Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.16, No.1, 2026

Fabrication and household level evaluation of wood gas cook stove using Control Cooking Test Method

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Abstract

2.7 billion People worldwide use solid biomass fuels for cooking, heating, and providing their daily energy needs. In most of the developing nations, the energy demand per household is covered mainly by woody biomasses. For instance, agricultural residues, animal dung, and charcoal are among the principal solid biomass fuels used in rural households for cooking and lighting. This research work aims to fabricate and performance evaluation of a wood gas stove for cooking purposes. The control cooking test (CCT) was conducted for wood gas stove evaluation and the results were compared with three stone traditional stoves and other related literatures. The stove's experimental performance was evaluated by cooking with potatoes and analyzed by the control cooking test version 2.0 spreadsheet using two pots (3.5 L and 5.5 L) with and without an insulator using conifer wood. The CCT experimental results indicate that the average specific fuel consumption and time for cooking 2,282 g of potatoes were 98 g/kg, 142 g/kg, and 24 min, 28 min. for the wood gas cook stove with and without an insulator, respectively, using a 3.5 L pot. The average specific fuel consumption and cooking time for cooking 2,745 g of potatoes were 171 g/kg, 271 g/kg, and 27, 30 min. for the wood gas cook stove with and without an insulator, respectively, using a 5.5 L pot.
Keywords*: Conifer wood, Cooking time, CCT, Gas stove, Insulator, SFC*
DOI: 10.7176/JETP/16-1-03
Publication date: January 28th 2026

1. Introduction

Domestic energy consumption in the developed and developing worlds is vastly different. Currently, the developed world predominantly consumes energy produced from fossil fuels, and to a growing extent, renewable energy sources. In contrast, the developing world is still largely dependent on biomass such as wood, dung, and agricultural waste for domestic energy fuel sources that are typically burned in traditional stoves [1].

Because of the world's high energy demand, the price of fossil fuels (oil and natural gas) has been steadily rising, and the energy crisis has been steadily worsening [2]. Wood based energy is the main source of cooking and heating fuel in Sub-Saharan Africa. Its use rises as the population increases [3]. In most of the developing nations, the energy demand per household is covered mainly by woody biomasses. For instance, agricultural residues, animal dung, and charcoal are among the principal solid biomass fuels used in rural households for cooking and lighting [4].

Traditional stoves are known to produce large amounts of emissions that contribute to indoor air pollution and health-harming air pollutants. Traditional stoves are also characterized by low overall efficiency and significant heat energy loss, which results in inefficient use of biomass fuel. Many households in rural parts of emerging countries use the traditional three-stone fire [5].

The conversion of energy into thermal energy for cooking was inefficient with these open fires.

Indoor cooking smoke has been linked to various diseases, the most dangerous chronic and acute respiratory infections like bronchitis and pneumonia. Cooking with firewood in a gasifier cook stove and use of the resultant charcoal as a by-product to cook another meal in a conventional charcoal stove saved 41% of the amount of fuel compared to cooking with firewood in the traditional three-stone open fire [6].

Gas cooking is advantageous compared to direct combustion improved cook stoves (ICS) by providing cleaner burning of solid biomass (considerable reduction of soot, black carbon, and indoor/outdoor air pollution), fuel efficient due to more complete combustion (less total biomass consumption), use a variety of small-sized

biomass residues (no need for stick-wood or charcoal) and easy lighting allows for cooking to commence within minutes [7]. The use of an inverted downdraft biomass gasifier cook stove had a significant impact on reducing fuel consumption, cooking time, and kitchen pollution. Though there are proven benefits of the improved cook stove, making available the cut wood and cost of the cook stove play an important role in end-user acceptability [8].

In Ethiopia, different organizations made an effort to avail improved gas stoves. Of these, the AAERC energy team fabricated a double cylinder inverted down draft gasifier. AAERC evaluated the performance of the stove by using WBT and its maximum thermal efficiency of the stove was 28.7% [9]. The controlled cooking test (CCT) is designed to assess the performance of the improved stove relative to the common or traditional stoves that the improved model is meant to replace. CCT is a laboratory or field test that evaluates the performance of the cooking stoves using a standardized local cooking task (s). This method reveals the behavior of the stove under the ideal cooking conditions in a locality/project area [10].

