



**THE DESIGN AND FABRICATION OF GAS AND CHARCOAL OVEN FOR
DRYING FISH AND AGRICULTURE PRODUCE**

BY

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ENG2006290

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FACULTY OF ENGINEERING UNIVERSITY

OF BENIN

BENIN CITY.

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**A PROJECT SUBMITTED TO THE DEPARTMENT OF INDUSTRIAL
ENGINEERING IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE
AWARD OF BACHELOR OF ENGINEERING (B.ENG),
UNIVERSITY OF BENIN, BENIN CITY.**

MAY, 2026

CERTIFICATION

This is to certify that this design project was carried out by **AMOFAWORAN OGHENEVIYENZE FORTUNE** with Matriculation Number **ENG2006290**, in partial fulfillment of the requirement of Bachelor of Engineering (B.Eng) Degree in Industrial Engineering, University of Benin, Edo State, Nigeria.

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DEDICATION

This project is dedicated to God Almighty for his grace and mercy throughout this journey.

ACKNOWLEDGEMENT

My sincere gratitude goes to God Almighty for His divine strength, wisdom, and guidance throughout the course of my project. I am deeply thankful to my parents, Mr. and Mrs. Brown for their unwavering love, encouragement, and support, which made this academic journey possible.

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TABLE OF CONTENT

CERTIFICATION	iii
DEDICATION	iii
ACKNOWLEDGEMENT	iv
TABLE OF CONTENT	v
LIST OF FIGURES	ix
LIST OF TABLES	x
LIST OF PLATES	x
ABSTRACT	xi
CHAPTER ONE: INTRODUCTION	1
1.1 BACKGROUND OF THE STUDY	1
1.2 STATEMENT OF THE PROBLEM	1
1.3 AIMS AND OBJECTIVES OF THE STUDY	2
1.4 SCOPE OF THE STUDY	3
1.5 SIGNIFICANCE OF THE STUDY	3
CHAPTER TWO: LITERATURE REVIEW	5
2.1 HISTORY	5
2.1.1 EVOLUTION OF COOKING TECHNOLOGIES	5
2.1.2 INTRODUCTION OF GAS AS A COOKING FUEL	5
2.1.3 EMERGENCE OF ALTERNATIVE COOKING FUELS	5
2.1.4 DEVELOPMENT OF MULTI-FUEL OVENS	6

2.2	TYPES OF OVEN FOR COOKING AND DRYING	6
2.2.1	STATIONARY THREE LAYER OVEN DESIGN	6
2.2.2	DIRECT FLAME OVEN	7
2.2.3	CONVECTIONAL OVEN	8
2.2.4	HYBRID OVEN	8
2.3	ADVANTAGES AND DISADVANTAGES	8
2.4	PREVIOUS RESEARCH AND PROJECTS	9
2.5	RESEARCH GAPS	9
2.6	CONCLUSION	10
	CHAPTER THREE:	11
3.1	DESIGN ANALYSIS AND FABRICATION METHODOLOGY	11
3.2	MATERIAL SELECTION	11
3.2.1	FABRICATION MATERIAL	12
3.2.2	EQUIPMENT AND TOOLS	13
3.2.2.1	DESIGN TOOLS	13
3.2.2.2	FABRICATION EQUIPMENT	13
3.3	METHODS	15
3.3.1	SURVEY OF EXISTING HYBRID OVEN	15
3.3.2	DESIGN CONSIDERATION	16
3.4	DESCRIPTION OF HYBRID OVEN	17
3.5	DESIGN DIMENSION	18
3.6	DESIGN ASSUMPTION	18

3.7	DESIGN CALCULATION	19
3.7.1	DETERMINATION OF MOISTURE TO BE REMOVED	19
3.7.2	ENERGY REQUIRED FOR MOISTURE EVAPORATION	19
3.7.3	DETERMINATION OF AIR FLOW RATE	20
3.7.4	CHARCOAL HEAT CONTRIBUTION	20
3.7.5	GAS ENERGY CONTRIBUTION	21
3.8	FABRICATION PROCESS	21
3.9	PERFORMANCE EVALUATION	26
3.10	SAFETY CONSIDERATION	27
	CHAPTER FOUR:	28
4.1	RESULTS	28
4.1.1	DEVELOPMENT OF CONCEPTUAL DESIGN	28
4.2	PERFORMANCE TESTING	29
4.3	EXPERIMENTAL RESULT	31
4.3.1	TEMPERATURE DISTRIBUTION	31
4.3.2	TIME VS WEIGHT	31
4.3.3	DRYING RATE ANALYSIS	32
4.3.4	MOISTURE CONTENT ANALYSIS	34
4.3.5	FUEL CONSUMPTION	35
4.3.6	DRYING EFFICIENCY	35
4.3.7	BILL OF ENGINEERING MEASUREMENT AND EVALUATION	36
4.4	DISCUSION OF RESULTS	37
4.4.1	TEMPERATURE UNIFORMITY	37
4.4.2	DRYING TIME	37
4.4.3	FUEL ECONOMY	37
4.4.4	PRODUCT QUALITY	38

4.4.5 OPERATIONAL FLEXIBILITY	38
4.4.6 ENVIRONMENTAL AND SAFETY BENEFIT	38
4.5 COMPARISON WITH OTHER DRYING METHOD	38
4.6 CHALLENGES ENCOUNTERED	39
4.7 SUMMARY OF FINDINGS	39
CHAPTER FIVE: CONCLUSION AND RECOMMENDATION	40
5.1 CONCLUSION	40
5.2 RECOMMENDATION	41
REFERENCE	42

LIST OF FIGURES

FIG 2.1	STATIONARY OVEN DESIGN	29
FIG 4.1	3D VIEW OF OVEN	29
FIG 4.2	TIME VS WEIGHT	32
FIG 4.3	DRYING RATE ANALYSIS	33
FIG 4.4	MOISTURE CONTENT ANALYSIS	34

LIST OF TABLES

TABLE 3.1 DESCRIPTION OF MATERIAL USED IN CONSTRUCTION	MACHINE	12
TABLE 3.2 LIST OF CONSUMABLE EQUIPMENT AND ACCESSORIES		13
TABLE 3.3 CRITICAL EQUIPMENT USED FOR THE FABRICATION	OVEN	14
TABLE 4.1 TEMPERATURE DISTRIBUTION RESULT		31
TABLE 4.2 MOISTURE REDUCTION RESULT		31
TABLE 4.3 FUEL CONSUMED RESULT		35
TABLE 4.4 BILL OF ENGINEERING MEASUREMENT AND EVALUATION		36
TABLE 4.5 DIFFERENT DRYING METHODS AND THEIR RESULT		38
LIST OF PLATES		
PLATE 3.1 MEASUREMENT AND CUTTING OF MACHINE COMPONENT		22
PLATE 3.2 ASSEMBLY OF MACHINE COMPONENT		23
PLATE 3.3 ASSEMBLY OF OVEN AREA		24
PLATE 3.4 A VIEW OF ASSEMBLED TRAY		25

ABSTRACT

Post-harvest losses remain a major challenge for fish and agricultural product processors in developing countries due to limited access to efficient drying and preservation technologies. Traditional methods such as open-sun drying expose products to contamination, weather variability, and non-uniform drying, resulting in significant quality degradation and economic loss. This project addresses these challenges through the design, fabrication, and performance evaluation of a hybrid gas and charcoal oven capable of drying fish and selected agricultural produce efficiently and hygienically.

The hybrid system integrates two energy sources—liquefied petroleum gas (LPG) and charcoal—to provide operational flexibility, continuous heat supply, and improved temperature control. Locally available materials including mild steel, galvanized sheet metal, wire mesh trays, and glass wool insulation were used to ensure cost effectiveness, durability, and maintainability. The oven was tested with products such as catfish, pepper, and cassava chips. Performance parameters evaluated include temperature distribution, moisture reduction, drying efficiency, fuel consumption, and final product quality.

