Global Journal of Science, Engineering and Technology (GJSET)
ISSN (Online) 2322-2441
| Open-Access | Volume 14, Issue 03, 2026

Printed Journal Indexed Journal Refereed Journal Peer Reviewed Journal

DEVELOPMENT AND PERFORMANCE EVALUATION OF A FUME EXTRACTOR USING LOCALLY MODIFIED MATERIALS

Francis-Akilaki Tina Ishioma[1], Amuchi Afokeoghene[2] Bashir Musa[3]
[1,2] Department of Production Engineering, University of Benin. Nigeria.
[3]Department of Mechanical Engineering, University of Benin. Nigeria.

ABSTRACT

This research presents the design and fabrication of a domestic heat extractor using locally sourced materials. The aim is to develop a cost effective and energy efficient device capable of removing excess heat and fume from domestic cooking areas, thereby improving thermal comfort and safety in homes, particularly in developing regions where ventilation and cooling systems are often inadequate. The project involves a detailed study of heat transfer principles, material selection and fabrication processes tailored to locally available resources. Components such as the extraction fan, heat duct, aluminum casing and power source were designed and assembled using affordable and easily obtainable materials. Performance evaluation showed that the fabricated heat extractor effectively reduced heat concentration in enclosed kitchen spaces, improving air circulation and thermal comfort. The outcome demonstrates that domestic engineering innovations can be achieved sustainably using local resources, contributing to environmental protection, cost reduction and industrial development.

KEYWORDS: *Extract, Fume, Local, Heat, Environment.*

1. INTRODUCTION

The need for safer, more comfortable, and healthier domestic environments is critical to indoor living. Many households in developing countries in sub-Sahara Africa still rely hugely on fossil fuel such as gas, kerosene, firewood for cooking. Unfortunately, these fuels in addition to the foods or heating activities carried out with them emit fume which is detrimental to human health and environment. Indoor fume propagation is exacerbated by poor ventilation infrastructure in many buildings in these developing nations arising from their kind of architecture which prioritizes security, hence the need for limited openings. Cooking areas such as kitchens are either poorly ventilated or completely enclosed, trapping the heat, and fumes that are generated in the process. This often results in elevated room temperatures, smoke-stained walls, discomfort, and health complications such as persistent coughing, eye irritation, and long-term respiratory distress due to prolonged exposure to indoor smoke [1] particularly for women and children who spend more time in the kitchen. Prolonged exposure to such environmental unfriendly elements have been linked to health problems which include respiratory infections, eye irritation, fatigue, and increased risk of chronic illnesses [2]. This challenge in heat and exhaust fumes generated from cooking and related activities has necessitated the need for improved home ventilation design and control through functional building and heat control facilities designs such as heat extractors also known as kitchen range hoods or exhaust. A heat extractor is fundamentally a mechanical device designed to remove excess thermal energy, moisture, and airborne contaminants from enclosed domestic environments during various household activities [3]. The primary function involves the strategic capture of warm air through intake vents, followed by its passage through filtration and heat exchange components before being exhausted externally or re-circulated after treatment [4]. Many available heat extractors in urban areas are imported, electrically powered, costly and often lack the vendor technical support required for their maintenance and servicing. All these have further made it quite inaccessible by rural inhabitants with low income and little or no technical competence to acquire and maintain such device respectively [5]. These challenge have necessitated the need to locally develop affordable and effective alternatives solutions that could meet the gaps in sourcing, affordability, sustainability and energy utilization in fume and heat extractor design to meet the domestic needs of rural and urban dwellers in Africa. Key aspects of a proposed solution heat extractor design in this paper is the use of cheap, alternative raw materials and alternative (renewable energy) source to develop and power a locally manufactured fume and heat extractor suitable for use in African kitchens. A typical modern imported fume and heat extractor is shown in Fig. 1.

Figure 1 Heat Extractor. Source: Google web

More than 4 million premature deaths occur annually due to household air pollution from inefficient cooking practices [2]. The systematic recovery of waste heat in domestic settings has a rich and evolving history that spans centuries. Understanding this historical progression provides valuable context for contemporary innovations and highlights the persistent challenges that have shaped heat and fume extraction technologies across different eras and geographical contexts [6] particularly where locally sourced materials and simplified fabrication methods represent essential requirements rather than optional considerations [7]. Modern extractors leverage fundamental thermodynamic principles of heat transfer; conduction, convection, and radiation, working together to maintain optimal indoor air quality and comfort [8]. Recent innovations have achieved thermal energy recovery rates of 70-85% [9], resulting in annual household energy savings of 10-15% compared to conventional extraction systems [10]. Heat and fumes extractors have been categorized based on design [11] as ducted and ductless extractors and also based on extraction method as mechanical [12], natural convection [13] and hybrid extraction process [14].

