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Design and Development of a Dual Powered Grill Oven for Application in Higher Institution of Learning

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Abstract –This study presents the design and development of a dual powered (charcoal and electricity) grill oven for application in higher institutions of learning. The equipment is powered by both electric power and charcoal, which provides the user with more options to choose from. The design of the oven is such that it can be used outdoors and indoors for grilling and roasting, which makes it a pocket-friendly and user-friendly kitchen appliance for students and researchers in higher institutions of learning. The study uses an indirect firing approach to the design and development process, which provides the users with the best experience possible. A prototype was also developed and tested to demonstrate the functioning of the dual powered grill oven. Results from the testing of the prototype showed that the dual powered grill oven is highly functional, reliable, efficient, and user-friendly. The design and development of the dual powered grill oven can thus be beneficial to students and researchers in higher institutions of learning by providing them with a kitchen appliance that can be used both indoors and outdoors

Keywords: carbonization, charcoal, electricity, grill oven, maintenance, smoke

Introduction

In foodservice systems, there is a need to quickly cook items like meat patties.In recent decades, the mark et for healthier food products in fast food has grown significantly (Berry, 1994).Foodservice establishmen ts frequently use curing, grilling, heating, drying, smoking, barbecuing, and other processes that entail ap plying heat to the food's surface.In rotisseries, or grill rooms, the grilling process can also be done indoors .For foods with natural scents and aromas, grilling is one of the most popular outdoor cooking methods.T he meat receives the majority of its heat from the grilling apparatus's side, bottom, or above (UK, 2016).T o create a temperature that is high enough, a heat source must be used, primarily from the bottom. Additionally,some of the nearby materials are reached (Adeyeye & Oyewole, 2020).Grilling is a popular method that is regularly marketed as a healthy alternative to cooking with oil (Beckett,2012).The reason f or this is that the elevated temperatures employed in grilling enable a greater amount of vitamins and min erals, including calcium and iron, to permeate into the meal.This enhances the nutritional value of the foo d and adds additional nutrients that are difficult to obtain with other cooking techniques (like boiling or ba king).

Even more, grilling lowers the chance of developing chronic illnesses, but preserving a desirable, reliable quality is crucial.According to NYH (2022), there is evidence from recent studies that grilling food meant for human consumption may reduce the risk of developing heart disease,type 2 diabetes,and certain heatr elated illnesses.This is possible because grilling keeps food's nutritional value intact while retaining flavor , reducing caloric intake and encouraging weight loss.Marinating may cause less of these important comp ounds to form, according to BBC News (2008).Two varieties of grilling that can be done outside under co ver as a smoker or grill are barbecue and roasting (Shrvell, 2022).grilling process also has ability to helps to produce delicious food taste without going through any extra stress.

There are lots of different styles of grill in the market, but they can all be used in more or less the same way. According to Zhang et al (2022), it usually requires that cooking food is done adjacent to the heat source. The classification of oven based on heating mode are charcoal, gas or electric grill oven.

However, the use of grill oven can cause inhale of dangerous chemicals. According to Arun et al (2023), major meat and meat products processing including cooking grilling can cause release of somewhat contain polycyclic aromatic hydrocarbons (PAHs), which is very dangerous to health of human being. To achieve an environmentally friendly process,
most developed countries use electric or gas grilling methods.
Although there are many various grill styles available, they can all be used in essentially the same way.Zh ang et al. (2022) state that cooking food must typically be done next to a heat source.Charcoal, gas, and el ectric grill ovens are the different types of ovens according to their heating modes.However, using a grill oven can result in chemical inhalation.Arun et al. (2023) state that a number of common meat and meat pr oduct processing methods, such as grilling and cooking, can release polycyclic aromatic hydrocarbons (P AHs), which are extremely harmful to human health.In most developed countries, grilling with gas or elec tricity is an environmentally friendly method.
Traditionally, grilling has been done by hand using a charcoal grill and a grid iron, sometimes called a ski llet, that is suspended above a source of heat.According to Berry (1994),there is a clear need in food servi ce systems to quickly cook items like meat patties while preserving a desired, consistent sensory quality.B ecause it can result in a more effective and higher-
quality product,indirect fired ovens are important.The majority of gas-
and electricfired grill ovens use direct heat.To characterize an electric grill, all that's required is a heating element to caramelize or brown food that's placed on top of the oven.There will also be an extra part that s erves as a grill located at on the top roof.
An outdoor charcoal grill, also known as a wood fuel grill, is a contemporary take on a classic grilling app liance.An outdoor charcoal grill, also known as a wood fuel grill, is a contemporary take on a classic grilli ng appliance.One simple type of grill that can be used is one that burns wood or charcoal.Due to the oven' s significance in the cooking process, numerous works have been done on it.The development of an inexp ensive domestic electric oven with a blower included for increased efficiency was done by Adegbola et al. in 2012.Major design in over-fabrication was described by Akinnuli & Olufemi (2019).
While these ovens have helped to lessen the stress associated with outdoor cooking, they are not very effi cient in terms of smoke release, and while they have helped to increase the potential of the grilling industr y in the country, little to no attention has been paid to optimizing the popular traditional grilling oven for better efficiency through process and design.An indirect fired oven prototype that can be used to grill a va riety of foods fueled by charcoal and requires the use of another heat source (gas or electricity) has not be en designed in this manner in any of the design literature mentioned above. It is necessary to design and manufacture an oven that follows the users need using the sustainable design technique.
Promoting the output of grilled products through process and equivalents design will enhance their market values, thereby resulting in economic empowerment for stakeholders in hotel, restaurant and fast-foodbusiness.Designing and producing an oven with the needs of the user in mind while utilizing sustaina ble design principles is mperative.Empowering stakeholders in the hotel,restaurant,and fastfood industries financially will come from promoting the output of grilled products through process and equivalents desi gn,which will raise their market values.
The goal of this project is to create a prototype grill oven that meets the hygienic and safety requirements of both users and consumers of grilled food while assessing operating energy consumption using the idea of an additional grill device.According to Bello & Bello (2020), in order to stay relevant in the field of fo od and hotel engineering, our conventional grilling method needs to be improved.The study explores traditional grilling system design, focusing on charcoal grills and electric elements for indoor use. It suggests using sustainable, high-quality restaurant-grade charcoal for rural cooking, as bio-fuels like agricultural residues and wood are insufficient. Harrison (2020) recommends alternative designs, which involve using 100% sustainable, finest quality restaurant -grade charchol..