Results revealed that the oven achieved a drying temperature range of 60–65°C with uniform heat distribution across trays. Moisture reduction from 72% to 12% for fish was attained within 6–7 hours under hybrid mode, compared to 10–12 hours in traditional charcoal dryers. A drying efficiency of approximately 60.7% was recorded, demonstrating significant improvement over conventional drying systems. The dried products showed enhanced sensory and hygienic quality with minimized contamination and discoloration.

The study concludes that the hybrid oven is a practical, reliable, and sustainable technology for small- and medium-scale food processors, contributing to food security, reduction of postharvest losses, and socio-economic development. Further improvements such as automation of temperature control and incorporation of forced convection are recommended to enhance performance and commercial viability.

Keywords: Hybrid oven, drying efficiency, fish preservation, agricultural products, gas and charcoal heating, post-harvest losses, food safety.

CHAPTER ONE

1.1 Background of the Study

Preservation of food, particularly fish and agricultural produce, is a major concern in many developing countries where post-harvest losses are common due to inadequate storage and drying facilities, with high cases of theft and spoilage. Traditional methods of drying—such as open sun drying or smoking over firewood—often result in inconsistent drying, contamination, and nutrient loss. Moreover, these methods rely heavily on unsustainable fuels like firewood, contributing to deforestation and indoor air pollution.

In rural and semi-urban areas, cooking gas (LPG) and charcoal are widely available and commonly used as cooking fuels. However, these energy sources have not been efficiently harnessed for multi-functional use in appliances such as drying ovens. By designing a dualfuel oven that utilizes cooking gas and charcoal for both cooking and drying of fish and agricultural produce, communities can benefit from improved food preservation, reduced postharvest losses, and more efficient energy use.

This project seeks to fill that gap by designing and fabricating an oven that is affordable, easy to use, and effective in preserving perishable agricultural goods. It combines traditional fuels with modern insulation and combustion techniques to create a reliable tool for small-scale farmers, fishermen, food vendors, and households.

1.2 Statement of the Problem

In many rural and developing communities, a significant portion of fish and agricultural produce is lost due to inadequate preservation techniques. Traditional methods such as openair sun drying, wood smoking, and rudimentary charcoal setups expose products to dust, flies, rain, uneven drying, and contamination. These methods are not only inefficient but also contribute to health hazards and environmental degradation, particularly through deforestation and air pollution from excessive firewood use.

While cooking gas and charcoal are widely available and commonly used as cooking fuels, existing oven technologies rarely leverage these fuels efficiently for dual-purpose drying and cooking. Most available ovens are either expensive, electricity-dependent, or designed solely for cooking, without the insulation and airflow control needed for effective drying. Additionally, conventional drying setups lack temperature regulation, leading to under-dried or scorched produce, loss of nutrients, and reduced market value.

There is a critical need for a simple, cost-effective, and energy-efficient oven system that can meet the dual demands of cooking and drying fish and agricultural produce, using locally available fuels—cooking gas and charcoal. Such a solution would directly address food preservation challenges, reduce dependence on firewood, and provide rural households and small-scale food processors with a cleaner, more reliable alternative.

1.3 Aim and Objectives of the Study

Aim:

To design and fabricate a dual-fuel oven that uses cooking gas and charcoal to efficiently dry fish and agricultural produce, while also serving as a functional cooking appliance.

Objectives:

- To design an oven structure compatible with both cooking gas and charcoal, ensuring effective combustion and safe heat distribution.
- To select appropriate construction materials based on durability, thermal insulation, and cost-effectiveness.
- To fabricate and assemble the oven, including the combustion chamber, drying chamber, fuel inlets, and insulation.
- To test the oven's performance in terms of heat retention, drying uniformity, fuel efficiency, and safety.

- To evaluate the oven's suitability for drying fish and agricultural products under local environmental conditions.

1.4 Scope of the Work

This study is limited to the design and construction of a dual-fuel oven (cooking gas and charcoal) for domestic and small-scale commercial use. The oven is specifically intended for drying fish and common agricultural products such as fruits, vegetables, and grains. The project covers:

- Structural and thermal design
- Material selection
- Fabrication and assembly
- Performance testing
- Evaluation of drying effectiveness for selected produce

This project does not include mass production, advanced automation, or integration of renewable energy sources such as solar or biogas.

1.5 Significance of the Study

This study is significant in several ways:

- **Food Preservation:** Provides a reliable method for preserving fish and agricultural produce, reducing post-harvest losses and increasing food security.
- **Alternative to Firewood:** Offers an improved alternative to open-fire drying, reducing deforestation and harmful smoke emissions.
- **Dual-Purpose Use:** The oven serves both cooking and drying functions, making it a cost-effective and space-saving appliance for rural households.

- **Energy Efficiency:** Promotes efficient use of cooking gas and charcoal, reducing energy costs for users.
- **Local Fabrication and Adaptability:** Can be built using locally available materials, making it adaptable and scalable across different regions.
- **Empowerment and Entrepreneurship:** Supports small-scale entrepreneurs, such as farmers and fish processors, by enabling year-round drying, improving storage, and increasing income opportunities.

CHAPTER TWO

LITERATURE REVIEW

2.1 History

2.1.1 Evolution of Cooking Technologies

Cooking practices date back to prehistoric times when early humans discovered fire and began roasting food. Over time, the evolution of cooking tools progressed through stages—stone hearths, clay ovens, metal stoves, and, eventually, sophisticated gas and electric ovens. These advances improved cooking efficiency, food hygiene, and diet diversity, contributing significantly to societal development (McGee, 2004). The 20th century saw gas and electric ovens dominate kitchens due to their speed and control. However, these systems often depend on fossil-based or grid electricity, which may not be accessible or sustainable in rural contexts.

2.1.2 Introduction of Gas as a Cooking Fuel

The 19th century marked a shift in household energy with the advent of gas stoves powered by natural gas. They offered faster, cleaner, and more consistent heat than coal or firewood. Despite their benefits, concerns have risen over emissions and the long-term sustainability of fossil fuels (IEA, 2021). Liquefied petroleum gas (LPG), a refined form of cooking gas, became widely adopted due to portability and convenience.

2.1.3 Emergence of Alternative Cooking Fuels

In regions with unreliable access to modern energy sources, alternative fuels such as charcoal remain essential. Charcoal is produced from biomass and offers a high energy yield, though it raises environmental concerns due to deforestation and indoor air pollution (WHO, 2018). Conversely, cooking gas (LPG) is cleaner and more efficient but can be costly or unavailable in remote communities. Combining these fuels in a dual-fuel system provides flexibility and resilience.

2.1.4 Development of Multi-Fuel Ovens

The push for affordable, accessible, and environmentally friendly cooking solutions has led to the development of multi-fuel ovens. These ovens can use both cooking gas and charcoal, offering adaptability depending on fuel availability. Their use has expanded from households to small-scale commercial applications such as bakeries and agricultural produce drying. Notably, fish, yams, vegetables, and grains benefit from controlled drying that these ovens enable (Akinbami et al., 2001).

2.2 Types of Ovens for Cooking and Drying

Multi-fuel ovens come in several designs, each tailored for specific uses and regional requirements. They are particularly effective in agricultural contexts for food preservation.

2.2.1 Stationary Three-Layer Oven Design

This oven is built for fixed installations and consists of:

- Top Layer: A baking/drying chamber equipped with trays or racks.
- Middle Layer: An insulation zone to minimize heat loss.
- Bottom Layer: A combustion area that accommodates both cooking gas and charcoal.

