GSJ: Volume 12, Issue 8, August 2024, Online: ISSN 2320-9186
www.globalscientificjournal.com

Design, Manufacturing, and Testing of Liquefied Petroleum Gas (LPG) Based Injera Baking Oven

Gudina Bekona Demie[1], Abdulkadir Aman Hassen[2], *

[1,2]Addis Ababa Institute of Technology, Addis Ababa University, P.O.Box 385, King George VI Street, Addis Ababa, Ethiopia

* Correspondence: Email: gudinabokona12@gmail.com; Tel: +251915961929

ABSTRACT

Access to clean and reliable energy for injera baking is the biggest problem in developing countries. However, biogas, solar, and electricity-based injera baking are clean and somewhat efficient; there are energy reliability and accessibility problems in Ethiopia. In Ethiopia, the majority of people rely on biomass which is not clean, inefficient, and also causes health and environmental problems. So, this study aims to propose a clean and reliable new type of injera baking stove where liquefied petroleum gas (LPG) is used as baking fuel. So, a baking stove with a 56 cm diameter and 1 cm thickness plate was used to test the stove. The test result obtained showed that the initial heat-up time was 21 minutes to reach 185℃, the average baking plate surface temperature, and 3.4 minutes baking with 3 minutes idle time. The stove consumed $0.0034 m^3$ per injera or 0.96 kWh/kg compared to 0.54 – 0.82 kWh/kg of electric stoves. The thermal efficiency of the stove achieved was 53.77 % against 5-15 %, 61 %, 57 % and 37 % for traditional three-stone, electric, biogas, and solar baking stoves respectively. The developed stove is economically feasible for mass injera production or for a group of people who bake by single initial heat up with a 2-month payback period. This successful test shows the possible and promising result of a reliable, efficient, and clean LPG-based injera baking stove and it could be widely disseminated.

Keywords: - LPG based baking oven, burner design, orifice, clean energy baking

1. Introduction

Biomass is the primary energy source for cooking and baking in underdeveloped countries. In 2020, around 69 % of the world's population had access to clean fuels and technology while 2.4 billion people lacked clean energy access for cooking [1]. The majority of these people live in south and southwest Asia, but more sub-Saharan Africans (SSA) suffer from the greatest lack of clean energy access. One of the UN's goals is to achieve Sustainable Development Goal 7 (SDG7), which calls for all people to have access to reliable, affordable, sustainable, and modern energy by 2030 is to address this issue [2]. Access to clean and modern energy cooking remains a challenging problem in most African countries, both for residential and commercial purposes [3].

Developing countries such as Ethiopia, which is home to more than 110 million people and more than 80 % live in rural areas do not have access to electricity. As a result, their livelihoods depend on inefficient biomass energy, and polluted cooking/baking systems [4]. Nowadays the world is rapidly modernizing, and technology is transferring to developing countries at an alarming rate. This transition includes the community's way of life, such as switching from traditional fuel use to modern and clean fuel energy.

The energy ladder model characterizes energy choices by switching linearly from primitive sources or biomass fuels such as wood, animal dung, and crop residues to transition fuel sources such as coal, kerosene, and charcoal to finally clean burning, more efficient, and advanced energy source fuels such as electricity, LPG, bio-fuels, and biogas [5].

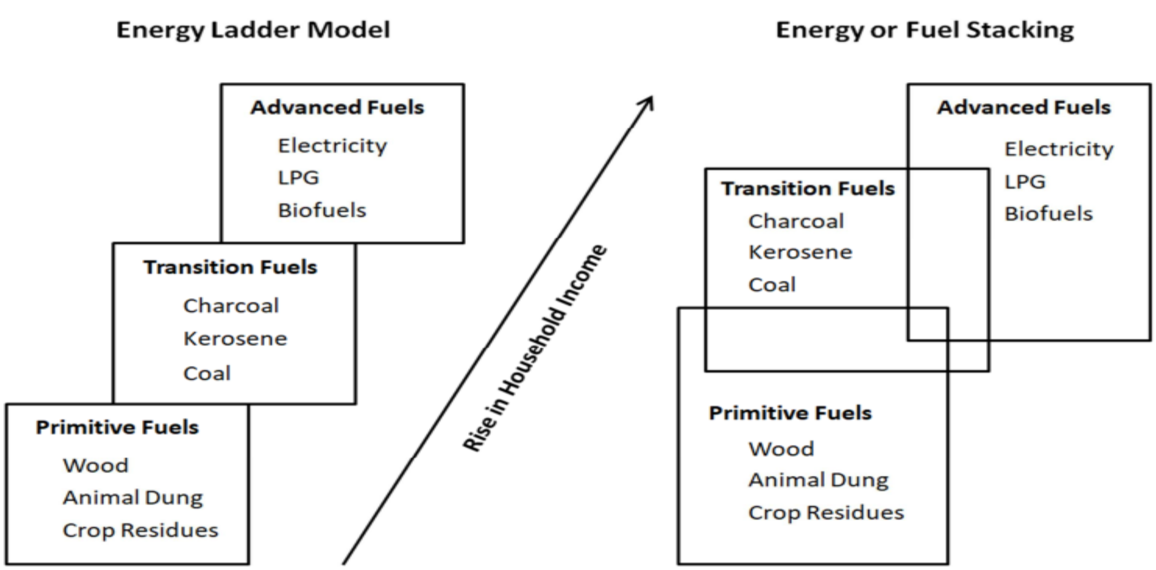


Figure 1 Energy choice or household fuel switching[5].

The use of wood fuel (biomass) for cooking/baking is shifting to clean energy sources such as electric, bioenergy, solar, kerosene, and LPG.

Cooking/baking is the preparation of food for human and animal consumption. It is a daily activity because it is consumed daily. As a result, injera baking is an energy-intensive and time-consuming process. Baking Injera requires a temperature of 180-220 ℃ to be baked properly for human consumption [6]. Most households bake injera on three stones with a low thermal efficiency of around 8-12 % [7]. This implies it uses more wood as fuel, resulting in the case of deforestation and environmental degradation.

Injera is a flatbread made from various cereals such as teff, sorghum, maize, millet, wheat, rice, and others, or combinations of those, that have been fermented and rigorously baked. It is widely consumed as a cultural food in some East African countries, including Ethiopia, Eritrea, and, to a lesser extent, Somalia and Sudan. It is typically made of teff, with a diameter of 40-58 cm and a thickness of 2- 4 mm based on the diameter of the cooking mitad [8].

