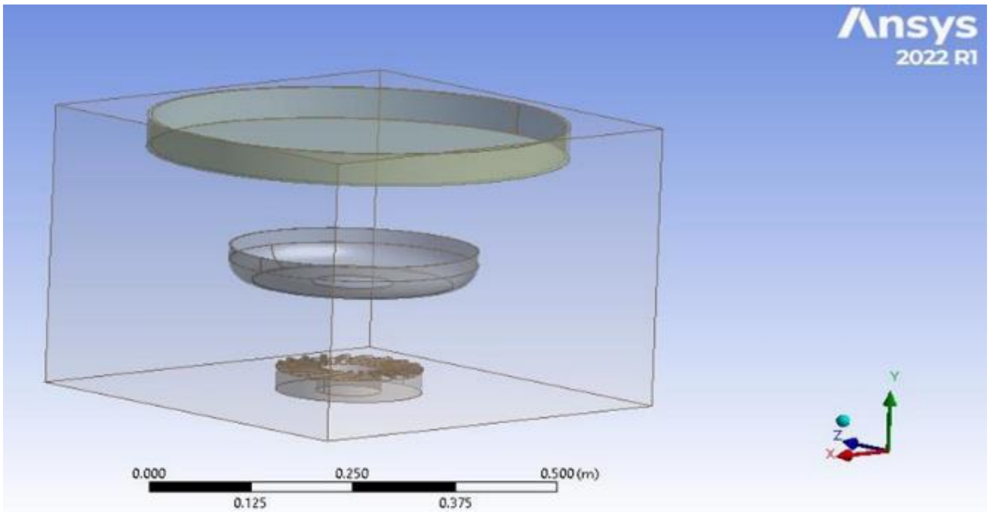


**Figure 5:** Machine Frame Stress Distribution Simulation Result

**Table 2: The Boundary conditions and simulation parameters**

| S/N | Parameter | Value |
|---|---|---|
| 1. | Standard temperature | 30 ºC/303 K |
| 2. | Energy from cooking gas | 40000 W/m3 |
| 3. | Velocity of air flow | 0.001 m/s |
| 4. | Material of grill | Stainless steel |

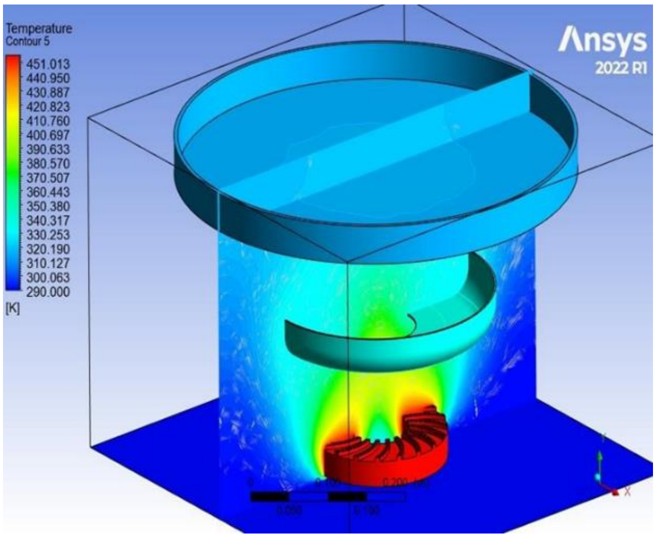


**Figure 3:** Heat Analysis Simulation Result

**Performance Evaluation of the Developed Meat Roasting Machine**

The front view of the developed meat roasting machine is presented in Plate 1.

For the performance evaluation of the developed meat roasting machine, 2 kg fresh meat was sourced for at Akure main market. The meat was cut into four equal parts, each part weighing 500 g each for the evaluation to be ran four times. The 500 g fresh meat was further sliced for the evaluation. A digital weighing balance was used to take the measurement and a digital stop watch was used for time reading. After washing the meat in a clean water, 500 g fresh meat was loaded into the grill and the grill cover was manually tightened. The burner was ignited. The spinning and flipping of the machine was achieved through the automatic control system. It was noted that waiting time before rotation and spinning after the commencement of roasting was 5 minutes, spinning and rotation time for the meat was 6 seconds, cooling time for the roasted meat was 6 minutes, weight of meat sample after roasting was 257 g and total roasting time was 30 minutes.

Plates 2, to 6 shows the fresh meat sample that was bought, the digital weighing balance under no load, the weighing balance when loaded with 500 g of meat, the meat roasting machine being used and the roasted meat sample, respectively.

**Plate 1:** Front View of the Developed Meat Roasting Machine

**Plate 2:** Fresh Meat

**Plate 3:** Digital weighing balance under no load

**Plate 4:** Weighing balance with 500 g of meat

**Plate 5:** Machine being used

**Plate 6:** Roasted Meat Sample

**Microbial Analysis of the Roasted Meat Sample**
The proximate analysis of the meat sample was done at Food Science Technology Laboratory of Federal University of Technology, Akure.
Two samples were used to check the microbes of the dried meat. The results are shown in Table 3.

**TVCC** is the total viable coliform count which is a crucial parameter in quality assessment of foods. It measures the overall microbial population, including bacteria, yeast, and mold spores, present in a sample. It is commonly used to assess the general cleanliness and potential contamination of water, food, and other substances. As shown in Table 3, two samples were analyzed with Sample 1 having a Total Viable Coliform Count of 24 CFU/100 ml and Sample 2 with Total Viable Coliform Count of 26 CFU/100 ml. These results indicate that the two samples do not exceed the permissible limit for Total Viable Coliform Count in meat, which is typically set at ≤100 CFU/g which makes it save to consume.