It includes airflow openings, visibility windows, and a chimney to enhance ventilation and safety.

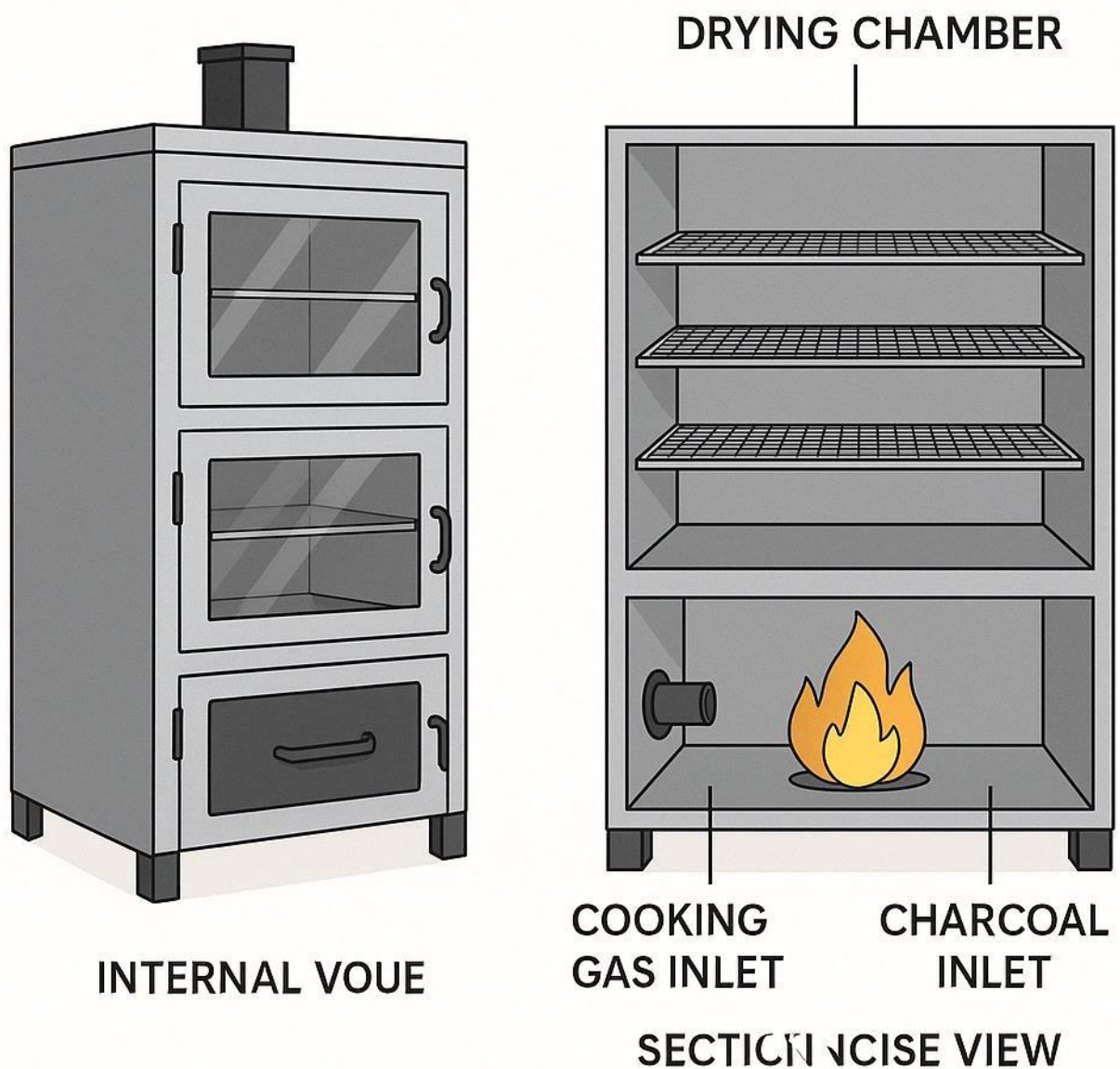


Fig.2.1: Stationary oven design

2.2.2 Direct-Flame Oven

Simple and inexpensive, this oven places food directly above an open flame. While easy to fabricate, it offers less control over heat distribution.

2.2.3 Convection Oven

Utilizes a fan to circulate hot air for uniform heat distribution, making it ideal for baking and drying. It may require electricity for fan operation.

2.2.4 Hybrid Oven

These ovens combine gas or charcoal with solar or electric elements, providing backup during fuel shortages. Though more expensive, they reduce emissions and long-term fuel costs.

2.3 Advantages and Disadvantages

Advantages:

- **Fuel Flexibility:** Operates on either charcoal or gas based on availability.
- **Food Preservation:** Ideal for drying fish, vegetables, and other perishables.
- **Adaptability:** Useful in rural, off-grid, or disaster-prone regions.
- **Energy Resilience:** Reduces dependence on unreliable electricity supplies.
- **Local Manufacturing:** Can be fabricated with local materials, encouraging job creation.

Disadvantages:

- **Startup Cost:** Some designs may require initial investment for materials and construction.
- **Maintenance:** Chimneys and combustion areas must be cleaned to ensure airflow.
- **Indoor Pollution:** Without proper ventilation, charcoal use may still produce smoke.
- **Training Required:** Users must be instructed on dual-fuel operation and safety.

2.4 Previous Research and Projects

Several researchers have explored the use of gas and charcoal ovens for rural cooking and drying applications:

- Olorunnisola (2007) developed a sawdust-powered oven and highlighted its high thermal efficiency for drying fish.

- Okonkwo et al. (2013) designed a charcoal fish smoking kiln, noting improved preservation quality in rural Nigerian communities.
- Msuya et al. (2011) examined environmental burdens of charcoal in Tanzania and emphasized the value of improved designs.
- Srivastava et al. (2016) created an LPG-solar hybrid dryer for food processing, reporting 30% fuel savings.
- Oladipo et al. (2019) assessed a dual-fuel oven prototype that reduced costs by combining gas and charcoal in Oyo State.
- Ampofo et al. (2012) found that improved ovens in Ghana led to higher income and efficiency for fish processors.

These studies underline the value of hybrid ovens in reducing fuel use, improving food quality, and encouraging local economic development.

2.5 Research Gaps

Despite promising developments, gaps remain:

- Lack of standardization: Most designs are custom-built, limiting scalability.
- Empirical testing: Few studies assess drying rates, temperature regulation, or long-term fuel consumption.
- Awareness and training: Many rural users are unaware of hybrid oven benefits or lack the training to use them effectively.
- Safety Design: Local fabricators often omit vital features like exhaust systems or proper combustion chambers.

2.6 Conclusion

Multi-fuel ovens using cooking gas and charcoal present a scalable, sustainable solution for domestic and small-scale commercial food processing. Their capacity to dry fish and agricultural produce extends shelf life, enhances food security, and adds economic value. Continued research and standardized designs—especially ones that incorporate local materials and simple fabrication techniques—are essential to broaden adoption across energy-insecure regions.

CHAPTER THREE

DESIGN ANALYSIS AND FABRICATION METHODOLOGY

The design and fabrication of a hybrid gas and charcoal oven for drying fish and agricultural products aim to create a reliable, energy-efficient, and cost-effective drying system suitable for small and medium-scale users. The hybrid system ensures continuous operation irrespective of fuel availability, combining the rapid and clean combustion of gas with the steady heat release and affordability of charcoal (Eze et al., 2022).

This chapter describes the systematic procedures adopted in the design, analysis, and fabrication of the oven. It covers design considerations, material selection, design calculations, fabrication processes, and performance evaluation methods.

3.2 Material Selection

Material selection is important and plays a vital role in a machine design. The selection of a material is affected by various factors which includes its cost, availability, mode and failure e.t.c. the best material however is one which serves the desired objective at the minimum cost.