To overcome these biomass-based baking problems solar, biogas, and electric-based baking are introduced as clean energy sources. Electric source-based baking is clean and efficient, but cannot made off the grid for those who are living far from the grid and have reliability problems due to power rationing. Even in urban itself, people look for other options when power is cut off unless dough gets soured or lost after a while. Although thermal injera baking is a promising new technology, it is dependent on solar energy availability and may not provide the required power if we do not regulate it with solar storage. Biomass gasified baking is a good and cost-effective technology that necessitates gasification skills.

LPG is an exceptional source of energy due to its relative advantage and being the most convenient, clean fuel, and very popular for domestic use, accounting for 3 % of total energy consumption. LPG produces no soot, emits very little sulfur, and contributes to less air pollution [9]. LPG is a portable, easy-to-use, clean-burning (no smoke), fuel-efficient byproduct of natural gas and oil production, as well as oil refining. However, there are numerous design efforts underway to improve the existing injera baking stove and mechanisms, the majority of which use direct cooking technology. Since LPG is still safe to use for cooking, it is possible to use it for injera baking. As a result, LPG-powered injera baking stoves are self-contained, clean, and dependable, as well as faster baking.

2. Materials and method

2.1.Materials

The raw materials used to develop this baking stove were clay soil, clay sand, and waterproofing collected from Oromia region lege tefo for mitad and, carbon steel sheet metal for burner and housing, aluminum sheet metal for lid cover, HRS metal for stove stand manufacturing, fiberglass, and ash for insulating as a whole from the supermarket. In addition, LPG gas is obtained from Nock madia for experimental tests.

2.1.1. Materials preparation and fabrication site

Figure 2 shows raw materials: a) waterproofing, b) clay sand, c) clay soil, d) RHS, and e) carbon steel sheet metal for developing prototype.

Clay baking mitad was manufactured at Lege tefo with the help of a local mitad manufacturer by the required design from clay sand, sol, and waterproofing collected raw materials in the same region. The burner, burner housing, lid cover, burner support, and stands, mixing tubes were manufactured in AAiT mechanical engineering workshop together with AAiT workshop/lab assistants. Drilling of a burner to create flame ports, welding processes, and assembling of the manufactured components were done here in the AAiT workshop from and by those purchased materials.

2.1.2. Design and fabrication processes

2.1.2.1.Design and fabrication of the burner

The burner's main components are an injector/jet, air-fuel mixing tube, manifold, flame ports, elbow tube, and throat. The jet tapered into an air-fuel mixing tube to inject the LPG gas. The air-fuel gas is opened to the burner manifold by an elbow tube to supply the air-fuel mixture at combustion pressure and temperature. The burner manifold is manufactured with a diameter of 540 mm and 74 numbers of flame ports with 2.5 mm holes in diameter through which the gas is ignited. The injector was manufactured from a round bar of mild steel on a lathe machine to construct the required dimension and drilled at 4 mm diameter with drill bits. The mixing tube/chamber was fabricated from the cast iron round bar by cutting it to 299.99 mm length, 4.99 mm, and 14.99 mm diameter at each end respectively.

The elbow was constructed from a cast iron tube of 15 mm internal and 24 mm external diameter with R = 3 mm and R = 27 mm internal and external curvature. The Manifold was manufactured from 2 mm thickness carbon steel sheet metal of 540mm diameter with a head cover of similar dimension drilled at equally spaced distances of 73 flame ports. The gap between the head cover and the bottom cover of the burner is 20 mm. The burner housing was fabricated from carbon steel of 2 mm thickness with 564 mm diameter by having 6 secondary air supplies cut 300 mm around the circular housing which are equally spaced. The burner side and bottom surface are insulated with fiberglass and ash to reduce heat loss. Finally, each part was assembled by welding, bolting, and drilling the flame ports on the burner's top sides. Figure 3 below shows the prototypes of the developed burner.

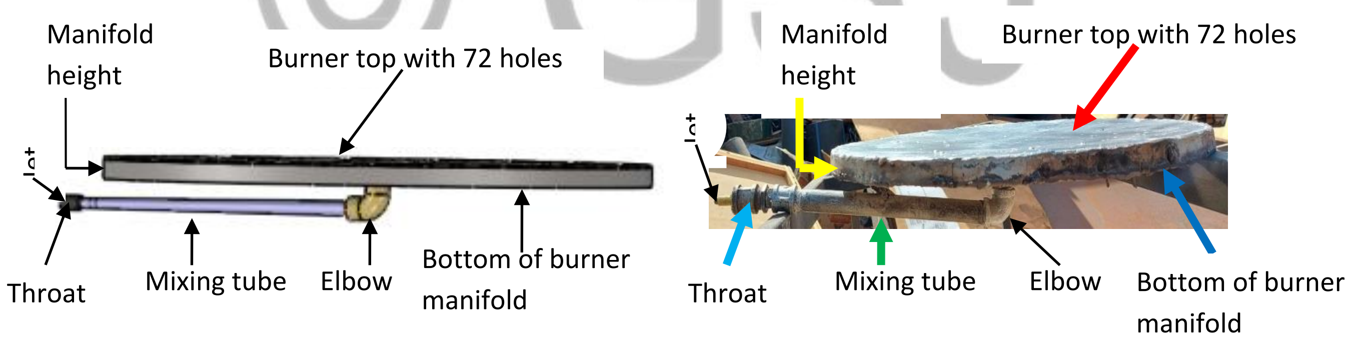


Figure 3 a) burner designed by solid work and b) manufactured burner

2.1.2.2.Design and fabrication of mitad support and stands

The mitad/pan and burner support stands were fabricated from carbon steel sheet metal and RHS as shown in Figure 4. The bottom of the burner was insulated by fiberglass and ash to prevent heat losses and reduce consumption. The support stand has four legs each 780 mm in length to hold the pan, insulation, and burner.