[15] demonstrate that effective extraction systems can reduce indoor particulate matter concentrations by up to 85% during peak cooking periods. The removal of volatile organic compounds (VOCs) represents another critical benefit. [16] found that efficient extractors can reduce kitchen ambient temperatures by 3-8°C during intensive cooking periods. [17] found homes with effective extraction reported 23% better sleep quality scores.

[18] developed a comprehensive study on mechanical ventilation with heat recovery (MVHR) systems for domestic applications. [19] investigated the performance of domestic heat recovery ventilators using locally sourced materials with emphasis on sustainable manufacturing practices. [20] developed an innovative PCM-based heat extractor for kitchen ventilation systems, emphasizing the utilization of indigenous salt hydrate materials for thermal energy storage. [21] investigated the thermal performance of domestic heat extractors using locally available clay-based PCMs, focusing on sustainable and cost-effective thermal storage solutions.

[10] developed a solar-assisted heat extraction system for domestic cooking applications, integrating photovoltaic and thermal collection technologies. [22] designed a horizontal ground loop heat extractor using recycled plastic pipes, emphasizing environmental sustainability and local material utilization. [23] developed an air-to-air heat extractor for domestic ventilation systems, focusing on modular design and local manufacturing capabilities. [24] developed intelligent control systems for domestic heat extractors using locally manufactured sensors and control components. [25] investigated machine learning algorithms for heat extractor optimization, utilizing locally available computing resources and data collection systems.

A major limitation in current literature is the lack of systematic characterization of thermal properties for locally available materials. While conventional materials like aluminum and copper are extensively documented, indigenous materials such as local clays, natural fibers, bamboo composites, and recycled materials remain insufficiently studied for heat extraction applications [26]. Local processing methods and alternative materials use can significantly affect extractors design and performance. This underscores the need for dedicated study of local based materials and utilization for heat extractors production. Modern day heat extractors have been designed to meet the structural features of foreign buildings hence many research works haven't detailed a design of heat extraction that harmonizes the African or Nigerian building design template while also putting emphasis on cheap, affordable and sustainable design tenable to the vast majority of low income earners in rural and urban locations of Nigeria.

2. MATERIALS AND METHOD

The materials and their respective functions required for heat extractor facility development are shown in the Table.1.

Table 1 Materials required for the development of the kitchen heat extractor

S/N	Materials	Function
1	Personal computer	For CAD drafting and typesetting
2	Sheet metal	Use for the production of the exhaust hood and duct
3	Structural steel	For construction of the cooking structure.
4	Wood dust	Bio material for hood insulation.
5	Cellulose filter	For greasing entrapment.
6	Forced draft (suction) fan	For heat and fumes extraction draft.
7	Foam	For noise damping.
8	Air flow pipe	Route for exhaust air supply.
9	Bolts and nuts	For joints1
10	Wire gauge	For particulate matter segregation
11	Gas head	For combustion cooking.

The systematic approach adopted for development of the heat extraction facility is as follows:

2.1 Conceptualization

Concepts of heat extraction are considered. Considering preliminary design considerations, two concepts meet the initial mark for potential consideration and onward production. A preferred concept will be selected amongst the two using a decision matrix. The two concepts considered based on specific design considerations using a decision matrix are:

2.1.1 Concept One: Electric powered heat extractor

This concept shown in Fig. 2 rely on electric power only. The facility consists of an electric powered extraction fan ducted within an exhaust hood. A propane cylinder with nozzle and hose which is connected to a high heat resistant burner is incorporated. The burner produces the hot flame for cooking and concurrently extracted by the heat and fume extractor. The major advantage of the electric powered heat extractor facility is that it relies on electric power with potential regular availability for use if electric power is also available. A significant disadvantage of the concept 1 is that it will not be readily available where there is irregular electric power supply.