2.Methods and Materials

This work aims to develop a prototype grill oven that meets the hygienic and safety requirements of both operators and consumers of grill foods while evaluating the energy consumption during operation by utili zing the concept of an additional grill device.In order to stay relevant in the field of food and hotel engine ering, our conventional grilling method needs to be improved, claim Bello & Bello (2020).

2.1 Methods

2.1.1 Design Concept

The grill oven is made with the intention of minimizing material waste. Instead of building two separate chambers for the two sources, the heating element and the charcoal pan are combined into one chamber.At the bottom of the oven chamber is the charcoal pan, and near the inside base of the oven is the heating element fixed to the central side of the main chamber.Figure 1 illustrates that the oven's exterior is composed of mild steel sheeting, while the interior is composed of aluminum sheeting.

The space between the outside and of the compartment is lag with fiber glass materials. fiberglass is a commonest form of insulation and reinforcing lightweight objects. The oven design (see Fig. 1) has a general outlook dimension of 760 mm x 510 mm x 920 mm (length x width x height). A vent of 20mm is provided at the top of the oven which is connected to the inner baking chamber for the purpose of achieving continuous removal of the smoke and humid air from the inner baking chamber during grilling.

Fiberglass materials are used to fill the gap between the compartment's exterior and interior. The most popular material for lightweight object reinforcement and insulation is fiberglass. The overall dimensions of the oven design (refer to Fig. 1) are 760 mm x 510 mm x 920 mm (length x width x height). To achieve continuous removal of smoke and humid air from the inner baking chamber during grilling, a 20mm vent is provided at the top of the oven and connected to the inner baking chamber.

2.1.2 Design Considerations

Prior to designing the small dual powered oven, many factors were taken into account.Among the variables taken into account are the moisture and fat content, as well as the texture and color characteristics of the meat patties, as well as the grilling/hot air cooking parameters (air velocity, air temperature, cooking time).Given that measuring cooking loss is the most efficient and significant method for estimating certain correlated quality attributes, like juiciness and certain economic factors (Kuō, and Jelonk,2023).These will be this study's primary parameters of interest.

The size and shape of the food to be grilled, the ease of cleaning and maintenance, the ease of assembling the oven's components, grilling techniques, and the amount of time needed to grill the food are all additional factors to take into account.The grilling oven is constructed with a rectangular cross-sectional area. A vent is located on the upper left side of the oven and is connected to the inner grilling chamber to remove hot and humid air continuously while grilling.Oven capacity, measured in bread loaves processed in a batch using the dimensions displayed in Fig. 2.