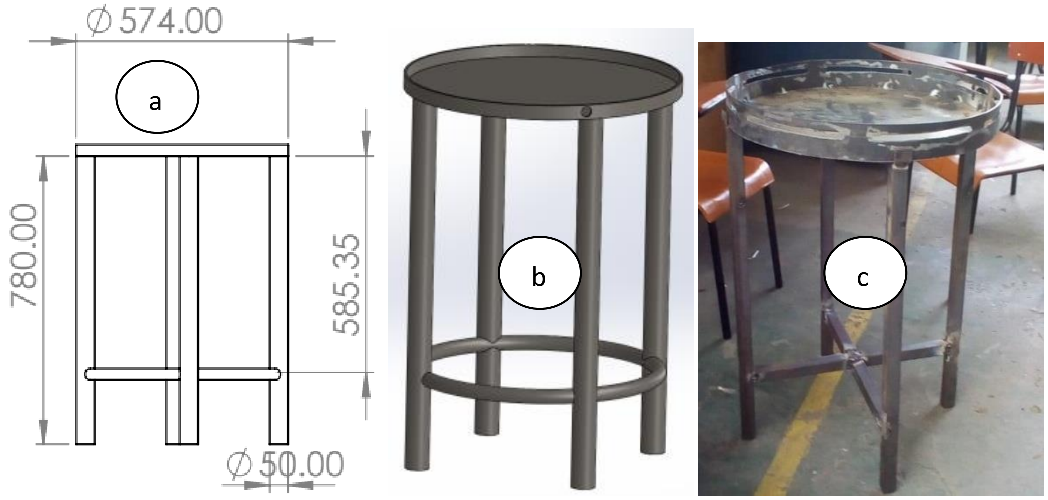


Figure 4 of support stands a) views, 3-D solid work model, and c) manufactured

2.1.2.3.Design and fabrication of mitad

The diameter and thickness of mitad are the other parameters that need to be considered during developing efficient baking stoves. So, this LPG-based baking stove mitad was constructed with 560 mm diameter, 540 mm effective area diameter, and 10 mm thickness to reduce fuel consumption by reducing heat up time from heat transfer and economic perspective. It was designed and manufactured to the optimum specific work of baking good quality injera with 52-54 mm diameter injera.

2.1.3. Assembly of prototype

Finally, the fabricated parts are assembled as in below to be ready for baking.

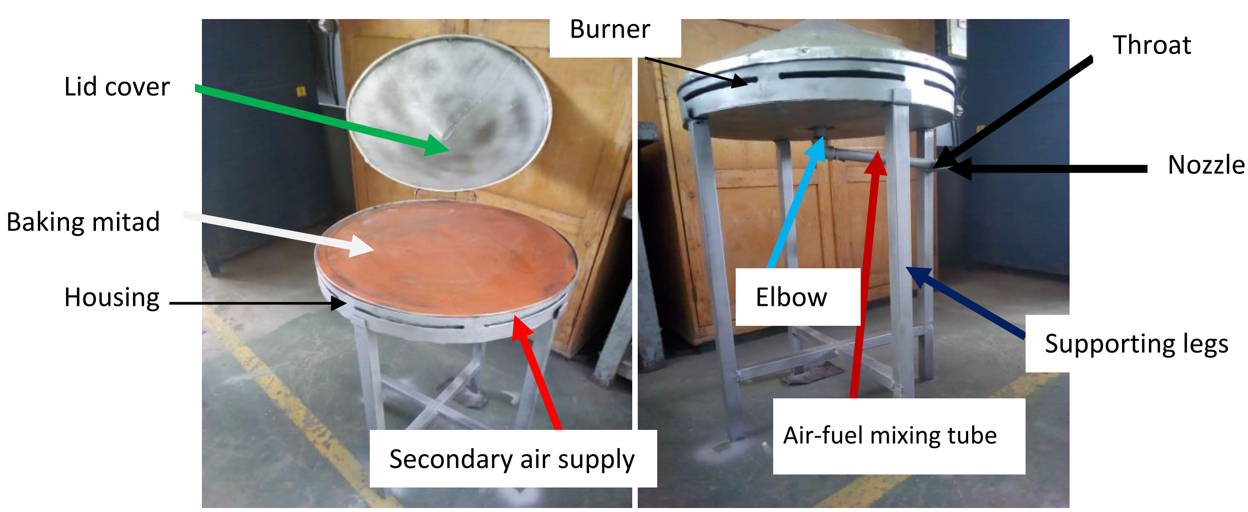


Figure 5 Manufactured Mechanical components assembled injera baking oven

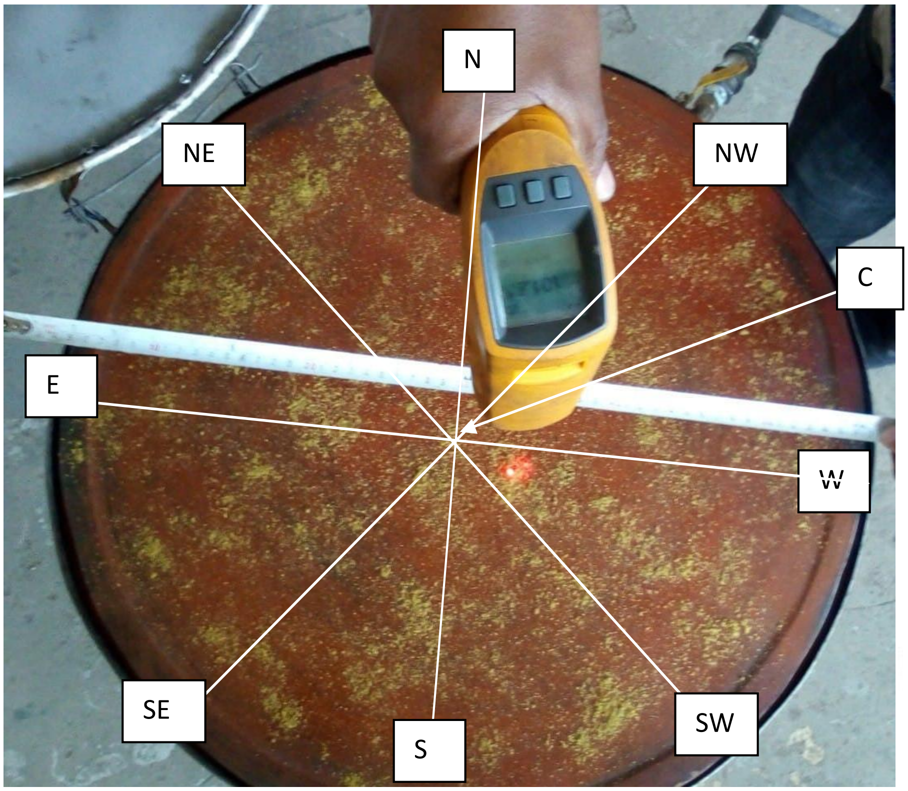
The overall summary of LPG-based baking oven fabrication processes