This research work was aimed at adapting and performance evaluation of a wood gas stove for cooking purposes. The control cooking test (CCT) was conducted for wood gas stove evaluation and the results were compared with three stone traditional stoves. The stove's experimental performance was evaluated by cooking with potatoes and analyzed by the control cooking test version 2.0 spreadsheet using two pots (3.5 L and 5.5 L) with and without an insulator using conifer wood. Therefore, the objectives of the study were: To adapt the wood gas stove and to evaluate the performance of the stove using the control cooking tests (CCT) method.

1.1 A Brief Related Literature Review

Table 1 A literature review related to the wood gas cook stove

Authors	Titles	Methods and the meal cooked	Results and its source
Usha Pawar1 *et al.*, 2022	A case study on the design and development of solar food cooking system with a PCM as a heat storage unit	➢ Controlled cooking test ➢ Rice and potato	➢ The time taken for cooking Rice (22 minutes) and (29 minutes) for Potato ➢ Source [11]
Solomon Tibebu and and Arkbom Hailu (2021)	Design, construction and evaluation of the performance of dual-axis sun trucker parabolic solar cooker and comparison of cooker	➢ Controlled cooking test ➢ Potato	➢ The time taken for cooking Potato was 100 minutes ➢ Source [12]
Dilip Kumar De *et al.*, 2014	Minimizing energy usage in cooking to protect environments and health	➢ Controlled cooking test ➢ Irish Potato	➢ The time taken for cooking Irish Potato was 17.51 minutes ➢ Source [13]
Onchoke Ismail *et al.*, (2015)	Conversion of rice husks into an energy source through gasification technology	Controlled cooking test ➢ Meat	➢ The time taken for cooking Meat was 22 minutes ➢ Source [14]
Isaac F. Odesola *et al.*, (2019)	Design and performance evaluation of energy efficient biomass gasifier cook stove using multi fuels	➢ Water boiling test ➢ Water	➢ The time taken for boiling 2kg of water was 20 minutes ➢ Source [15]
A. Kuhe *et al.*, (2019)	Performance of clay wood cook stove: An analysis of cost and fuel savings	➢ Controlled cooking test ➢ Beans	➢ The time taken for cooking Beans was 39 minutes ➢ Source [16]
S. B. Muhammad *et al.*, (2016)	Performance evaluation of a save 80 wood stove using Controlled Cooking Test Method	➢ Controlled cooking test ➢ Rice	➢ The time taken for cooking 0.55 kg of Rice was 28.29 minutes

			➢ Source [17]
Adem Tibesso *et al.*, (2024)	**Fabrication and household level evaluation of wood gas stove using Control Cooking Test Method**	**➢ Controlled cooking test ➢ Potato**	**➢ The time taken for cooking Potato were 24 and 27 minutes for 3.5 L & 5.5 L Pot respectively ➢ Source [This Study].**

*Table 1 shows a literature review related to the wood gas cook stove.

2. Materials and Methods

2.1 Materials

The raw materials used for manufacturing the wood gas stove were different sizes of sheet metals, square pipes, double rings and plain round bars. The fuel wood and food used for experimenting were Conifer and Potato respectively.

2.1.1 Instruments used for testing

The instruments used for testing the experiments are a digital balance, Digital thermometer, K-type thermocouple, Oven dry, hygrometer (to measure relative humidity), anemometer (to measure wind speed), Tape measure, Stopwatch, wood biomass sacks, Ash buckets, Pots or Dist and gloves for heat resistance.

Fig.1 The instruments used for data collection

*The fig.1 describes the instruments (Oven dry, Multimeter, Digital hygrometer and Thermometer) used during the data collection.

2.2 Methodology

2.2.1 Descriptions of the study area

The wood gas stove was manufactured at the Jimma Agricultural Engineering Research Center (JAERC) workshop, Oromia Agricultural Research Institute, Ethiopia. The experiment was done at Kilole kirkir kebele's of Gomma district, Jimma zone, Oromia, Ethiopia. The minimum and maximum annual temperatures of the district is found between 7°C-12 °C and 23°C-30°C respectively. The minimum and maximum annual temperatures of the district is found between 7°C-12 °C and 23°C-30°C respectively [18].