2.2 Design calculation

Volume of the grill oven

Volume of the grill oven: the capacity of the is directly related to the volume of the grill food (vg) and is calculated according to Adamu et al(2013)as :

$$Vg=lt\square bt \square ht \quad (1)$$

Where l = length of the tray = 760mm

b = width of the tray = 510 mm

h = height of the tray = 920 mm

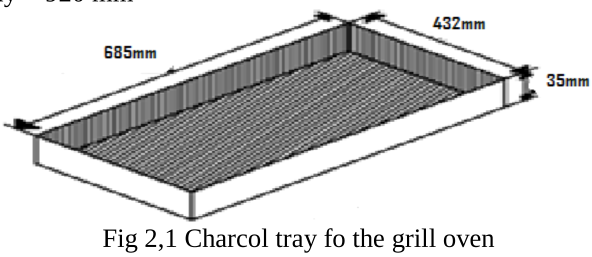

Fig 2,1 Charcol tray fo the grill oven

2.2.1 Volume of the Charcoal Tray (Vc)

Volume of the Charcoal Tray (Vt): it is computed using volumetric capacity of the charcoal pot (V2) using relationship given by John (2005) as:

$$Vt \square L\square B\square H\ 2 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where: L = Length of Charcoal Tray = 0.685m

b = width of Charcoal Tray = 0.432 m

h = height of charcoal tray =0.035m

Vc = 0.685× 0.432×0.03 = 0.0103572 m

2.2.2 Volumetric Capacity of the Charcoal Pot

Charcoal Volume: The charcoal pot's volumetric capacity was determined by comparing its volume to the amount of charcoal it holds. The design of the charcoal pot called for holding 15 kg of charcoal per operation. Khurmi and Gupta (2005) provided the following formula for calculating the volume of any material:

$$P_c = \frac{M}{\rho} \quad \text{..... (4)}$$

Where: V1 = volume of charcoal in m^3
M = mass of the material in kg = 30 kg
ρ= density of charcoal (kg/m3) = 641 kg/ m^3(Measured)

$$V = \frac{30}{641}$$

V1 = 0.047 m^3

The cuboid shape of the compartment was intended when designing the volumetric capacity of the charco al pot.The chosen dimensions for the charcoal pot were 685 mm (0.685 m) in length and 432 mm (0.432 m) in width.Figure 1 illustrates the detail.

2.2.3 Volumetric Capacity of the Charcoal Pot

Volume of the Charcoal: The volumetric capacity of charcoal pot was calculated in relation to the volume of charcoal it occupies. Charcoal pot was designed to contain 15 kg of charcoal per unit operation. The volume of the any material was calculated as given by Khurmi and Gupta (2005):

$$P_c = \frac{M}{\rho} \quad \text{..... (4)}$$

Where V1 = volume of charcoal in m^3
M = mass of the material in kg = 30 kg
ρ = bulk density of charcoal (kg/m3) = 641 kg/ m^3(Measured)

$$V = \frac{30}{641}$$

V1 = 0.047 m^3

In the designing of charcoal pot volumetric capacity, the shape of the compartment was designed to be cuboid. Lengths and breadth of the charcoal pot were selected to be 685mm (0.685m) and 432 mm (0.432m). The detail is shown in Figure 2.

2.2.4 Capacity of the oven grilling chamber (Cgc)

Capacity of the oven grilling chamber: the grill chamber is a cubical shape which appears as cube and it contain grilling plates. The capacity(C) of the oven was the volume of the grilling pans (Vgp) determined using the expression:

$$Vgp = Lgp \times BgpX\ Hgp2 \quad \text{..... (4)}$$

Where: Lgc = Length of the internal compartment of a section =0 .59mm
Bgc= Breadth of the internal compartment of a section = 0.34 m
Hgc =Height of a section the oven internal compartment = 0.860m

Bgc = breadth of the internal compartment of a section = 0.34 m
Hgc = height of a section the oven internal compartment = 0.860m
Cgc =0.59x0.34 x0×.860
= 0.17 m^3

The amount of goods (e.g meats)that the oven can hold for grilling in a single batch is known as its capaci ty.The total capacity of the oven, given its three layers,can be calculated by multiplying its section capacit y by the number of sections.

Total *Cgc* =0.17 x 4
= 0.68 m^3

2.2.4. Average Grilling Temperature (AGT)

Average grilling temperature (forfish) = 218.3^0 C = 491K

Let, Wf = weight of fish, 500g

Cb = Specific heat capacity of fish=1.67J/kgK (Hassan and Fung,2024)

GORT = Grill oven room temperature, 70^0C = 301K

Heat required,

QH = 0.5 kg x 14 x 1.67J/kgK x (491–301)

QH = 239.665 Joules

2.2.5 Moisture removal rate (MRR)

The amount of goods (e.g meats)that the oven can hold for grilling in a single batch is known as its capaci ty.The total capacity of the oven, given its three layers,can be calculated by multiplying its section capacit y by the number of sections.