Table 1 1: below shows the summary of manufacturing processes of LPG-based injera baking stove components

Component	Materials	Process Description	Specification	
			Dimension	Unit
Burner	Carbon steel sheet metal	Was constructed by cutting sheet metal and welding with similar size for an upper and lower cover of the manifold with the help of a 20 mm width of circular ring. Drilled with a drill bit to create flame ports.	Ø = 540 t = 2 upper & lower gap = 20	Mm
Nozzle/jet	Cast iron	Manufactured on a lathe machine and drilled with different size drill bits fixed with flexible hoses that supply gas and throat.	Ø =4 x 2 L= 20	Mm
Throat	Cast iron	Was fabricated on lathe machine to the required dimension after turning and surface finish. Finally, it is by a different-sized drill bit and joined with a nozzle and mixing tube.	Ø =15 x 4.5 L= 37	Mm
Mixing tube	Cast iron	Was manufactured after cutting a round hollow tube of cast iron and creating teeth for bolting it with an elbow purchased from the market by the required dimension and throat to the opposite end.	Ø =5 X 15 L= 299.99	Mm
Burner housing	Carbon steel sheet metal	Was constructed from carbon steel sheet metal by cutting on a cutting machine and creating a secondary air supply by the grinder. At the end, it will bend and be shaped to a circular pattern and welded with burner support with insulation.	Ø =564 circular, w= 64.5 having 6 holes	
Burner stands	RHS	The stand was constructed from RHS by cutting and welding to connect them.	hollow 3 x 3, h = 780	Mm
Lid cover	Aluminum	Was constructed from aluminum sheet metal by cutting, bending, welding, and fixed with a stove by fixers.	Ø = 574 h = 56	Mm
Baking mitad	Clay	Was manufactured from clay soil, sand, and waterproofing by mixing with water drying, then fired with firing at a high temperature which is above 1000℃ to get the required strength.	Ø =556 & Ø =554 effective area t = 10	Mm
Insulation	Fiberglass and ash	Insulation was constructed from fiberglass and ash to reduce heat loss through the bottom side and side of mitad.	-	-

2.1.4. Temperature distribution test over the surface of baking mitad/pan

The experimental test was done in the AAiT Mechanical Engineering workshop and AAU 4 kilo campus biogas laboratory by measuring mitad surface temperature with an infrared thermometer and thermal camera respectively. However, experimental data recording using infrared created delays in time to measure the first and the last point which creates temperature differences. For this reason, unexpected temperature differences may probably happen. To avoid such a problem, a thermal camera image was used for the last experimental test conducted in Addis Ababa University's 4-kilo campus biogas laboratory.



Temperature measurement taken at: -

C- Center of mitad (r=0)

N – in north direction at r,

S - in south direction at r,

E - in east direction at r,

W - in west direction at r,

NE - in north east direction at r,

NW - in North West direction at r,

SE - in South east direction at r,

SW - in south west direction at r,

Where, r- radius from the c

Figure. 6 shows the points where the temperature of the baking mitad was measured at an r-radius distance from the center during heat up and baking time

3. Result and discussion

The experiment test was conducted in the mechanical engineering workshop laboratory of Addis Ababa Institute of Technology (AAiT) and Addis Ababa University's 4-kilo campus biogas laboratory at different times in different conditions. The experimental tests conducted helped to observe the functionality and performance of the newly developed LPG-based baking stove. Having the starting baking temperature of the room measured 18.3 ℃ and assuming the evaporating temperature of the water in the dough as it evaporated at 92 ℃ [10] in the AAiT lab, the experiment was conducted.

During the experimental test conducted, the data collecting instruments like (infrared and thermal cameras), gas flow meter, volt craft, (digital mass and weight balance), and ruler are used to measure temperature distribution, fuel consumption, (temperature, pressure, and relative humidity) of the room, mass of (dough, injera, and cylinder) and the distance at which temperature measured respectively. The LPG-based injera baking experiment was conducted successfully and its result will be presented and discussed below.

3.1.Temperature distribution test

Temperature distributions over baking mitad surface were measured in different ways in different conditions and places with different data collecting instruments to see how heat distribution over mitad looks like. The temperature distribution was measured with infrared in respective as marked in Figure. **6**.

3.1.1. Heating-up temperature tests on baking mitad surface

Heating-up temperature distribution over the baking pan surface was measured at each point with the help of an infrared thermometer are shown in Table 2.**1** and in Figure **7** below. As shown in **Table 2.1** and Figure **7** the heat-up time with the LPG injera baking stove was about 21 minutes to reach an average of 185℃ baking temperature and temperature distribution over a baking pan was increasing proportionally and good for injera baking application.