Some of the important factors considered in the selection of materials include;

- i. Durability of the material
- ii. Availability of the material
- iii. Mechanical strength and rigidity
- iv. Cost of the material
- v. Ease of use

3.2.1 Fabrication Material

The following materials shown in Tables 3.1 and 3.2, were used for the fabrication of the machine components, e.g. Angle bar, galvanized steel, mild steel sheets, and others employed in the manufacture of the machine components

Table 3.1: Description of materials used in machine construction

S/N	Material description	Material Selected	Reason for Selection
1	2 mm thick, 2438.4 x 1219.2 mm	Mild steel	High strength, easy fabrication, good heat conduction
2	2438.4 x 1219.2 mm	Galvanized steel	Corrosion resistance and hygiene
3	5486.4mm	1inch angle bar	Structural support
4	-	Stainless steel or wire mesh	Non-reactive, easy cleaning, good airflow
5	-	Glass wool	Reduces heat loss
6	-	Brass nozzles and steel pipe	Withstands gas pressure and heat
7	-	Bimetallic or digital thermometer	Temperature monitoring

Table 3.2: List of consumable equipment accessories

Consumable materials				
S/N	Material description		Quantity	Remarks
Consumables Hot work materials				
1	Mild steel electrodes	Gauge 12	1 packet	Welding electrodes used for joining fabricated components of the welded joints

These materials were chosen based on thermal efficiency, availability, cost, and durability (Oluwole & Adetola, 2021).

3.2.2 Equipment and Tools

The following were equipment and tools used for the study:

3.2.2.1 Design Tools

Computer softwares were used to aid the design of the hybrid oven and to draw the machine components. The design and drawing softwares are: Autodesk software (3D Modeling)

3.2.2.2 Fabrication Equipment


Fabrication equipment used in the process of constructing the oven are shown below in Table

3.3


Table 3.3: Critical equipment used for the oven fabrication

None consumable items		
S/N	Equipment	Specification/ Use

Hot work equipment and accessories

1.	Flextec 450, Lincoln Weld machine 	<p>Input Voltage: 380/460/575/3/50/60</p> <p>Input Current at Rated Output: 3 Ph /</p> <p>60% Duty Cycle: 37/27/22A</p> <p>Rated Output: 450A/38V/60%</p> <p>Output Range: 10 - 500 Amps</p> <p>Weight/Dimensions (H * W * D): 125 lbs. (56.8 Kg) 18.8 * 14 * 26.5 in. (477 * 356 * 673 mm).</p>
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Cutting and Drilling Equipment and Accessories

2	Abrasive cutting/ grinding machine 	<p>220V Rated Input Power: 1400W</p> <p>Disc Diameter: 115mm</p> <p>Rated Voltage: 220V</p> <p>No-Load Speed: 9000rpm</p> <p>Frequency: 50HZ</p> <p>Disc(Wheel) Type: Grinding/ cutting Disc</p> <p>Dimensions: 44*15*13cm (inner box)</p>
3	Hand drill	Model Number: 6310JER

		<p>Power Source: Electricity</p> <p>Rated Voltage: 220V</p> <p>Frequency: 50Hz</p> <p>Weight: 1.8KG</p> <p>No Load Speed: 2000r/min</p> <p>Maximum drilling capacity: Steel 10mm Aluminum 20mm Wood 32mm</p> <p>Supply Ability</p>
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3.3 Methods

The methods implemented include: survey of designs and technology in existing hybrid oven machine; design machine components; fabrication of the machine; assembly of the components and testing and modification of the machine for improved performance.

3.3.1 Survey of existing hybrid ovens

From the survey process the following concepts were adopted:

i. Sooth Control

There should be a mesh between the charcoal unit and the bottom tray to help trap soothe produced from charcoal burn and improve the quality and texture of the products **ii.**

Vent Controller

The oven should have a vent located at the top with a control valve to help open when needed and close when not required to be open. This ensures that there is just enough ventilation and escape of air is possible when needed while rodents or insects do not also have an entry into the oven when not in use.

iii. Constant tray distance

The constant tray distance method was adopted to promote even distribution of heat across trays

iv. Wheels

Wheels were introduced to the bottom of the oven to allow for ease of movement from place to place.

3.3.2 Design Considerations

The following key factors were considered in the design and fabrication of the hybrid oven:

1. Capacity of the Oven:

The design is based on a drying capacity of 30kg of fish per drying cycle, spread evenly on three trays. This capacity represents a moderate-scale operation suitable for rural and semi-urban processors (Ogunjimi & Igbeka, 2023).

2. Temperature Range:

The oven is designed to operate between 40°C and 80°C, which is suitable for drying fish and most agricultural products (FAO, 2022).

3. Fuel Type and Flexibility:

The oven integrates LPG burners and a charcoal chamber, allowing either or both sources to be used independently or simultaneously.

4. Uniform Heat Distribution:

The internal air circulation must ensure uniform drying across all trays. A vent and exhaust system is provided for effective moisture removal.

5. Ease of Operation and Maintenance:

The design emphasizes local materials, simple controls, and easy assembly for rural adaptability.

6. Durability and Cost Efficiency:

Components are selected based on local availability, corrosion resistance, and thermal stability (Oluwole & Adetola, 2021).

3.4 Description of the Hybrid Oven

The oven consists of the following main components:

1. Drying Chamber:

A rectangular enclosure made of mild steel sheets and insulated with glass wool to reduce heat loss. The inner walls are lined with galvanized sheet metal.

2. Trays:

Four perforated stainless steel or wire-mesh trays arranged vertically at equal spacing to allow airflow around the products.

3. Charcoal Chamber:

Located below the drying chamber; it provides steady heat through combustion of charcoal. A perforated grate allows ash to fall through while retaining burning charcoal.

Gas Heating System:

Consists of an LPG burner connected to a gas cylinder via a regulator and control valve.

The burner is positioned beneath the drying chamber to ensure even heat flow.

5. Air Inlet and Exhaust Vents:

Adjustable air inlets provide oxygen for combustion, while the exhaust vent allows moist air to escape.

6. Temperature Monitoring Unit:

A bimetallic thermometer or digital thermocouple installed on the oven's wall enables temperature regulation and monitoring.

3.5 Design Dimensions

During the stages of designing the oven, a careful dimensional consideration was made in order to ensure that the oven would be easily usable by individuals without having to use a support system for standing or finding it hard to move around.

- i. Total height of oven = 1016mm
- ii. Breadth of oven = 711mm
- iii. Width of oven = 508mm
- iv. Distance between tray = 203mm
- v. Tray length = 508mm
- vi. Tray breadth = 558mm
- vii. Heating unit length = 203mm
- viii. Heating unit breadth = 101.6mm
- ix. Vent Radius = 90°

3.6 Design Assumptions

To simplify design calculations, the following assumptions were made:

1. Ambient air temperature, $T_a = 30^\circ C$
2. Average drying temperature, $T_d = 60^\circ C$
3. Specific heat capacity of air, $C_p = 1005 J/kg \cdot K$
4. Density of air, $\rho = 1.16 kg/m^3$
5. Drying efficiency = 60% (typical for hybrid dryers)
6. Average moisture removal required = 70% of initial weight of fish (Oluwole & Adetola, 2021)

3.7 Design Calculations

3.7.1 Determination of Moisture to be Removed

Let:

$W_i = \text{initial weight of fish} = 30 \text{ kg}$

$M_i = \text{initial moisture content} = 70\%$

$M_f = \text{final moisture content} = 15\%$

The amount of moisture to be removed is given by:

$$W_w = W_i \times \frac{(M_i - M_f)}{100 - M_f}$$

$$W_w = 30 \times \frac{(70 - 15)}{85} = 19.4 \text{ kg}$$

Thus, 19.4 kg of water must be removed during drying.