2.2.2 Descriptions of the stove

The wood gas stove prototype has different components such as a pot holder, outer cylinder, top cover, riser, combustion chamber, and grate.

Fig.2 The manufactured wood gas cook stove prototype

*Fig.2 indicates the components of wood gas cook stove such as a pot holder, outer cylinder, top cover, riser, combustion chamber, and grate manufactured at Jimma Agricultural Engineering Research Center Metal Workshop.

2.2.3 Methods used to conduct the experiment

The controlled cooking tests (CCT) were used to determine the performance efficiency of the wood gas stove.

Controlled Cooking Test (CCT)

Controlled cooking test will be performed in order to evaluate the performance of a cook stove while actually cooking food. This test differs from the WBT in the medium through which the heat is transferred. In contrast to water in the WBT, food is used as a medium in CCT.

Controlled cooking test depends up on a number of factors:

- Composition and physical properties of food
- Type of cooking operation
- Mass of food to be cooked
- Method of preparation of food and
- Type of vessels used

Test analysis of the CCT

Variables

As in the WBT, there are many several variables that are directly measured. These include environmental variables and physical test parameters. The environmental variables may vary slightly from one test to another but should be nearly constant.
Environmental variables: Wind conditions and Air temperature.

Physical test parameters:

Variables	**Label**
Average dimensions of wood (centimeters)	--
Wood moisture content (% - wet basis)	m
Empty weight of Pot # 1 (grams)	P1
Empty weight of Pot # 2 (grams)	P2
Empty weight of Pot # 3 (grams)	P3
Empty weight of Pot # 4 (grams)	P4
Weight of container for char (grams)	k
Local boiling point of water (°C)	Tb

Measurements and Calculations
For experimental results obtained, many measurements were taken. Those include:
Initial weight of fuel wood (wet basis) (grams) f_i
Final weight of fuel wood (wet basis) (grams) f_f
Weight of charcoal with container (grams) c_c
The weight of each pot with cooked food (grams) Pj_f
Start and finish times of cooking (minutes) t_i and t_f
These measurements are then used to calculate the following indicators of stove performance:
Total weight of food cooked (W_f) – was the final weight of all food cooked; it is simply calculated by subtracting the weight of the empty pots from the pots and food after the cooking task is complete.
$W_f = \sum_{i=1}^{4}(Pj_f - pj)$ where j is an index for each pot
Weight of char remaining (Δc_c) – the mass of charcoal from within the stove, including the char removed from the ends of the unburned fuel that is extinguished just at the end of the cooking task. This is found by simple subtraction:
$\Delta cc = c_c - k$
Equivalent dry wood consumed (f_d) – This was defined as for the CCT, adjusting for the amount of wood that was burned in order to account for two factors: (1) the wood that must be burned in order to vaporize moisture in the wood and (2) the amount of char remaining unburned after the cooking task is complete. The calculation was done in the following way:
$fd = f_f - f_i \times [1-(1.12\times MC)]-1.5\times \Delta C$
Specific fuel consumption (SFC) – was the principal indicator of stove performance for the CCT. It tells the tester the quantity of fuel required to cook a given amount of food for the "standard cooking task". It was calculated as a simple ratio of fuel to food:
$SFC\ (\%) = \frac{f_d}{w_f} * 100$
This was reported in grams of fuel per kilogram food cooked, whereas W_f was reported in grams. Thus a factor of 1000 was included in the calculation.
Total cooking time (Δt) – This was also an important indicator of stove performance in the CCT. Depending on local conditions and individual preferences, stove users may value this indicator more or less than the fuel consumption indicator. This was calculated as a simple clock difference:
$\Delta t = t_f - t_i$

General parameters studied

Constant variables that were used for evaluation

✓ Gross calorific values of biomass, Net calorific values of biomass, the effective calorific value of biomass, the net calorific value of char/ash, Dry mass of an empty pot, and the weight of an empty container for char.

Measured Variables

The main parameters that were measured are Temperatures**,** The moisture content of the biomass (wood)**,** Specific fuel consumption**,** Weight of biomass (fuel)**,** Time for cooking**,** proximate analysis of the biomass**,** Char contents, and Weight of cooked food.