$M_R = \frac{\Delta Mc}{T}$ …… (4)

ΔMc = Change in moisture content

T= Grilling time = 4 hours

2.2.6 Output capacity

Output capacity of the grilling oven can be measures for any case of grilled food by consider the quantity of food the grilling oven can handle per unit time of operation. It is estimated using expression given by Adamu et al., (2012) as:

$$OC_g = \frac{Mt}{t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where: WT = total weight of food handled by the grilling oven (say 50 kg)

T = total time taken to smoke (say 2hours)

$$OC_g = \frac{50}{3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

OCg=25 kg / hr

2.3 Materials and construction

A mild steel metal sheet was used for the construction of charcoal tray and graying tray and main over door. While the frame was made from angle bar iron, which formed the main support and of the entire

2.3.1 Construction of components

Some important components of grilling oven are

i. **Frame:** made up of angle iron of 25 x 25 mm. The angle irons were cut and welded together to form the mounting support for the kiln with 570 mm x 300 mm x 580 mm as the length, width and height respectively (Figure 1).

ii. **Door:** The oven has two doors which is use to cover the oven when necessary.

iii. **Tray:** a sheet of flat pan, rectangular metal pan used in an oven for baking. The dimension is 685mm by 432mm.

iv. **Power switch:** is a device that starts or stops the flow of electricity to the oven when it is moved up and down.

v. **Plug:** is a device use for making an electrical connection between an appliance and the mains, consisting of an insulated casing with metal pins that fit into holes in a socket. The plug is using 13A.

vi. **Body casting:** For the body casting, mild steel was used for covering the oven while stainless steel was used for the inner part.

vii. **Heating Element:** The standard 1000 wat electric heating element was used.

viii. **Thermostat:** It was installed to control the electric unit current flow

ix. **Trolly tires:** they were installed to allow easy movement of the grilling equipment.

x. **Grate:** They were the mech hole tray use to place tray when grilling meat that produce limited oil.

Keys: A- Electric heating element; B-Door; C—Position for charcoal tray; D Oven door

Fig. 2: Prototype dual fired grilling oven

3. Result obtained

Five different types of meats with the following volumes were used to test the best grilling in the dual-powered grill oven's electric and charcoal units:38 cm^3 of cow meet,38 cm^3 of goat meat,38cm^3 of beef,38 $cm^3$of chicken,and 38 cm3 of turkey.Temperature range for grilling process in a dual oven is between temperature of 100-140°C;cooking time:15 minutes;cooking duration:1 day.
Meat samples were superheated to a temperature of 30 degrees Celsius in the charcoal unit, ensuring that both sides of the samples received the same amount of heat.They were given ten minutes to cool before b eginning the gilling process.Vegetable oil at room temperature was added to the meat during the gilling pr ocess, and each side was slowly stirred until the meat's color changed on each side.The meat was quickly removed from the charcoal and allowed to cool once both sides had reached the necessary grilling temper atures.The dualpowered grilling oven's design prioritized inexpensive, easily accessible,
and nonpoisonous materials,
In this work, we proposed a straightforward design that can produce grilled meat products that are depend able, productive,and efficient for use in nearby fast-food restaurants, hotelsetc,
This apparatus is a suitable substitute for the manual grilling equipment that is primarily used in Nigeria.It is suitable for usage in both indoor and outdoor settings.The electrical component is intended for use ind oors, where the smoke released by the charcoal grilling unit may cause an annoyance.However, pregrillin g over charcoal will add appeal to the process and lower the electricity bill.The design of the equipment m akes cleaning and maintenance simple and affordable.

4.Conclusion

In designing the dual-powered grill oven, the focus was on cheap, eco-friendly, readily-available materials and we proposed a simplistic design that can deliver productive, efficient, and reliable cooking for use in fast foods, restaurant, hotels that deal with grill product (such as barbeques). This equipment can adequately replace smoking pan in must public food vendors in Nigeria, as well as rural area where there is no or limited supply of electricity, saves cost that would otherwise be spend to service utility bills and equipment is cheap in term of maintenance. In other to increase the grilling time in the charchol unit of the oven and reduce the high cost of electricity heated to the electric unit, the use of pe-grilling method is recommended, and this is done in the chachol oven unit. The use of charchol with high level of ecofriendly performance is recommended for the system. This will help to reduce the excess smoke related to the charchol unit of the grill oven. This
work focused on lowcost,materials when creating the dualpowered grill oven, and we suggested a straight forward design that can produce reliable, efficient, and productive cooking for use in fast food establishm ents, restaurants, and lodging facilities that offer grill products (like barbecues).
This equipment saves money that would otherwise be spent on utility bills and is inexpensive to maintain. It can effectively replace smoking pans in the majority of Nigerian public food vendors as well as rural ar eas with little to no electricity supply.The pregrilling method is advised in order to lengthen the grilling ti me in the oven's charchol unit and lower the expensive cost of electricity heated to the electric unit.

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