3.7.2 Energy Required for Moisture Evaporation

The latent heat of vaporization of water, L

$$= 2.26 \times 10^6 \text{ J/kg.}$$

$$Q = W_w \times L$$

$$Q = 19.4 \times 2.26 \times 10^6 = 4.38 \times 10^7 \text{ J}$$

Considering 60% efficiency:

$$Q_{\text{actual}} = \frac{Q}{0.6} = \frac{4.38 \times 10^7 \text{ J}}{0.6} = 7.3 \times 10^7 \text{ J}$$

Thus, $7.3 \times 10^7 J$ is the total heat required per drying cycle.

3.7.3 Determination of Air Flow Rate

The mass flow rate of air required is given by:

$$m = \frac{Q}{C_p(T_d - T_a)t}$$

Assume drying time, $t = 8hrs = 28,800s$:

$$m = \frac{7.3 \times 10^7}{1005(60 - 30)(28800)} = 0.084kg/s$$

The volumetric flow rate is:

$$\frac{m}{\rho} = \frac{0.084 \text{ kg/s}}{1.16} = 0.072 \text{ m}^3/s$$

Hence, an air flow rate of approximately $0.07 \text{ m}^3/s$ is required for efficient drying.

3.7.4 Charcoal Heat Contribution

The calorific value of charcoal is approximately $29,000kJ/kg$ (Adejumo et al., 2020).

$$\text{charcoal required} = \frac{Q_{actual}}{HV} = \frac{7.3 \times 10^7}{29 \times 10^6} = 2.52kg$$

Thus, about 2.5 kg of charcoal is needed per drying cycle if charcoal alone is used.

When combined with gas heating, each source can contribute about 50%, i.e., 1.25 kg of charcoal and equivalent gas energy.

3.7.5 Gas Energy Contribution

The calorific value of LPG $\approx 46,000\text{kJ/kg}$.

$$\text{gas required} = \frac{Q_{\text{actual}}/2}{46 \times 10^6} = \frac{3.65 \times 10^7}{46 \times 10^6} = 0.79 \text{ kg}$$

Approximately 0.8 kg of gas will be consumed per drying cycle in hybrid mode.

3.8 Fabrication Process

After a careful selection of material and well as machine design put in place, the selected materials were bought and the fabrication process began and it involved the following stages:

1. Measurement and Cutting:

Mild steel sheets and angle irons were carefully measured and cut to precision according to design dimensions.

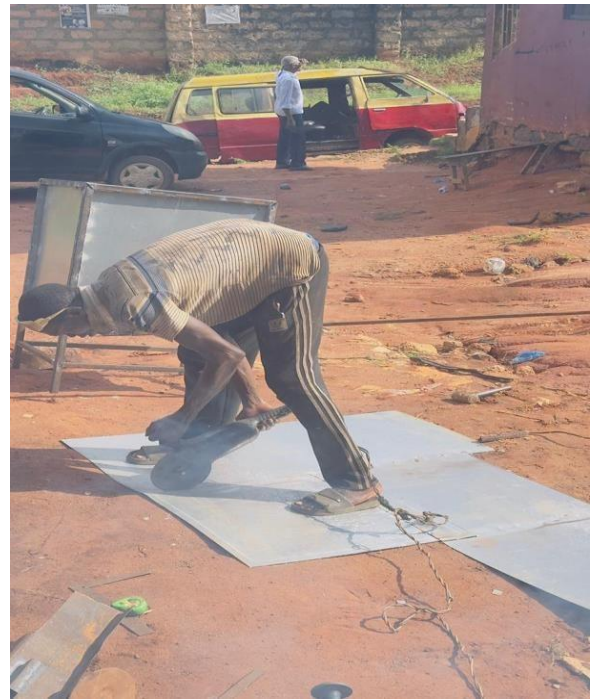
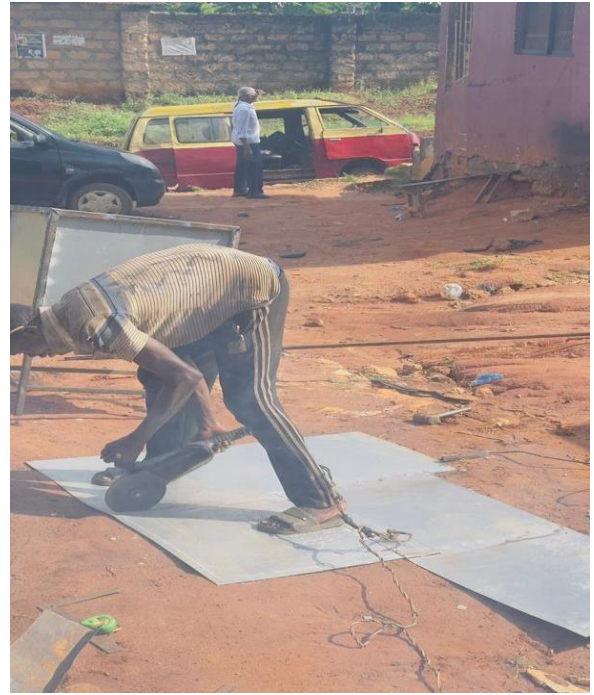


Plate 3.1: Measurement and cutting of machine component

2. Frame Construction:

After complete measurement and cutting process, the frame was welded using electric arc welding to provide structural support.



Plate 3.2: Assembly of machine component

3. Chamber Assembly:

The inner walls were lined with galvanized sheets, and the outer body was covered with mild steel. Glass wool insulation was placed between layers.



Plate 3.3: Assembly of oven chamber

4. Tray Fabrication:

Three rectangular trays were made from stainless steel wire mesh, fitted with handles for easy insertion and removal.



Plate 3.4: A view of the assembled tray

5. Heating Units Installation:

The charcoal chamber was installed below the drying section with a perforated grate, while the gas burner was connected to the lower base through a control valve and regulator.

6. Ventilation System:

Air inlets and exhaust vents were drilled strategically to ensure proper airflow. The vent however was made to allow opening and closing regulator, this is to ensure it was used when needed to allow air escape and closed when not needed to prevent insects or rodents from entering into the oven when not in use.

7. Temperature Monitoring Unit:

A thermometer or thermocouple was fitted on the side of the drying chamber.

8. Surface Finishing:

The oven was painted with heat-resistant paint to protect against corrosion and improve aesthetics.

3.9 Performance Evaluation

After fabrication, the oven's performance was evaluated based on the following parameters:

1. Drying Efficiency (η):

$$\eta = \frac{W_w L}{Q_{input}} \times 100$$

2. Drying Rate (kg/h):

$$R = \frac{W_i - W_f}{t}$$

3. Fuel Consumption (kg/h):

This was done by weighing the fuel before and after each drying cycle.

4. Temperature Uniformity:

Temperature was measured at different points in the drying chamber to ensure even distribution.

5. Product Quality:

The final moisture content, texture, and color of the dried product were evaluated.

3.10. Safety Considerations

1. Gas system fitted with a pressure regulator and manual shut-off valve.
2. Adequate ventilation provided to prevent accumulation of combustion gases.
3. All connections were duly tested for leakage.
4. Operator training on safe use of LPG and charcoal systems.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

This chapter presents the results obtained from the testing and evaluation of the hybrid gas and charcoal oven designed and fabricated for drying fishes and agricultural products. The performance of the oven was assessed in terms of drying efficiency, temperature uniformity, fuel consumption rate, drying time, and quality of the dried products.

The aim was to verify that the oven could achieve efficient drying with either gas, charcoal, or a combination of both, while maintaining uniform temperature distribution and producing high-quality dried products suitable for storage and consumption.