2.2.4 Characterization of the used biomass

Proximate analysis of the conifer wood

The proximate analysis of conifer wood samples was tested at the Ethiopian Ministry of Water and Energy Workshop and Laboratory Desk.

Table 2 Proximate analysis report of biomass at the Ethiopian Ministry of Water and Energy Workshop

Sample type	Moisture content (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Calorific value (Cal/gm)
Conifer wood	9	78	12	1	4980.14

*Table 2 showed that, the proximate analysis of biomass (conifer wood) results was done at the Ethiopian Ministry of Water and Energy Workshop as similar work done by [2].

2.2.5 Data collection methods and sampling

- The data was taken by testing the performance evaluation of a wood gas stove.
- The test was conducted by using the Conifer wood for two types of pots
- The controlled cooking test (CCT) method was conducted while data was taken during the experiment.

Fig.3 The MC for Conifer wood (a) and Weighting potato for cooking (b) during experimental work

*Fig.3 indicated that the moisture content of Conifer wood (a) and Weight of potato for cooking (b).

Experimental setup

- The experiment was conducted using conifer wood with average area of (3×3×3.5) cm particle dimensions.
- The controlled cooking test was also conducted by cooking Potato with 3.5 liter pot, and 5.5 liter pot, with three replications using conifer wood.
- The wood gas cook stove was also analyzed and compared with traditional three stone stove.

Experiment procedures

The procedures that were followed for CCT:

- Peoples were consulted about the location where the stove was introduced
- Local conditions were recorded as instructed on the data collection form
- The ingredients was weighed and prepared
- A pre-weighed bundle of fuel was started with a cook stove
- Any relevant observations and comments were recorded during the cook performs the cooking task
- The time was recorded, when the task was being finished
- The pot(s) of food was removed from the stove
- The cooked food weight was recorded
- The unburned wood was removed from the fire
- Finally, the test was complete

2.2.6 Data analysis methods

The measured data were analyzed using software such as the CCT spreadsheet version 2.0, Engineering Equation Solver (EES), and Origion Pro 2018 according to its suitability.

The data obtained from the experiment were subjected to statistical analysis of variance (ANOVA) at a 5% significance level. The results are considered statistically significant when their corresponding p-values are less than 0.05.

3. Results and Discussion

Initially, the flames come out of the top of the stove, but after a few minutes, the combustion changes. The wood is slowly converted to charcoal and the gas released by this process burns with a higher flame height than the wood would give as well as burning for a much greater length of time. After a while, flames no longer come out of the top of the stove, they come out of the ring of holes around the base of the outer cylinder.

3.1 Summary results of the stove performance using CCT

3.1.1 Using CCT without an insulator and by 3.5 L Pot and Conifer wood

Table 3 The average controlled cooking test (CCT) results for 3.5 L pot without insulator

1. CCT results: Stove 1	Units	Test 1	Test 2	Test 3	Mean	St dev.
Total weight of food cooked	g	2,273	2,592	2,278	2,381	183
Weight of char remaining	g	51	86	56	64	19
Equivalent dry wood consumed	g	1,049	1,009	970	1,009	40
Specific fuel consumption	g/kg	148	144	135	142	7
Total cooking time	min	29	27	26	27	2
2. CCT results: Stove 2	**Units**	**Test 1**	**Test 2**	**Test 3**	**Mean**	**St dev.**
Total weight of food cooked	g	2,273	2,592	2,278	2,381	183
Weight of char remaining	g	109	122	112	114	7
Equivalent dry wood consumed	g	556	460	572	529	61
Specific fuel consumption	g/kg	298	269	291	286	15
Total cooking time	min	45	42	43	43	2
Comparison of Stove 1 and Stove 2		**Difference (%)**		**T-test**	**Sign @ 95%?**	
Specific fuel consumption	g/kg	-101%		-15.18	YES	
Total cooking time	min	-59%		-12.83	YES	

*Where WGS- is Wood Gas Stove

The Table 3, Table 4, Table 5 & Table 6 average controlled cooking test (CCT) results were obtained using CCT spreadsheet version 2.0 protocol [10] by inserting the collected raw data's.