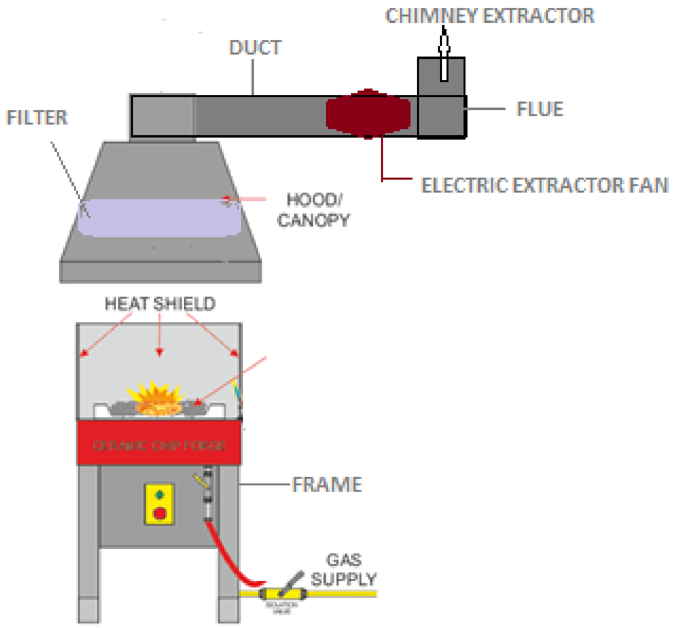

Figure 2 Electric powered kitchen heat extraction facility

2.1.2 Concept Two: Hybrid heat extractor

This is shown in Fig. 3. the hybrid heat extraction facility is intended to utilize both grid electricity and solar/inverter system to power the forced draft extractor. It consists of a heat resistant exhaust hood, extractor fans, a solar cell and an inverter. The system may incorporate a photo voltaic cell for solar energy utilization.

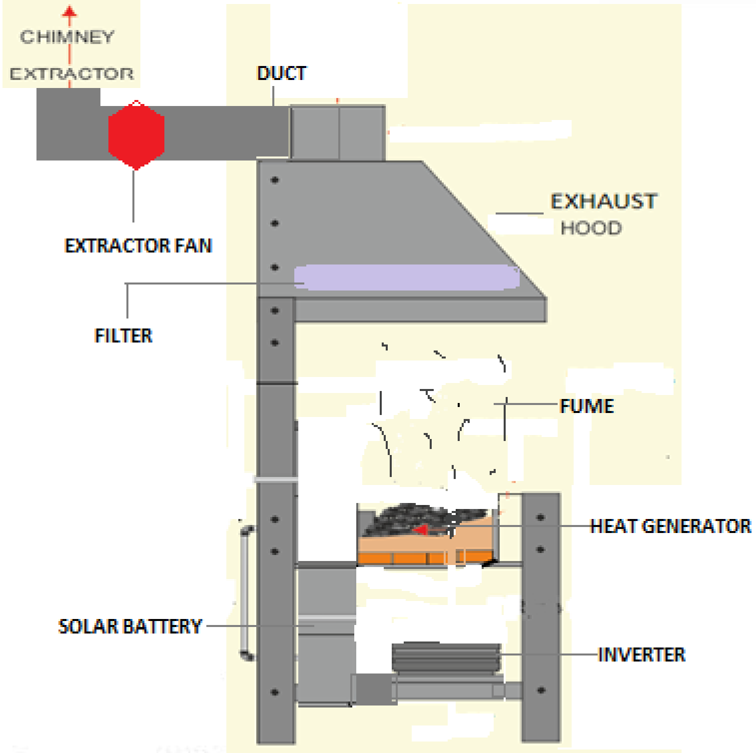

Figure 3 Hybrid (electric/solar) powered kitchen heat extraction facility

The incorporation of alternative renewable energy will ensure it is readily available for use at most times, however, the concept 2 is relatively costlier to produce and or acquire.

2.2 Evaluation and selection of concept using decision matrix

The two concepts highlighted are reviewed based on selected operational and design criteria. The most viable concept is selected using a decision matrix as shown in Table 2.

Table 2 Decision matrix for kitchen heat extractor concept selection

S/N	Design Specification	Concept 1	Concept 2
1	Ready availability for use at most times	1	2
2	Ease of use in varying locations and energy availability.	1	2
3	Energy use and conservation	1	2
4	Cost of production and acquisition	2	1
	TOTAL	**5**	**7**

From the Table 2, it is observed that the concepts 2 has the highest weighted score based on the criteria considered, hence the concept 2 is adopted for further development.

2.3 Detail Design

The significant components design of the facility using empirical analysis is as follows:

2.3.1 Heat and amount of fumes to be extracted

This is the amount of heat and fumes to extracted from a given space or enclosure housing the cooking or heat generation source. It is a function of the temperature of heat generated and amount in volume of the operational cooking space where heat is generated. This is necessary to determine the followings:

i. The nature of heat resistant materials to be used in the heat extraction hood and ducting.
ii. The extraction fan capacity and material make up.
iii. The level of insulation and
iv. The size and material type of the fume duct.
v. Nature and type of filters.

For a typical cooking kitchen area where propane gas is used for cooking, temperature range as measured from experimental determination was between 80 to 110^{0}C

For a small scale cooking area measuring between 1.5m length by 1.5m width and 3m height.

Therefore, volume in space of kitchen or cooking area can be expressed as:

$$V = \pi r^2 h \quad (1)$$

For a small sized student cooking area = 6.75m^3 = 250ft^3

This can be used as an estimate of the amount of fumes to be extracted from the heat propagation area.