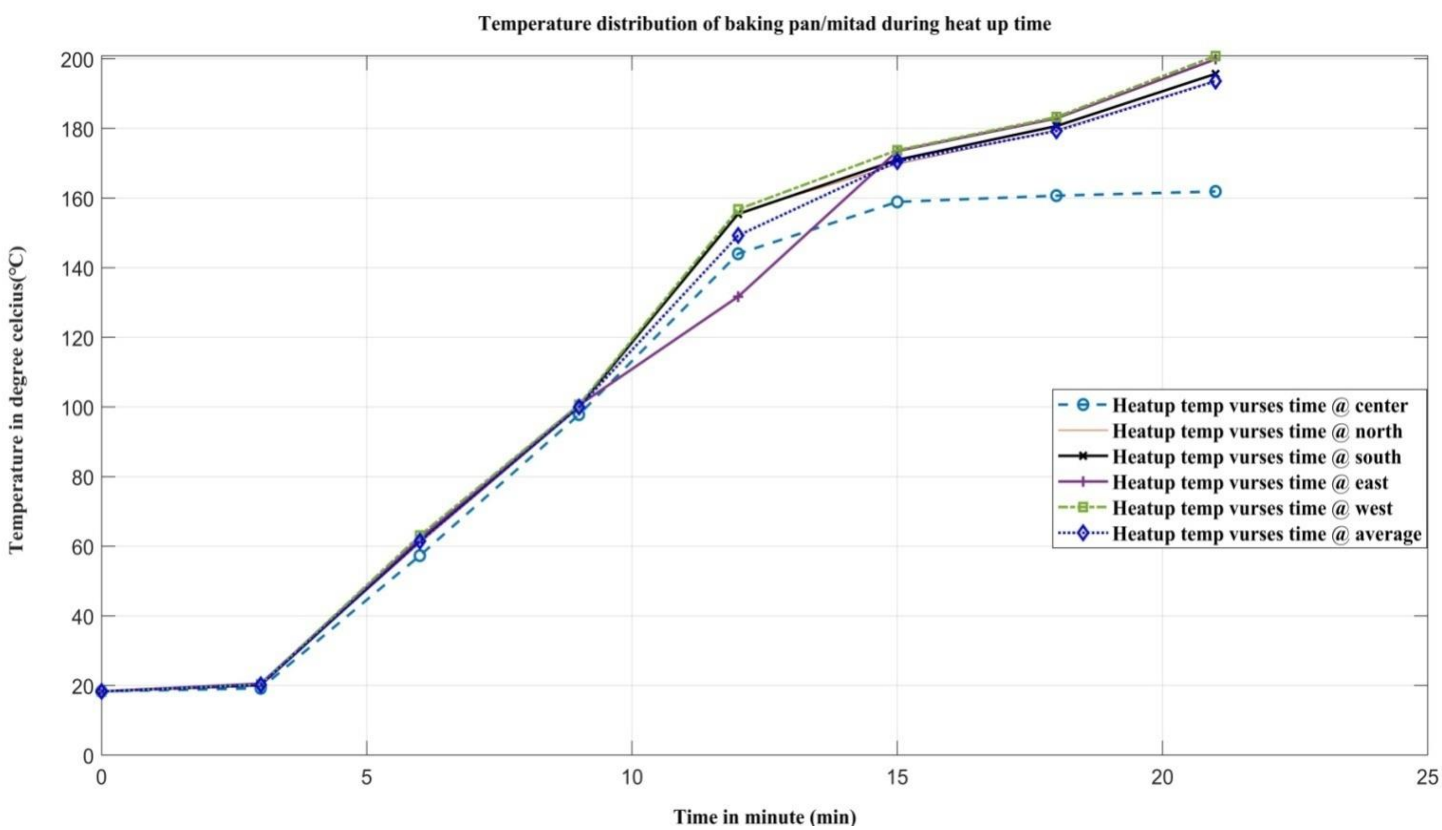


Figure 7 Temperature distributions over baking mitad/pan during heat-up time

3.1.2. Baking pan/mitad surface temperature distribution test during baking

The temperature distribution over a baking pan surface of using LPG during injera baking concerning time and each baking activity are shown in Table 2.**1** and Figure **8**. Due to the dough being poured on the pan surface taking the temperature of the baking pan, there was a slight up and down temperature. The uniform temperature distribution was achieved except the temperature around the center was somewhat lower than the other pan surface due to insufficient excess oxygen for combustion supplied through primary and secondary air supply was not balanced with other parts. However, the center temperature was lower, it didn't affect the injera product quality. The maximum and minimum temperature difference throughout the baking process recorded was 92.66 ℃ and 53℃ respectively. The baking time and successive gap of each baking are 3.4 and 3 minutes respectively.

Table 2.1: Temperature distributions over a baking mitad surface during baking cycles

Heat up time in min	Temperature in degrees centigrade (℃)					
	Center	North	South	east	west	average
0	18.3	18.3	18.3	18.3	18.2	18.3
3	19.2	20.283	20.1	20.55	20.3	20.19
6	57.7	57.3	61.63	62.2	63.067	61.42
9	99.7	97.8	100.12	100.5	100.6	99.96
12	155.67	144	155.43	131.68	156.75	149.24
15	169.73	158.9	170.97	173.5	173.75	170.5
18	179.58	160.7	180.68	182.9	183.27	179.28
21	193.77	161.9	195.67	199.87	200.83	193.58
23	225.35	162.8	222.83	227.48	233.68	220.16
27	152.20	145	154.42	153.92	156.68	152.24
30	200.98	166	190.87	197.62	206.63	192.47
33	158.23	151	161.93	162.87	213.85	165.64
35	219.52	196	217.03	217.8	188.25	209.02
38	161.73	156	162.15	167.78	162.23	163.09
41	212.9	193.7	212.28	212.07	216.05	207.81
44	161.43	158.4	169.35	160.17	165.83	169.11
46	213.38	195.2	213.55	213.45	215.22	208.49
49	163.18	162.5	164.07	166.07	168.5	167.68
52	216.52	189.1	217.65	220.6	222.88	216.04
56	163.18	160.3	165.95	177.6	169.67	161.46
58	216.58	184.3	217.48	220.9	222.05	215.37
61	162.47	161.5	164.07	166.58	167.77	160.36