**TVFC:** The Total Viable Fecal Count (TVFC) is a crucial parameter used in microbiology to assess the level of fecal contamination in various samples. The Samples analysis show no TVFC indicating no contamination.

**TVEC:** E. coli is a bacterium commonly found in the intestines of humans and animals which serves as an indicator organism for fecal contamination in water, food, and other environments. The analyzed samples show no presence of E. coli as shown in Table 4 which makes the meat consumable.

**TVYMC:** The Total Viable Yeast/Mold Count in the sample analyzed indicates the total number of viable yeast and mold present in the sample. The total viable yeast/mold count obtained suggests that the sample may have been exposed to conditions conducive to yeast and mold growth. Sample 1 shows a TVYMC value of 2 Cfu/ml and sample 2 shows a TVYMC value of 4 Cfu/ml. When compared to the standard TVYMC allowed according to FDA is less than 10 yeast v/mold, the meat is safe for consumption.
Table 4 shows the agents used for the identification of the bacterial count seen in the meat during the analysis.

**Proximate Analysis**
Proximate analysis is a crucial method used to determine the nutritional composition of meat products. It provides valuable insights into the nutritional composition of meat products. Three Samples was used for analysis of each nutritional component and their average was taken as presented in Table 5.

**Protein Content**: By measuring the nitrogen content of the sample, the protein content based on nitrogen-to-protein conversion factors was calculated and determined to be 28.316%.
**Fat Content**: Fat content was calculated and determined to be 7.282% through solvent extraction methods.

**Ash Content**: Ash content (the mineral content of the meat sample after complete combustion at high temperatures) was determined to be 0.944. It provides insights into the inorganic components present.

**Fiber Content**: No Fiber content was seen in the samples as presented in Table 5.
**Carbohydrate Content**: The Carbohydrate content was calculated as 20.748% using Equation 17 below.

$$CC = 100\% - (\%PC + \%AC + \%FC + \%FC) \tag{17}$$

Where CC is the carbohydrate content of the sample,
%PC is the % protein content,
%FC is the fat content,
%AC is the %ash content, and
%FC is the %fiber content from 100%, as carbohydrates are calculated by difference.

**Table 3: Microbial Analysis Table**

| Samples | TVCC (Cfu/ml) | TVFC (Cfu/ml) | TVEC (Cfu/ml) | TVYMC (Cfu/ml) |
|---|---|---|---|---|
| 1. | 24 | NIL | NIL | 2 |
| 2. | 26 | NIL | NIL | 4 |

Where;
TVCC is the total viable coliform Count
Cfu is the colony forming unit
TVFC is the total viable Feacal count
TVEC is the total viable E.coli count
TVYMC is the total viable yeast/mold count

**Table 4: Cultural and Biochemical Characteristics of Bacterial Isolated from Roasted Meat Samples**

| Sample | | | | |
|---|---|---|---|---|
| S/NO | ISO 1 | ISO 2 | ISO 3 | ISO 4 |
| GRAM | - | + | + | + |
| SHAPE | S.rod | L.rod | Cocci | Cocci |
| CATALASE | + | + | + | + |
| GAS | + | + | + | + |
| $H_2S$ | + | - | - | - |
| LACTOSE | - | - | - | - |
| SUCROSE | + | + | + | + |
| GLUCOSE | + | + | + | + |
| M.R | + | + | + | + |
| V.P | + | + | + | + |
| STARCH HYDROLYSIS | - | - | + | + |
| CASEIN HYDROLYSIS | + | + | + | - |
| LIPASE HYDROLYSIS | - | + | + | - |
| MOTILITY | - | + | + | - |
| CITRATE | - | - | + | + |
| NITRATE | - | - | + | + |
| FRUTOSE | + | + | + | + |
| XYLOSE | + | + | + | + |
| GALACTOSE | + | + | + | + |
| MANOSE | + | + | + | - |
| MALTOSE | + | + | + | + |
| SOBITOL | + | + | + | + |
| ARABINOSE | + | + | + | + |
| STARCH | + | + | + | - |
| GLYCEROL | + | + | + | + |
| INDOLE | - | - | - | - |
| PROBABLE ORGANISM | Enterobacter spp | Bacillus subtilis | Staphylococcus epidemidis | Micrococcus leutus |

**Table 5: Proximate Analysis**

| Nutritional Composition | Sample 1 (%) | Sample 2 (%) | Sample 3 (%) | Average (%) |
|---|---|---|---|---|
| Protein | 28.234 | 28.457 | 28.257 | 28.316 |
| Moisture | 43.477 | 42.325 | 42.328 | 42.710 |
| Fat | 7.097 | 7.466 | 7.283 | 7.282 |
| Ash | 0.878 | 1.010 | 0.944 | 0.944 |
| Fibre | Nil | Nil | Nil | |

## Conclusion

A research on development of a dual operated gas-fired meat roasting machine has been carried out. Appropriate design equations were used in the analysis of some of the machine components. The design drawings and simulation were done using solidworks and ANSYS software. The results from the simulation. Stress distribution along the structural frame shows that maximum stress experienced on the machine frame is 55.56 MPa. The yield strength of the material for the frame (Plain Carbon Steel) is 220.6 MPa. This indicates that the structural beam is capable of bearing the stress imposed on it without failure with the high measure of stability of the structure at the legs. Similarly, amount of deformation experienced by the structural stand shows that the maximum deformation experienced is 28.23 mm. This maximum deformation was experienced at the side curved members of the frame. This maximum deflection from neutral position is very negligible in size and cannot cause failure. The roasting machine performance evaluation shows that cooling time for the roasted meat was 6 minutes, weight of meat sample after roasting was 257 g and total roasting time was 30 minutes. The results of microbial and proximate analyses carried out indicated that the roasted meat is safe for human consumption.

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