*Table 3 results indicated that, the average specific fuel consumption and cooking time for cooking 2,381g of potatoes were 142, 286 g/kg and 27, 43 min. for the wood gas cook stove and three stone traditional cook stove, respectively, using a 3.5 L pot. The result obtained was better when compared with the cook stove done by [13] in which SFC & cooking time were 236 g/kg and 36.23 minutes respectively.

3.1.2 Using CCT without an insulator and by 3.5 L Pot and Conifer wood

Table 4 The average controlled cooking test (CCT) results for 5.5 L pot without insulator

1. CCT results: Stove 1	Units	Test 1	Test 2	Test 3	Mean	St dev.
Total weight of food cooked	g	2,545	2,685	2,973	2,734	218
Weight of char remaining	g	120	131	150	134	15
Equivalent dry wood consumed	g	1,105	1,274	1,411	1,263	153
Specific fuel consumption	g/kg	266	270	278	271	6
Total cooking time	min	30	29	30	30	1
2. CCT results: Stove 2	**Units**	**Test 1**	**Test 2**	**Test 3**	**Mean**	**St dev.**
Total weight of food cooked	g	2,545	2,685	2,973	2,734	218
Weight of char remaining	g	163	193	235	197	36
Equivalent dry wood consumed	g	970	952	992	971	20
Specific fuel consumption	g/kg	374	412	420	402	25
Total cooking time	min	45	47	49	47	2
Comparison of Stove 1 and Stove 2		**Difference (%)**		**T-test**	**Sign @ 95%?**	
Specific fuel consumption	g/kg	-133%		-21.19	YES	
Total cooking time	min	-58%		-14.42	YES	

*Where TCS- is three stone traditional cook stove

*Table 4 results indicated that, the average specific fuel consumption and cooking time for cooking 2,734 g of potatoes were 271, 402 g/kg and 30, 47 min. for the wood gas cook stove and three stone traditional cook stove, respectively, using a 5.5 L pot. The studied wood gas stove was saved the 17 minutes total cooking time when compared with traditional three stone cook stove.
The result was similar with the cook stove done by [13] in which SFC & cooking time were 236 g/kg and 36.23 minutes respectively.

Fig.4 The wood gas cook stove tests without insulator
*Fig.4 showed that, the experiment tests of the cook stove without insulator

3.1.3 Using CCT with insulator and by 3.5 L Pot and Conifer wood

Table 5 The average controlled cooking test (CCT) results of the wood gas stove (WGS) versus a three-stone traditional cook stove (TCS) for a 3.5 L pot with an insulator

1. CCT results: WGS	Units	Test 1	Test 2	Test 3	Mean	St dev.
Total weight of food cooked	g	2,273	2,508	2,065	2,282	222
Weight of char remaining	g	111	142	100	126	8
Equivalent dry wood consumed	g	237	249	189	225	32
Specific fuel consumption	g/kg	109	94	92	98	10
Total cooking time	min	24	22	25	24	2
2. CCT results: TCS	**Units**	**Test 1**	**Test 2**	**Test 3**	**Mean**	**St dev.**
Total weight of food cooked	g	2,273	2,508	2,065	2,282	222
Weight of char remaining	g	125	134	112	112	9
Equivalent dry wood consumed	g	556	572	460	529	61
Specific fuel consumption	g/kg	180	183	178	180	17
Total cooking time	min	41	35	38	38	2
Comparison of WGS and TCS		**Difference (%)**		**T-test**	**Sign @ 95%**	
Specific fuel consumption	g/kg	-174%		-15.39	YES	
Total cooking time	min	-81%		-12.91	YES	

*Where TCS- is three stone cook stove

*Table 5 results indicated that, the average specific fuel consumption and cooking time for cooking 2,282 g of potatoes were 98, 180 g/kg and 24, 38 min. for the wood gas cook stove and three stone traditional cook stove, respectively, using a 3.5 L pot.
The result obtained was better when compared with the cook stove done by [13] in which SFC & cooking time were 236 g/kg and 36.23 minutes respectively.