2.3.2 Extraction fan selection and capacity.

This is a function of the amount of heat and fumes to be extracted periodically, the cubic feet per minute (CFM) of the fan, the kitchen size in area and the resistance offered by the ducting configuration. For different space configurations an exhaust fan CFM chart is utilized. From a typical chart shown in Fig. 5. For a kitchen area measuring Length x breadth. = 1.5 x 1.5 = 2.25m^2 = 25ft^2

The area falls within the 100 sq. feet area in the CFM chart requiring 27CFM of extraction. It therefore means that the proposed extraction fan is expected that it will take approximately = 8min for the fan to extract the amount of fumes within the given area provided there is a counter open ventilation for re-ventilation. Considering the lower limit of 27CFM as against the 100CFM on chart Table, the fan is selected as evaluated without further consideration of the ducting configuration for a simple duct type for the small scale kitchen configuration.

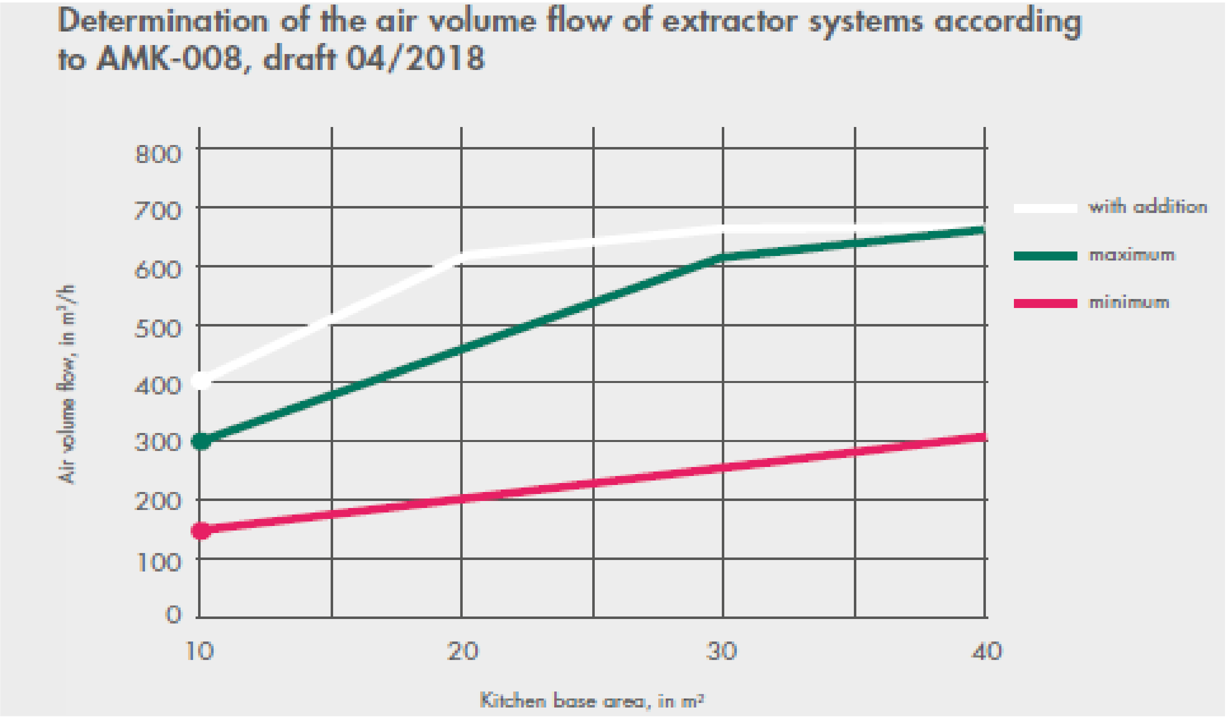

Figure 4 Air volume flow chart for extractor fans.

A centrifugal fan with an axial air intake and radial air outlet shown in Figure 5 was selected due to its versatility, availability and cost.

Figure 5 Centrifugal Fan

2.3.3 Duct sizing

The duct sizing is such that its opening can accommodate an instantaneous volume of fumes = $27ft^3$ = $0.7m^3/m$ or $0.012m^3/s$.

A possible duct size configuration for $0.012m^3$ = 0.23m by length, width and height for a square duct or its equivalent of a cylindrical duct.

2.3.4 Material selection for ducting and hood production

Typical metals and their thermal characteristics suitable for use in heat extraction ducting is shown in Table 3.

Table 3. Thermal characteristics of metals for heat extraction ducting and hood.

Metal	Softening temperature (°C)
Brass	0.42 – 0.44
Copper	800
Bronze	913
Nickel	(720-122) for its alloys
Steel	900 (may vary due to carbon content)
Aluminum	500

From the Table 3. it can be inferred that virtually all the listed metals except brass can be suitably employed for ducting of the extraction facility since their softening temperature is above the prevalent temperature of heat generated within the cooking space which is 110^0C. the selection of a preferred metal amongst the favored one is now dependent on local availability and cost. Aluminum is the most suitable in terms of cost and availability.