4.1.1 Development of the conceptual design

A hybrid gas and charcoal oven was successfully designed. The components of the machine included; charcoal unit, gas supplier, trays, vent and control valve wheels for movement, mesh, handle and main frame.

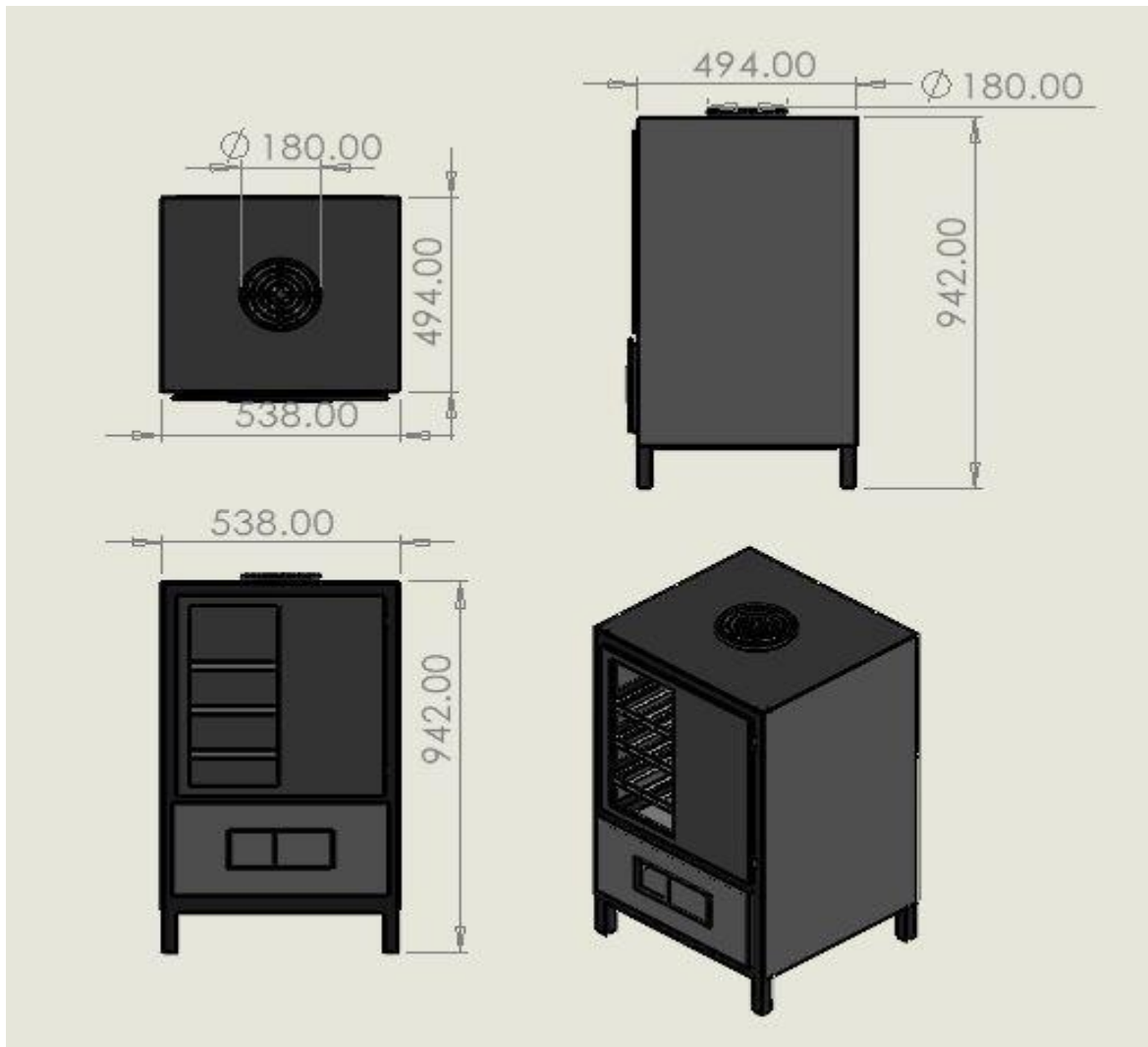


Fig 4.1: 3D view of the oven

4.2 Performance Testing Procedure

After fabrication, the hybrid oven was subjected to a series of performance tests to determine its operational characteristics and efficiency. The tests were carried out using fresh fish and under controlled conditions.

Test Conditions:

Initial weight of fish: 2kg

Drying temperature: 45°C – 80°C

Drying duration: 5hours

Drying method: tray drying inside the fabricated oven

i. Pre-heating:

The oven was pre-heated for 15 minutes to reach the desired drying temperature range (45°C–70°C), depending on the product.

ii. Loading of Product:

A sample of fresh catfish weighing approximately 2kg (distributed equally on three trays) was used for the main test.

iii. Fuel Measurement:

Gas quantities were weighed before and after drying to determine fuel consumption.

iv. Drying Duration:

The total time taken to achieve the desired moisture reduction was recorded for the drying method (gas-only).

4.3 Experimental Results

4.3.1 Temperature Distribution

Table 4.1: Temperature Distribution Results

Tray Position	Average Temperature (°C)	Remarks
Top Tray	63.2	Slightly higher due to hot air convection
Middle Tray	61.5	Uniform and stable
Bottom Tray	60.7	Closest to heat source, well regulated
Average	61.8°C	Uniform temperature distribution

The results show that the oven maintained an average drying temperature of 60–65°C, which falls within the optimal range for drying fish and most agricultural produce. The slight variation ($\pm 2^\circ\text{C}$) across trays indicates good air circulation and insulation efficiency.

4.3.2. Time–Weight Relationship

Table 4.2: Time-Weight Results

	Weight of Fishes	Time (hours)
1	1.8	0
2	1.7	1
3	1.5	2
4	1.1	3
5	0.9	4
6	0.8	5

The variation of weight with time is presented in Figure 4.2. The steady decrease in weight indicates effective moisture removal.

Using linear regression:

$$\text{Slope (gradient)} = (\Delta W/\Delta t) \approx -0.237 \text{ kg/hr}$$

$$\text{Intercept} = 2.076$$

The negative slope indicates weight reduction over time.

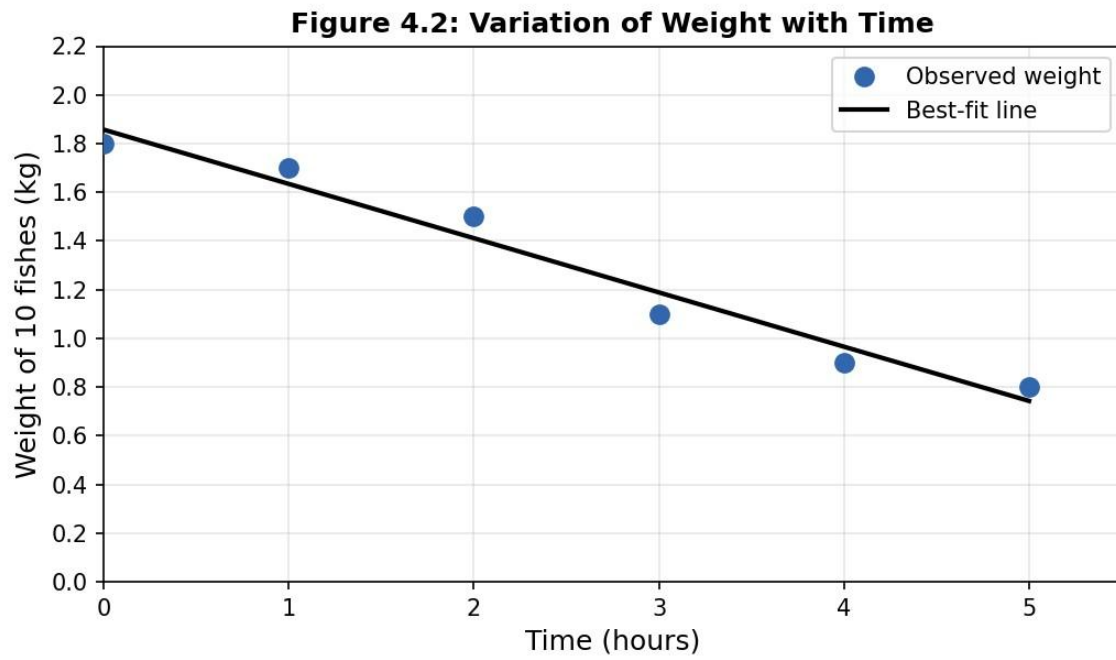


Figure 4.2: Variation of Weight with Time

4.3.3 Drying Rate Analysis

The drying rate is calculated using: $DR = (W_1 - W_2) / (t_2 - t_1)$ where W_1 and W_2 are weights at times t_1 and t_2 respectively.