3.1.4 Using CCT with insulator and by 5.5 L Pot and Conifer wood

Table 6 The average controlled cooking test (CCT) results of the wood gas stove (WGS) versus the three-stone traditional cook stove (TCS) for a 5.5 L pot with an insulator

1. CCT results: WGS	Units	Test 1	Test 2	Test 3	Mean	St dev.
Total weight of food cooked	g	2,951	2,777	2,507	2,745	224
Weight of char remaining	g	132	122	105	120	14
Equivalent dry wood consumed	g	487	472	444	468	22
Specific fuel consumption	g/kg	188	165	160	171	15
Total cooking time	min	28	26	27	27	1
2. CCT results: TCS	**Units**	**Test 1**	**Test 2**	**Test 3**	**Mean**	**St dev.**
Total weight of food cooked	g	2,951	2,777	2,507	2,745	224
Weight of char remaining	g	235	193	163	197	36
Equivalent dry wood consumed	g	992	970	952	971	20
Specific fuel consumption	g/kg	290	284	278	284	23
Total cooking time	min	44	42	43	43	1

Comparison of WGS and TCS		Difference (%)	T-test	Sign @ 95%
Specific fuel consumption	g/kg	-247%	-26.75	YES
Total cooking time	min	-44%	-14.70	YES

*Table 6 results indicated that, the average specific fuel consumption and cooking time for cooking 2,745 g of potatoes were 171, 284 g/kg and 27, 43 min. for the wood gas cook stove and three stone traditional cook stove, respectively, using a 5.5 L pot. The result was similar with the cook stove done by [13] in which SFC & cooking time were 236 g/kg and 36.23 minutes respectively.

Fig.5 The wood gas cook stove test with insulator (glass wool)
*Fig.5 showed the experiment tests of the cook stove with insulator

3.2 Specific fuel consumption and cooking time results

3.2.1 The specific fuel consumption and cooking time for WGS with 3.5 L and 5.5 L pots

Fig.6 The SFC and cooking time versus pot types for WGS
*Fig. 6 indicated that, the average Specific fuel consumption and cooking time of wood gas stove for 3.5 L Pot with insulator and without insulator were 98 g/kg, 142 g/kg and 24 min., 28 min. respectively. The average Specific fuel consumption and cooking time of wood gas stove for 5.5 L Pot with insulator and without insulator were 171 g/kg, 271 g/kg and 27 min., 30 min., respectively. The result was similar with the cook stove done by [13] in which SFC & cooking time were 236 g/kg and 36.23 minutes respectively.

3.2.2 The specific fuel consumption and cooking time for WGS & TCS with 3.5 L & 5.5 L pots

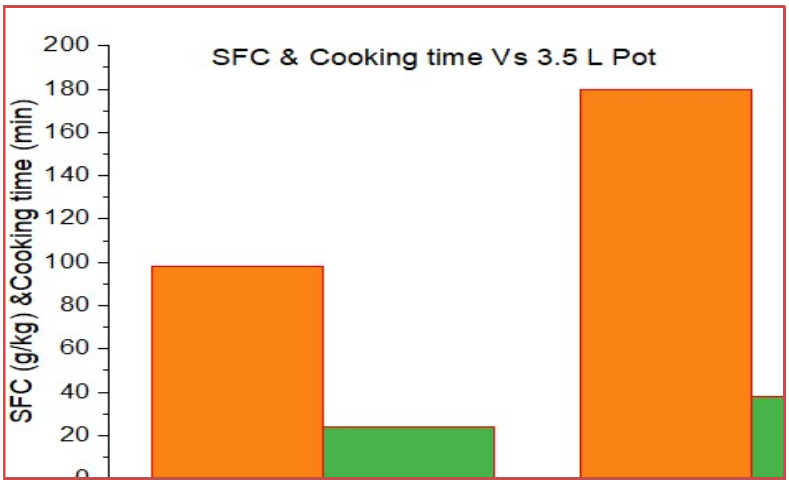

Fig.7 The SFC and cooking time VS pot types for WGS & TCS

*Fig. 7 indicated that, the average Specific fuel consumption of wood gas stove and traditional three stone stove for 3.5 L Pot were 98 and 180 g/kg respectively. Whereas the average cooking time of wood gas stove and traditional three stone cook stove for 3.5 L Pot were 24 and 28 min respectively. The result obtained was better when compared with the cook stove done by [13] in which SFC & cooking time were 236 g/kg and 36.23 minutes respectively.