2.3.5 Filter Material Selection

Considering heat generated in the typical cooking area where heat and fumes are to be extracted, a synthetic porous membrane made of a composite material of metal wool (aluminum fibre) was selected for use as the extractor filter due to its availability, thermal resistance and low cost. Operational performance of the filter is depended on some quantitative metrics for selection which include the permeability (P) values of filter membranes which is estimated as: [27].

$$P = F_i = () \; () \; () 10^{10} \text{Barrer} \qquad (.2)$$

where: F_i = volumetric flow rate (cm^3/s) of the permeate component at i at room temperature (24^0C)

A = surface of the filter membrane (cm^2), T_{STP} = standard temperature in K with 273.15 K being used

p_{STP} = atmospheric pressure [atm]; $T_{permeate}$ = the temperature of the fume or permeate

$P_{permeate\ absolute}$ = the absolute pressure (cm. Hg), L = thickness of the membraneous filter

The multiplication by 10^{10} converts the permeability form (cm (STP)cm units to Barrer. The synthetic membranous filter used is shown in Fig. 6.

Figure 6 Heat extractor membranous filter

2.3.6 Resistance to Airflow

This is the amount of resistance exerted by the filter against the fumes extract. It also determines the specification requirement of the extractor fan.

Total resistance needed for the fan can be computed as;

$$Rf = Tf \times Sr \qquad (3)$$

where:

Rf - resistance of filter equivalent to pressure of a column cm of H_2O

Tf - thickness of filter column, m

Sr - specific resistance, cm of filter equivalent to water/m depth.

The specific pressure resistance of water per m depth can be read off in charts. Taking specific pressure resistance of 1 cm water per m depth of the membrane.

2.3.7 Insulating material

For the extractor hood, cellulose (wood material) was used due to its poor conduction of heat. The wooden plate shown in Fig. 7 was embedded inside the extractor cone and hood made of aluminum plate.

Figure 7 Wood insulated for extractor hood

2.3.8 Size of hood and installation

The extractor hood is designed to have solid trapezoidal shape with a diverging air suction face to enhance air flow through larger surface area of the filter while also creating a convergent throat at the other end of the hoof for increased pressure and turbulent air extraction. The size of the extractor hood shown in Fig. 8 is function of the fan specification and the amount of fumes to be extracted.

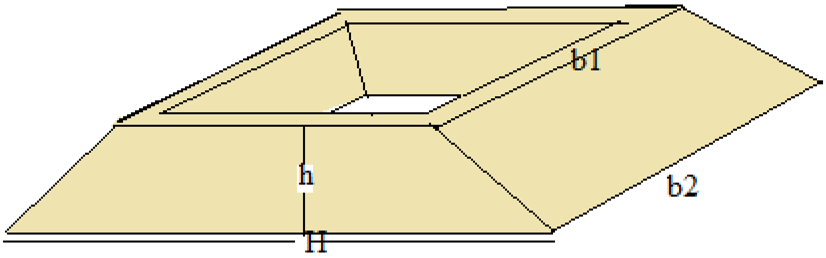

Figure 8. Trapezoid extractor hood

The amount of air passing through the hood per time is equivalent to the volume of the trapezoid hood which is expressed as:

Volume V of trapezoid = x ($b_1 + h_2$) x h x H (4)

where:

b_1 = length of first parallel side of trapezoid
b_2 = length of second parallel side of trapezoid
h = height of trapezoid
H = height of the prism or distance between the two trapezoidal bases.

2.3.9 Development of the Kitchen cabin

A mini kitchen cabin suitable as a student cooking corner or a small commercial cooking stand suitable for a 6ft tall human to navigate is constructed for installation of the extractor fan. The cabin shown in Fig. 9 is a rectangular cabin measuring 1.9m height by 0.6m width and 0.6m breadth. It is made of wooden boards and structured with steel. The cabin structure is designed such that the lower side is cut open with a rectangular hole, each measuring 0.5m length by 0.5 in breadth to enhance cross ventilation and updraft, to further increase fan extraction efficiency and reduce fan power specification. A door for access and exit the kitchen cabin is also installed on the structure.

Figure 9. Kitchen Cabin

The developed heat and fume extractor installed on a mini kitchen cabin was tested to determine its operational performance as follows:

i. A typical cooking activity was set up and carried out inside the kitchen cabin using a kerosene stove with considerable flue emission.

ii. Test probes for measuring temperature were inserted in and outside the facility measure temperature and fume concentration inside and outside the cabin before and after cooking.

iii. The stove was lighted and used to cook oily food which also emits a lot of oily fumes.

iv. The extractor fan was switched on to extract heat and fume and the time it took for completed extraction of fumes was documented.

v. The result obtained from the experiment is documented in result section of this work in chapter four.