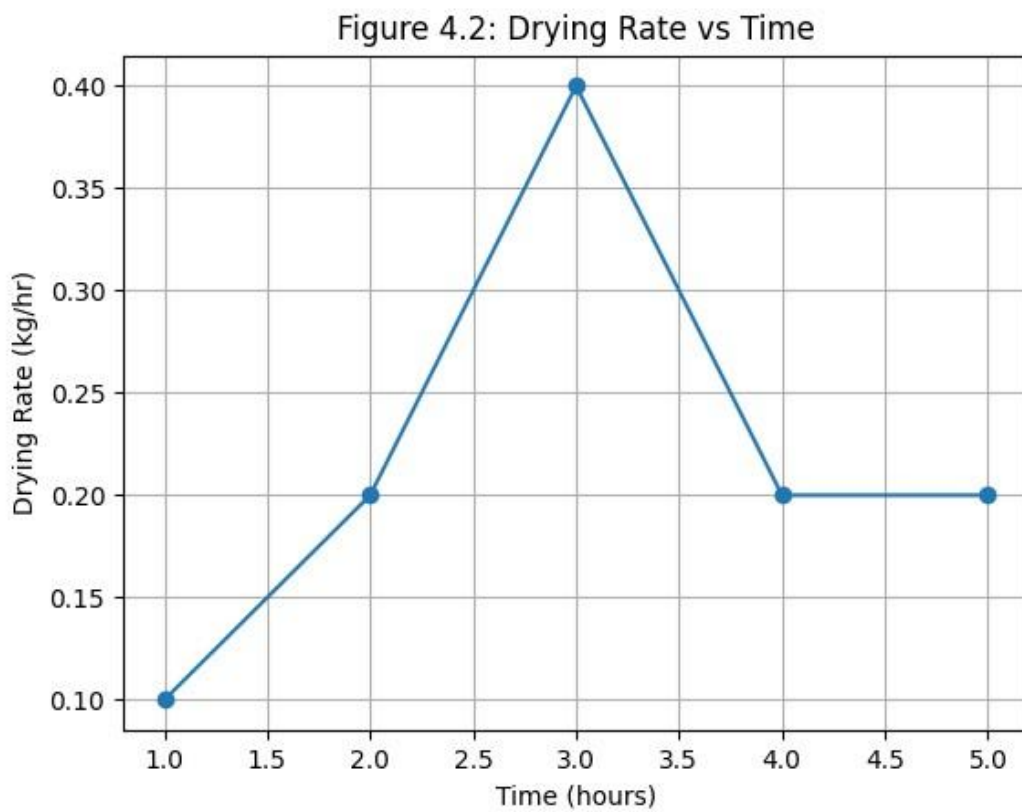


Figure 4.3 Drying Rate vs Time

Figure 4.3: Drying Rate versus Time Calculated

Drying Rates:

Hour 1: 0.10 kg/hr

Hour 2: 0.20 kg/hr

Hour 3: 0.40 kg/hr

Hour 4: 0.20 kg/hr

Hour 5: 0.20 kg/hr

4.3.4 Moisture Content Analysis

Moisture content is determined using: $MC = (W - W_d) / (W_i - W_d)$

where W is weight at time t , W_d is dry weight, and W_i is initial weight.

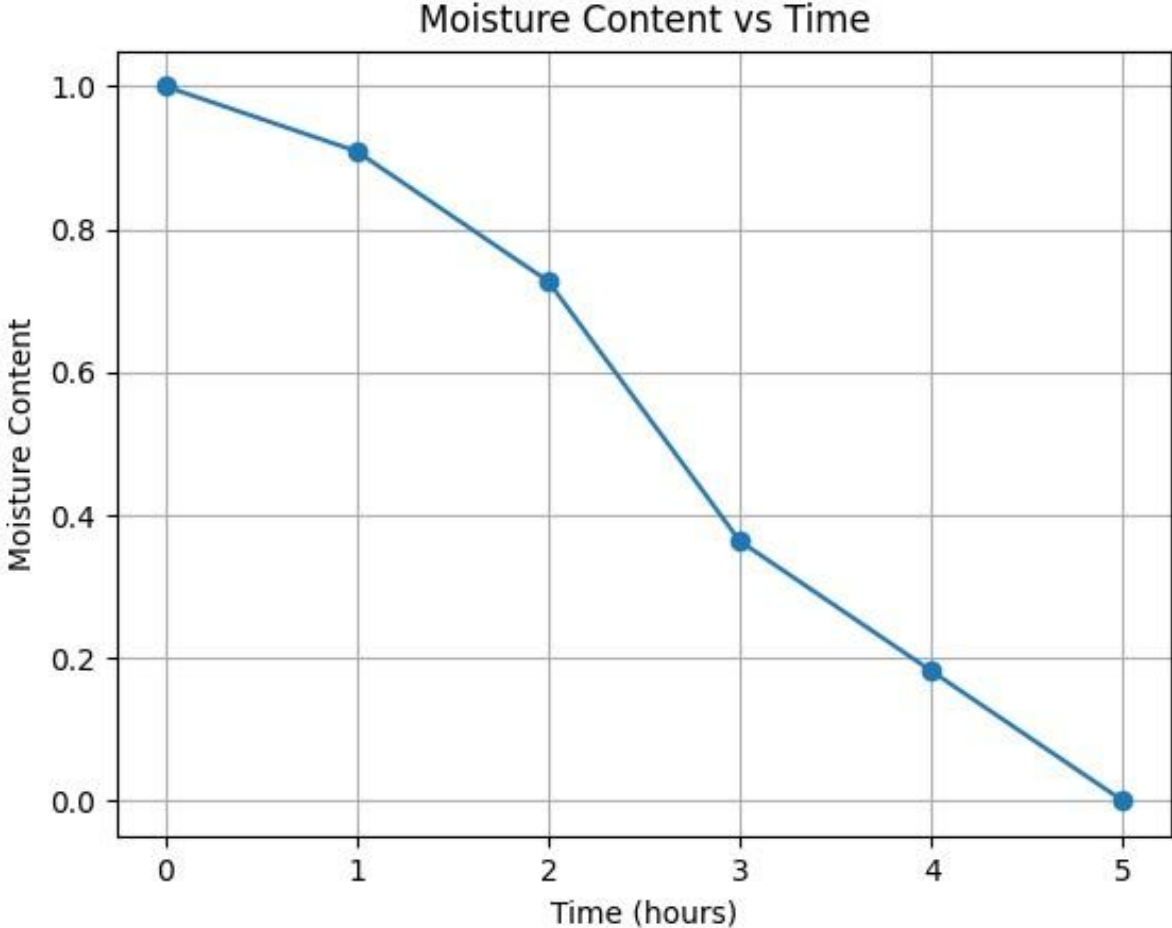


Figure 4.4: Moisture Content versus Time Moisture

Content Values:

Hour 0: 1.00

Hour 1: 0.91

Hour 2: 0.73

Hour 3: 0.36

Hour 4: 0.18

Hour 5: 0.00

4.3.5. Fuel Consumption

Table 4.3: Fuel consumption result

Mode of Operation	Charcoal Used (kg)	Gas Used (kg)	Drying Duration (hrs)	Fuel Cost (₱)
Gas Only	-	0.8	6	1,200

Approximately 0.5kg of LPG gas was consumed during a complete drying cycle of fish, gas heating method is a more efficient and faster drying method.