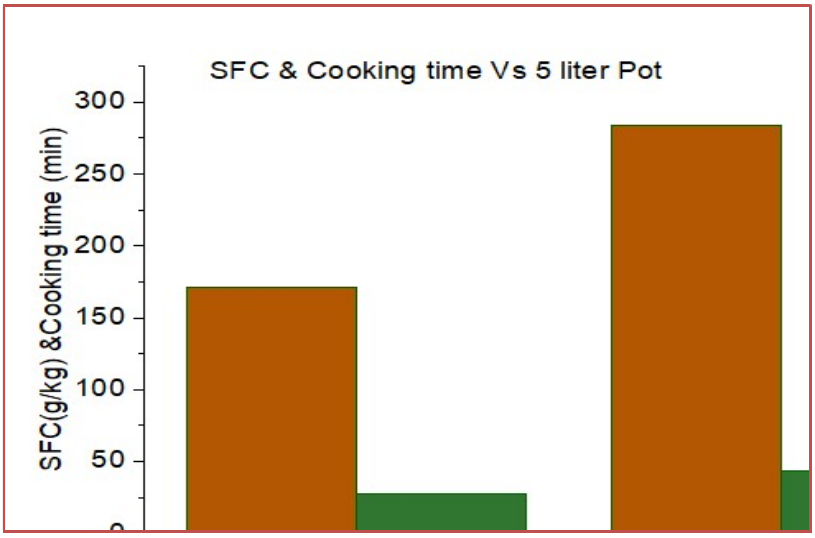

Fig.8 The SFC and cooking time versus pot types

*Fig. 8 indicated that, the average Specific fuel consumption of wood gas stove and traditional three stone stove for 5.5 L Pot were 171 and 284 g/kg respectively. Whereas the average cooking time of wood gas stove and traditional three stone cook stove for 5.5 L Pot were 27 and 43 min respectively. The result was similar with the cook stove done by [13] in which SFC & cooking time were 236 g/kg and 36.23 minutes respectively.

3.3 The picture indicated final cooked food

Fig.9 The final cooked potato for final eating
*Fig. 9 showed that, final cooked potato eaten by participants.

4 Conclusions and Recommendation

4.1 Conclusions

A wood gas cook was successfully developed, fabricated, and evaluated. The control cooking test (CCT) was conducted for the stove evaluation and the results were compared with three stone traditional stoves. The stove's experimental performance was evaluated by cooking with potatoes and analyzed by the control cooking test version 2.0 spreadsheet using two pots (3.5 L and 5.5 L) with and without an insulator using conifer wood.

The CCT experimental results indicate that the average specific fuel consumption for the wood gas cook stove and three stone traditional cook stove was 98 g/kg and 180 g/kg, respectively, using a 3.5 L pot. This means a wood-gas cook stove indicates a 45.56% reduction in specific fuel consumption compared to a three-stone traditional stove. The average cooking time for the wood gas cook stove and three stone traditional cook stove were 24 min. and 38 min respectively, using a 3.5 L pot. This also showed a 36.84% reduction in cooking time compared to a three-stone traditional stove.

4.2 Recommendations

Based on the results and conclusions, the following recommendations were made:
The fabricated and evaluated wood gas cook stove could be recommended for small to medium-household families where conifer biomass is available. The developed cook stove was relatively, easy to operate, continuous feed and low cost. Therefore, it is better to use and popularize it for household cooking purposes.
Since, the technology was performed better than traditional cooking methods by most of thermal indicators, it is recommended to be promoted and collecting the feedback from end users for further dissemination.

Acknowledgements

The author thanks Jimma Agricultural Engineering Research Center (JAERC) and Oromia Agricultural Research Institute, for their financial supports. Special thanks for JAERC Workshop workers.

Author contributions

Adem Tibesso: Conceptualization, writing the original draft, manufacturing the prototype, methodology, software, data analysis, writing review and editing. **Yahikob Docha**: Writing the original draft, manufacturing the prototype, methodology, software, data analysis, writing review and editing. **Abduselam Aliyi**: Writing the original draft, manufacturing the prototype, methodology, writing review and editing.

Funding

This work was supported by Oromia Agricultural Research Institute (OARI), Ethiopia.

Data availability

The analyzed data during this study which supports its findings are available only upon official request to the corresponding authors.

Declarations

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work done in this paper.

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