3. RESULT

The results of the experimental testing of the heat and fume extraction facility is shown in the Table 4.

Table 4. Experimental data for heat extraction facility.

Temp. (^{0}C) of cabin before cooking.	Ambient Temp. (^{0}C) around extractor before cooking	Temp. (^{0}C) of cabin during cooking	Ambient Temp. (^{0}C) around extractor during cooking	Time (s) for complete extraction of fumes.
28.8	28.7	31.8	31.6	12
29.1	29	32.5	31.3	25
28.8	29.1	34.7	34.2	35
27.9	27.6	33.2	32.1	48
28.3	28.2	32.8	31.2	60
Av. = 28.58	Av. = 28.52	Av. = 33	Av. =32.08	

The corresponding graphs detailing the data in Table 4 are shown in Fig. 10 and Fig. 11.

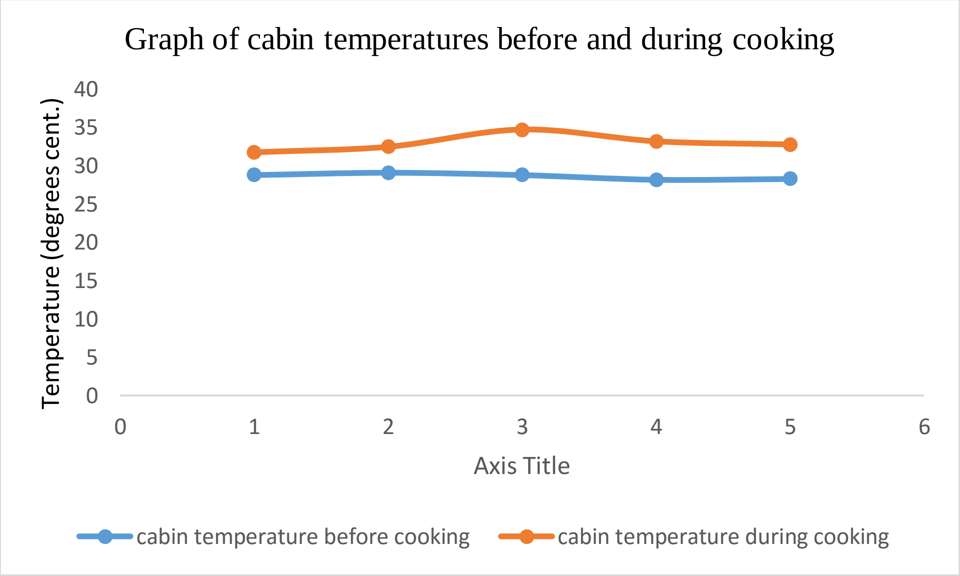

Figure 10 Graph showing kitchen cabin temperature

From Fig. 10 and Fig, 11 it is inferred that prior to cooking in the kitchen kiosk or cabin, the temperature around the kitchen was virtually same as the ambient temperature within the environment. However, as cooking commenced there was relative increase in the kitchen temperature compared to the ambient temperature indicating heat production in the kitchen with evident presence of fumes from the heated oil. Owing to the extractor fan was switched on to extract the heated fumes from the kitchen within a given period.