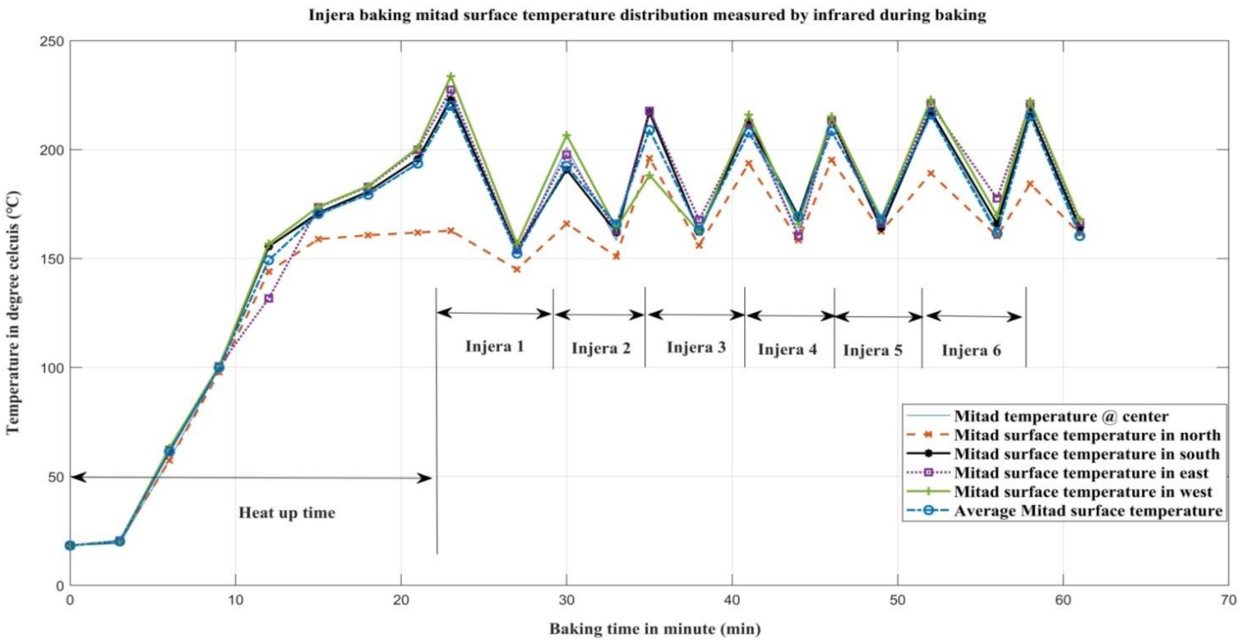


Figure 8 Temperature distributions over baking mitad/pan during baking cycles

3.2.LPG consumption and Baking efficiency of injera baking oven/stove

3.2.1. LPG consumption

Based on experimental data recorded, the LPG consumed to bake injera for about 43 minutes is 0.043 m^3. During the heat-up time, the amount of LPG required to heat the baking pan/mitad was (0.043 m^3/43 min) x 21 min = 0.021 m^3 of LPG. Since the baking time for each injera on average is 3.4 minutes, the amount of LPG required to bake one injera was (0.043m^3/43 min) x 3.4 min = 0.0034 m^3 of LPG. So, the amount of fuel consumed per unit of injera baked in (0.0034m^3).

3.2.2. Baking efficiency (η)

Baking efficiency is the ratio of useful energy (energy required to evaporate water in the dough at the boiling temperature of the water and bake injera at a required quality) to net energy input or LPG supply for this process. The amount of water evaporated (M_w) is the difference between the initial mass of dough (M_d) used for baking one injera and the mass of injera baked (M_i). The energy input is the product of the amount of gas consumed to bake one injera (V_{LPG}) and its caloric value (Cv_{LPG}) [11].

$$\eta = \frac{(M_{bm}C_{pbm} + M_i C_{pi} + M_w Cp_w)(T_b - T_a) + h_{fg}(M_d - M_i)}{V_{LPG} Cv_{LPG}} \quad \text{……………………………………. eqn}$$

Where,

M_d- Average mass of dough (544.4g) & h_{fg} - is water latent heat of vaporization (2260kJ/kg)

M_{bm} – Is the average mass of baking mitad (3966.3g) & C_{pbm} - Is specific heat capacity of baking mitad (1.381kJ/kg.°C)

M_w –Mass of water in dough (327g) & C_w - is the specific heat capacity of water (4.19kJ/kg°C)

M_i- Average mass of baked injera (328.4g) & C_i - is the specific heat capacity of injera (3.488 kJ/kg.K)

T_a - Initial temperature of the room or ambient temperature (20°C)

T_b – boiling temperature of water in dough (92°C)

V_{LPG} - Average volume of LPG consumed (0.043m^3) & Cv_{LPG}– caloric value of LPG (46MJ/ m^3)

From this result, the LPG-based injera baking oven/stove has a baking capacity of 53.77% which is more efficient, clean, reliable, and free from IAP than biomass-based of 5-15% [12], 16-21%, 23% efficiency of traditional 3-stone, mirt and Gonzie baking stoves respectively [13], 16% of the first injera baking gasifier stoves [10], 57% of biogas [11], 61% electric [14], and 37% solar [15], based injera baking stoves. It is also more convenient and environmentally friendly than biomass-based because it emits almost negligible IAP and particulate matter. Therefore, the government of Ethiopia and different organizations like GIZ who are working on cooking and baking stoves should encourage and try to give training and some other subsidence to adopt the community as they use this clean and efficient stove to conserve nature and save our communities from health problems.