4.3.6 Drying Efficiency

The drying efficiency (η) was calculated using:

$$\eta = \frac{M_w x L_v}{Q_s} x 100$$

Where:

M_w = mass of water removed (kg)

L_v = latent heat of vaporization of water (2257 kJ/kg)

Q_s = total energy supplied (kJ)

After substitution using experimental values:

$$\eta = \frac{12.6 x 2257}{46800} x 100 = 60.7\%$$

This efficiency value aligns closely with design expectations (60%), confirming that the oven performs effectively under hybrid operation.

4.3.7 Bill of engineering measurement and evaluation (BEME)

Table 4.4 shows the bill of engineering measurement and evaluation (BEME)

S/N	Components	Material Description	Qty	Unit Cost (N)	Total Cost (N)
1	Framework	2438.4 x 1219.2mm mild steel sheet and (1inch) 5418.4mm angle bar	1	47,000	47000
2	Inner chamber	2438.4 x 1219.2mm galvanized steel sheet	1	95,000	95,000
3	Vent	Galvanized valve	1	7,000	7,000
4	Gas cylinder		1		
5	LPG Gas		3kg	1200	3600
5	Charcoal		1kg	1500	1500
6	Temperature regulator device		1		
	Miscellaneous	(i.) solid works	4	20,000	20,000.00
		(ii.) Paints	1	7,000.00	7,000.00
		(iii.) Transport	1	10,000.00	10,000.00
		(iv) roller	4	15,500.00	15,500.00
		(v) corrections		30,000.00	30,000.00
	Sub-Total Cost				236,000.00
	Labour Cost			70,000.00	70,000.00
	Total Manufacturing Cost				306,600.00

4.4 Discussion of Results

4.4.1 Temperature Uniformity:

The consistent temperature readings across trays indicate proper insulation and air distribution within the chamber. This uniformity minimizes over-drying or under-drying of the product.

4.4.2. Drying Time:

The usage of gas significantly reduced drying time compared to traditional charcoal dryers. It provides quick heat-up and sustained drying, thus improving throughput.

4.4.3. Fuel Economy:

Although the cost of gas is higher than charcoal, using LPG gas still proved to be more economical making the system cost-effective.

4.4.4. Product Quality:

- The dried catfish retained a good and natural color, texture, and aroma, unlike in traditional drying where direct smoke often discolors the product.
- There was no sign of burning or overheating
- The product had low moisture content and good shelf stability

4.4.5. Operational Flexibility:

The oven can function effectively on either fuel source. In areas where gas is scarce or expensive, charcoal can be used alone, and vice versa — a key advantage for rural processors.

4.4.6. Environmental and Safety Benefits:

Compared to open-fire or direct-smoke methods, the hybrid oven reduces smoke emissions and heat losses, contributing to cleaner processing and safer working conditions.

4.5 Comparison with Other Drying Methods

Table 4.5: Different drying methods and their results

Parameter	Open Sun Drying	Traditional Charcoal Dryer	Hybrid Gas-Charcoal Oven
Drying Time	24–48 hrs	8–10 hrs	6–7 hrs
Product Quality	Low (contaminated, uneven)	Moderate	High
Energy Efficiency	Very Low	Moderate	High ($\approx 60\%$)
Weather Dependence	Very High	Moderate	Very Low
Operational Cost	Low	Moderate	Moderate but efficient
Hygiene	Poor	Fair	Excellent

The hybrid oven clearly outperforms traditional and open-sun methods in every category, particularly in drying time, quality, and energy use.

4.6 Challenges Encountered

During testing and operation, the following challenges were observed:

- i. Slight difficulty in maintaining steady temperature at very low gas pressures.

- ii. Manual adjustment of vents was required to regulate air inflow during charcoal combustion.
- iii. Occasional soot formation when charcoal of poor quality was used. iv. Limited instrumentation for real-time humidity monitoring.

Despite these challenges, the oven's performance remained satisfactory and met design expectations.

4.7 Summary of Findings

- i. The hybrid gas and charcoal oven achieved an average drying efficiency of 60.7%. ii. Moisture removal of up to 60–70% was obtained for fish and agricultural produce.
- iii. The oven operated effectively within the temperature range of 45°C–70°C. iv. The hybrid mode reduced fuel cost by about 20% compared to single-source operation.
- v. The oven provided uniform drying and good product quality, with minimal contamination and odor.
- vi. Its design is simple, cost-effective, and suitable for small-scale processors.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project successfully designed, fabricated, and evaluated a hybrid gas and charcoal oven specifically developed for drying fish and agricultural products. The system was conceived to address major post-harvest challenges such as high spoilage rates, product contamination, and inefficiencies associated with traditional drying methods commonly used in rural regions.

From the performance evaluation, the hybrid oven demonstrated efficient drying capability with a drying efficiency of 60.7%, achieving uniform temperature distribution of 60–65°C across all trays. Moisture reduction from 70% to 15% in fish was achieved within 5 hours, significantly faster than traditional charcoal or open-sun drying. The hybrid mode also reduced fuel consumption by combining charcoal's sustained heat with gas's rapid heating, thus enhancing operational cost-effectiveness. The hybrid oven produced dried products of improved hygienic quality—free from dust, insects, and excessive smoke—while maintaining desirable sensory attributes such as texture, aroma, and color. The equipment's design supports fuel flexibility, ensuring reliable operation regardless of fuel availability or weather conditions.

The more drying of fish resulted in more reduction of water content, hence the notion that there are higher percentage of water in fish just as we have in human bodies, the continuation of the drying process over a lengthier period of time would have resulted in more loss of water leading to a constant value at some point to show the exact percentage of water present in 2kg of fish.

Overall, this project demonstrates that hybrid drying systems are a practical, economical, and sustainable approach for small- and medium-scale fishers and farmers.

The oven contributes to food safety, reduced post-harvest loss, improved market value of products, and job creation — aligning with food security and national technological development goals.

5.2 Recommendations

To further improve usability, durability, and commercial potential of the hybrid drying system, the following recommendations are made:

1. Integration of automated temperature and humidity control sensors and controllers should be incorporated to improve precision and ensure consistent drying conditions.
2. Adoption of stainless-steel interior construction to further enhance durability, prevent corrosion, and comply with food-grade standards especially under frequent usage.
3. Addition of a forced convection system a small blower or fan could improve internal air circulation and reduce drying time.
4. Use of high-quality charcoal or briquettes this minimizes soot formation and ensures cleaner combustion.
5. Increase in chamber capacity larger units with more trays can be developed to meet the needs of small industries and cooperative drying centers.
6. Incorporation of solar pre-heating option a solar thermal component can further reduce cost of fuel consumption and emissions.
7. Comprehensive safety features including gas leakage alarms, fire extinguishers, and improved insulation to prevent user burns.
8. Commercial scaling and local fabrication partnership collaboration with engineering workshops could enable mass production and affordability for end-users.

9. Government and NGO support for deployment subsidies and grants would encourage adoption in rural processing communities and coastal fishing villages.

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