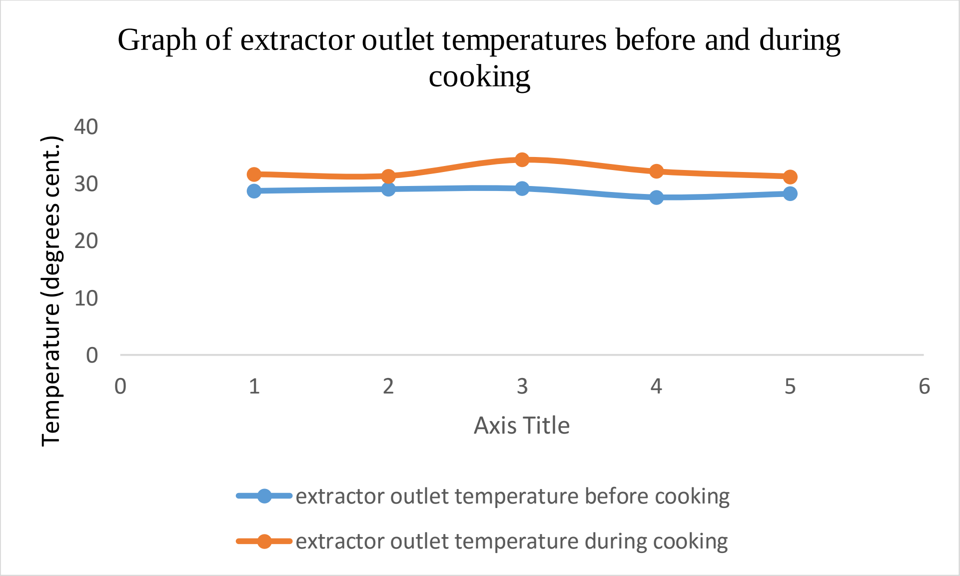

Figure 11 Graph showing extractor hood temperature

Inference from Table 4 and the graph in Fig. 11 reveals a temperature gradient within the extractor hood zone. There was marked increase in temperature around the inlet and outlet of the extractor fan during cooking compared to when there was no cooking taking place indicative of a working of the extractor fan in extracting heated fumes from the kitchen cabin. It was also inferred from the Table 4 and the graphs in Fig 10 and Fig. 11 that as time elapsed, the heat transfer within the kitchen cabin during cooking increases from ambient temperature up to a peak temperature before residing around the kitchen compartment and the extractor hood zone. The harmonic temperature curves of the cabin and extractor hood temperatures clearly showed a temperature curve increasing, peaking and decreasing after a given time T. The time is the period between which the extractor started and finished extracting the hot fumes from the kitchen which took about 1 minute. This follows that in an hour the extractor fan could recirculate the kitchen heated fumes 60 times which is typical of an effective heat extraction which is expected to change air in the kitchen 10 times an hour.

4. CONCLUSION

The design, fabrication, and performance evaluation of a kitchen heat extractor using locally sourced materials was successfully completed, demonstrating that effective ventilation solutions can be developed using materials readily available within our local environment. The fabricated heat and fume extractor utilizes a combination of natural and forced draft mechanisms to effectively remove heat and cooking fumes from kitchen spaces, creating a healthier and more comfortable cooking environment. The system consists of several locally sourced components that proved both functional and cost-effective. Local wood was successfully utilized as insulation material, providing adequate thermal protection while being readily available and affordable. A recyclable automobile air conditioning fan was adapted and integrated as the mechanical draft fan, demonstrating the potential for repurposing existing components rather than purchasing new ones. The extractor casement and hood were fabricated using aluminum fittings available in local markets, which provided the necessary structural integrity while keeping costs minimal. Additionally, a locally available synthetic filter was incorporated into the design to trap grease and particulate matter, protecting the fan mechanism and improving air quality.

Performance testing of the developed proof of concept revealed important findings about the system's operational characteristics. The most significant discovery was that cross ventilation plays a crucial role in the overall effectiveness of the heat extraction system. It became clear during testing that the extractor does not simply remove air from the kitchen; it must work in conjunction with adequate fresh air intake to create proper air circulation. This cross ventilation serves a dual purpose: it enhances the extraction effect of the fan by preventing vacuum conditions that could reduce efficiency, and it ensures human safety by providing fresh oxygen-rich air to replace the extracted air. Quantitative measurements showed that the mechanical draft fan used in this project could completely extract and recirculate approximately 0.432 cubic meters of air within one minute in the kitchen space developed for this research. This air exchange rate translates to multiple complete air changes per hour within the test kitchen, which aligns with standards for effective heat extraction in domestic and small commercial kitchen settings. The ability to achieve this level of performance using locally sourced and recycled components validates the core premise of this research: that effective kitchen ventilation does not necessarily require expensive imported equipment. By deliberately selecting materials and components available within local markets, the project has demonstrated that communities need not depend entirely on imported solutions for their basic environmental comfort needs. The sustainability aspect is particularly noteworthy, as the use of recyclable materials extends the useful life of components that might otherwise become waste, while the use of natural materials like local wood reduces dependence on synthetic materials. The objective to source and incorporate local materials was achieved through careful selection and testing of indigenous resources. The objective to design a functional heat extractor was accomplished through proper engineering calculations and thoughtful integration of components. The fabrication objective was met by working with local artisans and fabricators who demonstrated considerable skill in bringing the design to life. Finally, the performance evaluation objective was fulfilled through systematic testing that provided concrete data on the system's capabilities.

Beyond the technical achievements, this project carries important implications for local capacity building and economic development. It has shown that local fabricators possess the skills necessary to produce functional environmental control equipment when provided with appropriate designs and guidance. This opens possibilities for small-scale manufacturing enterprises that could provide employment while meeting genuine community needs. The relatively low cost of the completed unit makes it accessible to a wider range of users, including small restaurants, home kitchens, and food processing facilities that might not afford expensive commercial systems. The success of this project also contributes to the growing body of knowledge on appropriate technology development. It demonstrates that engineering solutions can be adapted to local contexts by thoughtfully selecting materials and manufacturing methods that match available resources and skills. This approach to technology development is particularly relevant in developing economies where imported solutions may be prohibitively expensive or difficult to maintain due to lack of spare parts and technical expertise. In conclusion, this research has produced a functional, affordable, and sustainable kitchen heat extractor that meets its performance objectives while utilizing locally sourced materials. The system's ability to effectively change air multiple times per hour within the test kitchen, combined with its low production cost and use of readily available components, makes it a viable alternative to imported heat extraction systems. The insights gained regarding the importance of cross ventilation for both system efficiency and human safety add valuable knowledge that will inform future improvements and installations.