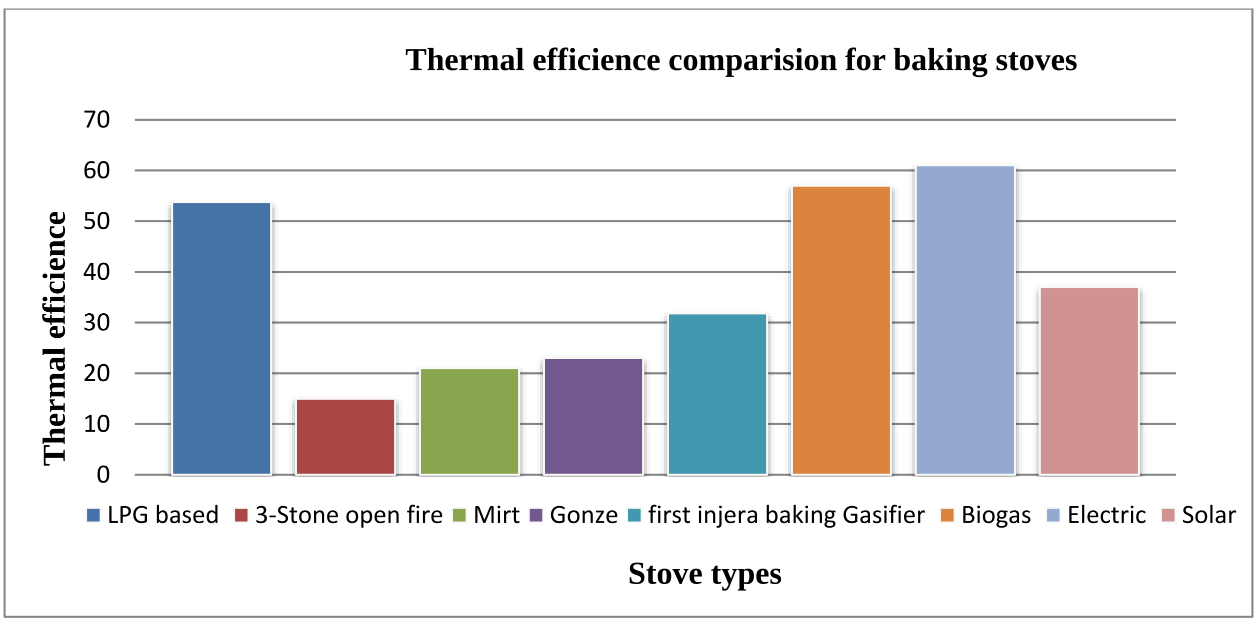


Figure 9 Thermal efficiency comparison of LPG based with other baking stoves

3.2.3. LPG-based oven/stove under baking

With an LPG-based injera baking stove, anyone can bake on average 12-20 pieces of injera per hour with a 54cm diameter of mitad effective area by $0.043m^3$ LPG consumption at the required level of injera qualities. As it is shown in Figure **10**, Figure **11** and Figure **12** below, the progress of pouring dough on mitad, just during baking and take off from the baking mitad is observed. The main challenge of the test result was to maintain uniform heat distribution over the baking mitad surface due to excess air insufficient at the center.

Figure 10:- a. During dough poured on mitad b. Just at injera baked and c. During injera take-off

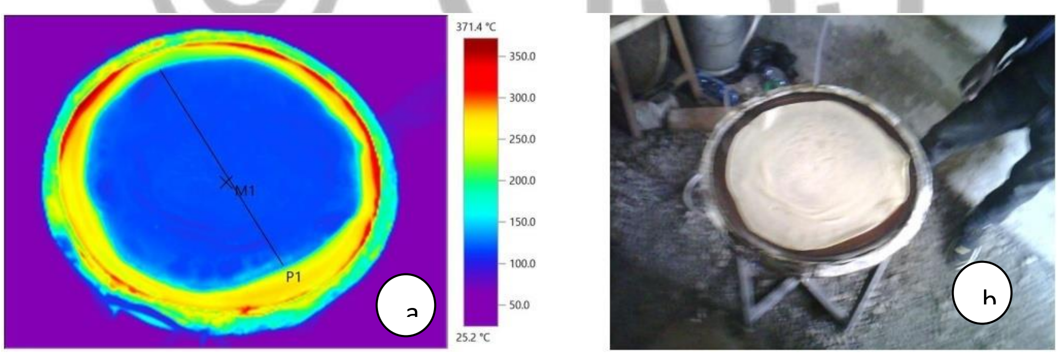


Figure 11 a. thermal camera image and b. real image of baked injera ready for take off

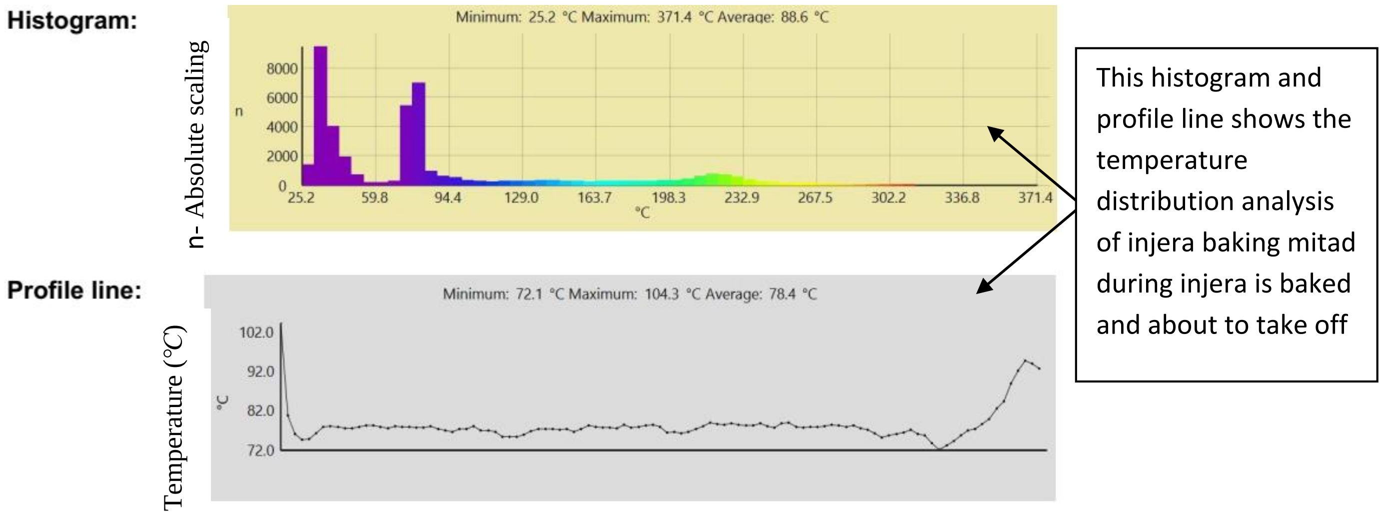


Figure 12 thermal camera image historical and line graph profile analyzed result by testo software

Figure 13 Quality of Injera baked by Liquefied petroleum gas-based stove

4. Conclusions and recommendations

4.1.Conclusion

The existence of life in this world has a strong relationship with energy. So, the relationship between development, climate, and energy are inseparable and without energy, it is impossible to have technology. Based on this fact designing, developing, fabricating, and performance evaluation have been employed to introduce LPG-based injera baking stoves. This study presents the design and fabrication of a liquefied petroleum gas (LPG) based injera baking oven/stove which is the optional clean energy fuel to reduce biomass-based baking problems like air and indoor pollution.