REFERENCES

1. Adebayo, M. & Morrison, D., (2021). Stack ventilation in tropical domestic architecture: Natural solutions revisited. Journal of Environmental Design, 9(1), pp.89–98.
2. World Health Organization, (2018). Household air pollution and health.
3. Adeyemi, P. & Johnson, L., (2022). Mechanical extractors in residential buildings: Trends & Energy considerations. Domestic Technology Quarterly, 18(1), pp.44–51.
4. Nwafor, M., Obi, K. & Johnson, B., (2021). Airflow dynamics in mechanical extractors. Applied Home Engineering, 9(4), pp.158–172.
5. Fasheun, A. & Adegoke, L., 2022. Post-war advances in domestic heat recovery. Historical Energy Developments, 12(1), pp.50–64.
6. Adeniran, R. & Olawale, B., (2021). Historical perspectives on waste heat recovery in traditional Nigerian homes. Energy History Review, 5(2), pp.40–56.
7. Ekwueme, A. & Okechukwu, D., (2023). Locally adapted ventilation designs for domestic applications. African Journal of Built Environment, 18(2), pp.97–108.
8. Nguyen, T. & Roberts, A., (2022). Principles of thermodynamic heat transfer in extractors. Heat Transfer Fundamentals, 17(1), pp.64–78.
9. Ikechi, R. & Thompson, S., (2021). Modern heat extractors and thermal recovery. Applied Home Engineering, 6(1), pp.88–96.
10. Ahmed, Z., Bello, T., & Musa, K., (2023). Thermal energy savings in Nigerian homes: A study on extractor use. Energy Sustainability Reports, 31(4), pp.205–212.
11. Brown, S. & Wilson, J., 2021. Performance limitations of recirculating extractors. Household Ventilation Studies, 11(2), pp.130–138.
12. Ahmad, M. & Santos, R., (2023). Domestic heat extractor fans: Axial vs centrifugal performance. Appliance Engineering Journal, 22(3), pp.139–147.
13. Ibrahim, R. & Chen, K., (2022). Natural convection in domestic spaces: Stack systems revisited. Energy Conservation Review, 10(2), pp.109–120.
14. Segun, L. & Williams, T., (2022). Hybrid ventilation solutions for Nigeria's low-income homes. Appropriate Technology Quarterly, 15(2), pp.109–121.
15. Adetola, R. & Emmanuel, T., (2021). Heat recovery ventilators in domestic applications: Design and performance. Energy Systems Journal, 14(2), pp.155–168.
16. Johnson, T. & Williams, M., (2021). Thermal comfort via extractor deployment in homes. Home Comfort Studies, 9(2), pp.125–136.
17. Garcia, M. & Thompson, F., (2022). Impact of kitchen extraction on sleep and wellness. Wellness Architecture Journal, 11(1), pp.65–74.
18. Zhang, Y., Johnson, B. & Williams, A., (2020). CFD simulation in MVHR optimization. Heat Exchange Engineering, 12(2), pp.123–138.
19. Johnson, R. & Smith, T., (2019). Domestic HRV units with recycled aluminum. Energy and Materials Innovation, 5(2), pp.33–47.
20. Rodriguez, L., Hassan, Y. & Bello, S., (2020). PCM-based heat extractors using salt hydrates. Thermal Storage Applications, 14(2), pp.104–118.
21. Williams, K. & Brown, S., (2019). Clay-PCM composites for cost-effective heat storage. Materials Science for Domestic Use, 11(2), pp.88–100.

22. Roberts, G., Omotayo, F. & Adewale, K, (2021). Recycled pipe heat loops for green homes. Green Building Tech, 12(1), pp.99–113.
23. Clark, B. & Moore, J., 2020. Modular design of heat recovery ventilation using local materials. Engineering for Sustainable Homes, 13(3), pp.190–203.
24. Zhang, L. & Okonkwo, E., 2022. Roof-mounted extractor designs in West Africa. Tropical Building Services Journal, 16(1), pp.91–104.
25. Ward, A. & Cook, E., (2019). Predictive extraction control with local systems. Machine Learning in HVAC, 5(3), pp.120–134.
26. Kumar, V. & Patel, R., (2018). Thermal storage systems using paraffin wax. Applied Thermal Materials, 13(1), pp.70–83.
27. Tanimu, D. & Osigwe, F., 2022. Heat capture in ancient structures. Architectural Thermodynamics, 10(1), pp.55–69.