The performance and economic feasibility of the newly 0.061 kWh developed LPG-based stove were compared with traditional three-stone open fire and electric injera baking stoves. The experimental test and result show the possibility of injera baking using LPG and the following points are concluded from the experimental results,

- ✓ The developed LPG-based baking oven/stove has a thermal efficiency of 53.77 % which is higher than biomass-based traditional three-stone and higher/lower than electric stove.
- ✓ The fuel consumption of this stove was 0.0034 m^3 (0.061 kWh) per injera and 0.96 kWh/kg which is lower emission than biomass and higher than electric power of 0.54 - 0.822 kWh/kg.
- ✓ The heat-up time to bring the baking mitad surface to baking temperature 185 ℃ was 21 minutes and the time required for each injera was 3.4 minutes with an idle time of 3 minutes on average.
- ✓ The insulation system used to prevent heat loss from the lower part of the baking oven by using ash and fiber reduced the bottom temperature from 134 ℃ to 28.5 ℃ of using only fiber.
- ✓ The injera was baked at the required quality and can satisfy the market demand.
- ✓ The energy cost of an LPG stove is more expensive than both biomass and electric stoves with a six-month payback period. However, this research work is economic for mass producers or a group of people who come together to bake on a single mitad rather than by individual users.

In general, the newly developed LPG-based baking stove solves the reliability problem with solar, biogas, and electric stoves in our country and needs special consideration to work on it. So, it is a clean and reliable injera baking stove.

4.2.Recommendations and future work

The prototype was developed and an experimental test was conducted with good results. But I recommend to the governments and the researchers who will work in this area as follows;

- ✓ The Ethiopian government needs to grant VAT exemption for LPG and establish clean cooking policies and strategies.
- ✓ The country needs to launch a national awareness program for LPG use through different media as well as the country's schools on; the risk of air indoor pollution from wood fuel, environmental damage by deforestation, and providing other clean energy sources like LPG with their safety.
- ✓ Ethiopia's government needs to subsidize to encourage the community to use LPG.
- ✓ To overcome the heat distribution uniformity, it is better to work on burner design by the required energy with their complete combustion.

ACKNOWLEDGEMENT

First and foremost, I'd like to express my gratitude to Almighty God for providing me with the endurance, wisdom, and patience I needed during a long period of study. Next, I want to thank my advisor, Dr. Abdulkadir Aman Hassen, for sharing his wealth of knowledge and making himself available for guidance at various stages of this work. My gratitude goes to Mr. Meseresha, Mr. Israel, and Mrs. Bekalu, who are Lab technicians and AAiT employees who assisted me during the manufacturing of the thesis prototype at the AAiT laboratory and the conduct of experimental tests, for their encouragement, patience, and support in my academic career. Finally, I'd like to thank Dr. Bilat for his assistance in testing instruments such as the thermal camera, gas flow meter, and volt craft by allowing me to conduct my tests in his workshop, as well as Addis Ababa Institute of Technology University for funding this research project, and all of those people for your more contributions and generous support, which will be etched in my mind.

References

[1] Access to clean fuels and technologies for cooking, Sdg7-Report. (2022) 25.

[2] F.M. Bayu, Heliyon Cost reduction and forest preservation potential of advanced stoves and challenges of their adoption in higher education : the case of werabe university , Ethiopia, Heliyon. 6 (2020) e04693. https://doi.org/10.1016/j.heliyon.2020.e04693.

[3] F. Kemausuor, M.S. Adaramola, J. Morken, A Review of Commercial Biogas Systems and Lessons for Africa, Energies. 11 (2018) 1–21. https://doi.org/10.3390/en11112984.

[4] S. Africa, S. Asia, The bottom line., Eur. J. Cancer. 42 (2006) 2859.

[5] J. Keese, C. Guzman Vazquez, M. O'Brien, B. Richter, LPG Cookstove Use and Fuel Subsidies in the Cuzco Region of Peru, Int. J. Sustain. Dev. Res. 6 (2020) 14. https://doi.org/10.11648/j.ijsdr.20200601.13.

[6] A.A. Hassen, S.B. Kebede, N.M. Wihib, Design and Manufacturing of Thermal Energy Based Injera Baking Glass Pan, Energy Procedia. 93 (2016) 154–159. https://doi.org/10.1016/j.egypro.2016.07.164.

[7] K.D. Adem, D.A. Ambie, A review of injera baking technologies in Ethiopia: Challenges and gaps, Energy Sustain. Dev. 41 (2017) 69–80. https://doi.org/10.1016/j.esd.2017.08.003.

[8] M. Tadesse, The Developmental Patterns of Injera Baking Stoves : Review on the Efficiency , and Energy Consumption in Ethiopia, 7 (2020) 7–16.

[9] E. Cecelski, M. Matinga, Cooking With Gas: Why Women in Developing Countries Want LPG and How They Can Get it, (2014) 72. https://www.wlpga.org/wp-content/uploads/2015/09/2014-cooking-with-lp-gas-women-report.pdf.

[10] K.D. Adem, D.A. Ambie, M.P. Arnavat, U.B. Henriksen, J. Ahrenfeldt, T.P. Thomsen, First injera baking biomass gasifier stove to reduce indoor air pollution, and fuel use, AIMS Energy. 7 (2019) 227–245. https://doi.org/10.3934/ENERGY.2019.2.227.

[11] D.T. Nega, B. Mulugeta, S.W. Demissie, Improved biogas ‘Injera’ bakery stove design, assemble and its baking pan floor temperature distribution test, Energy Sustain. Dev. 61 (2021) 65–73. https://doi.org/10.1016/j.esd.2020.12.009.

[12] R. Jones, J.C. Diehl, L. Simons, M. Verwaal, The Development of an Energy Efficient Electric Mitad for Baking Injeras in Ethiopia, (2017). https://doi.org/10.23919/DUE.2017.7931827.

[13] A. Gulilat, Stove Testing Result, A Report on Controlled Cooking Test of Gonzie Stove, (2014). https://energypedia.info/images/1/19/Gonzie_Stove_CCtest_report_2014.pdf.

[14] M. Hayelom, M. Bayray, A. Haileslasie, O. Issa, Energy consumption performance analysis of electrical mitad at Mekelle City Energy Consumption Performance Analysis of Electrical Mitad at Mekelle City, (2017). https://doi.org/10.4314/mejs.v9i1.4.

[15] M.H. Hailu, O.J. Nydal, M.B. Kahsay, A.H. Tesfay, A direct solar fryer for injera baking application, ISES Sol. World Congr. 2017 - IEA SHC Int. Conf. Sol. Heat. Cool. Build. Ind. 2017, Proc. (2017) 1475–1485. https://doi.org/10.18086/swc.2017.24.02.