



Research Article

Pre-Extension Demonstration and Evaluation of Biomass Stove in Selected Districts of Jimma Zone, Oromia Regional State, Ethiopia

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Abstract

Large quantities of agricultural and agro-processing residues, including coffee husk and pulp, are generated annually in Ethiopia. Southwestern Oromia, particularly Jimma Zone, has abundant biomass resources such as coffee husk, rice husk, sawdust, and other agro-processing residues. However, these resources are often underutilized or burned using inefficient traditional cooking practices, contributing to environmental pollution and household exposure to smoke. This study was conducted to demonstrate and evaluate a household biomass stove under farmers' conditions in selected districts of Jimma Zone, Oromia Regional State, Ethiopia. The specific objectives were to evaluate the performance of the stove under farmers' conditions, create awareness about its use for household cooking, and assess farmers' and other stakeholders' feedback on the technology. The stove was tested using rice husk and coffee husk as fuels, with 5.5 L of water used for each test. The water temperature reached 96°C after 8.4 min using rice husk and 95°C after 7.7 min using coffee husk. Training was provided to 66 participants, comprising 57 farmers and 9 development agents (DAs), of whom 45 were women and 21 were men. A mini-field day was subsequently conducted with 104 participants, including 73 farmers, 7 DAs, 6 subject matter specialists (SMSs), and 18 other stakeholders. Feedback was collected from 63 respondents concerning the utility, suitability, availability and accessibility, maintainability, and portability of the stove. The majority of respondents expressed positive opinions regarding the technology. The results indicate that the biomass stove has potential for wider promotion in areas where suitable biomass residues are readily available. Scaling up the technology through farmer training, stakeholder linkages, local manufacturing, and improved access to maintenance and spare parts is recommended.

Keywords

Biomass Stove, Coffee Husk, Rice Husk, Household Energy, Demonstration, Jimma Zone, Farmers

1. Introduction

Biomass is one of the major sources of household energy, particularly for cooking and heating in rural areas. Traditional cooking practices, including open fires and inefficient stoves,

generally have low thermal efficiency and can produce substantial amounts of smoke and other pollutants. Continued dependence on traditional biomass fuels can therefore contribute

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to household air pollution, environmental degradation, and increased pressure on natural resources [2, 9-14].

Agricultural and agro-processing residues such as coffee husk and pulp, rice husk, sawdust, and other crop-processing wastes are generated in large quantities. When these materials are poorly managed, they may be dumped, burned in the open, or left to decompose, resulting in environmental problems. Coffee processing residues, in particular, have been investigated as potential sources of alternative energy [3-6]. However, the physical characteristics of loose biomass residues can make them difficult to use efficiently in conventional cooking systems, creating a need for appropriately designed biomass stoves [18]. In addition, smoke produced from the incomplete combustion of solid fuels can contribute to household air pollution and adverse health effects [2, 8].

Jimma Zone has substantial potential for biomass resources, particularly because of its extensive coffee production and agro-processing activities. Despite the availability of these residues, many rural households continue to depend heavily on firewood and other traditional biomass fuels for cooking. Such dependence contributes to pressure on forest resources, deforestation, and land degradation and may increase the burden associated with collecting and transporting fuel [1, 7, 9-11].

The Jimma Agricultural Engineering Research Center (JAERC) has previously developed and evaluated a household biomass stove designed to utilize locally available biomass residues, particularly coffee husk and rice husk. Earlier evaluation by the research team showed promising performance of the stove in terms of burning rate, thermal efficiency, and fire-power. Recent studies have also demonstrated the potential of improved biomass and husk-based cookstoves for increasing cooking efficiency and reducing dependence on conventional cooking practices [13-18].

Although laboratory and controlled performance evaluations are important, demonstration and evaluation under farmers' conditions are necessary to assess the practical applicability, usability, and acceptance of the technology. Therefore,

this study was conducted through participatory demonstration and evaluation of the household biomass stove in selected potential biomass-producing areas of Jimma Zone. The study focused on stove performance under farmers' conditions, awareness creation, training on operation and maintenance, and farmers' and stakeholders' feedback on the technology.

2. Objectives

2.1. General Objective

To demonstrate and evaluate a household biomass stove using locally available biomass residues under farmers' conditions in selected districts of Jimma Zone.

2.2. Specific Objectives

- 1) To demonstrate and evaluate the performance of the household biomass stove using coffee husk and rice husk under farmers' conditions.
- 2) To create awareness among smallholder farmers about the use of the household biomass stove for cooking.
- 3) To assess farmers' and other stakeholders' feedback on the utility, suitability, availability and accessibility, maintainability, and portability of the biomass stove.

3. Materials and Methods

3.1. Materials

The household biomass stove prototype was manufactured at the Jimma Agricultural Engineering Research Center (JAERC) workshop using raw materials purchased from the local market. Coffee husk and rice husk were used as demonstration fuels because they are locally available biomass residues in the study areas.

Table 1. Raw materials used for construction and demonstration of the biomass stove.

No.	Material	Unit	Quantity	Unit price (ETB)	Total price (ETB)
1	Steel sheet	Pcs	4	500	2,000
2	Iron steel sheet	Pcs	2	1,000	2,000
3	Double-ring round bar	Pcs	2	500	1,000
4	Plain round bar	Pcs	4	400	1,600
5	Hand gloves	Pcs	4	50	200
6	Biomass (coffee and rice husk)	Sack (100 kg)	10	500	5,000
7	Biomass sacks	Pcs	6	15	90

3.2. Study Site and Farmer Selection

The demonstration and evaluation were conducted in three selected districts of Jimma Zone, namely Shabe, Goma, and Mana. The districts were purposively selected based on the availability and potential of biomass residues, particularly coffee husk and rice husk.

Four kebeles were selected from the three districts. Gasara and Kishe were selected from Shabe District, Kenteri from Mana District, and Omo Gurude from Goma District. The kebeles were selected based on biomass availability, suitability for the technology, accessibility, and feasibility of follow-up and monitoring.

One Farmer Research Group (FRG) consisting of approximately 20 members was organized in each selected kebele in collaboration with DAs and the respective district agricultural offices. The groups included farmers from different categories, with emphasis on the participation of women and men. Approximately 85% of the FRG members were women and 15% were men. One host farmer was selected from each FRG based on the suitability of the farmer's location, accessibility, and proximity to other farmers.

3.3. Data Collection

Both quantitative and qualitative data were collected during the demonstration and evaluation activities.

Quantitative data included:

- 1) thermal efficiency;
- 2) burning rate;
- 3) specific fuel consumption;
- 4) firepower;
- 5) time required to boil water; and
- 6) number and sex of participants attending training and mini-field-day activities.

Qualitative information was collected from farmers and stakeholders concerning:

- 1) applicability and utility;
- 2) suitability;
- 3) availability and accessibility;
- 4) maintainability; and
- 5) portability of the biomass stove.

Data were collected through direct observation, field measurements, discussions with farmers, and feedback from participants during training and mini-field-day activities.

3.4. Data Analysis

The quantitative data were summarized using averages and percentages. Farmers' and stakeholders' perceptions were summarized using frequency and percentage distributions. Responses to the perception questions were categorized using a three-point Likert scale according to the alternatives provided for each attribute.

4. Results and Discussion

4.1. Training and Awareness Creation

Training was provided to farmers and development agents on the operation, use, and maintenance of the household biomass stove. The training was conducted using participatory theoretical and practical approaches. Participants were introduced to the operation of the stove, appropriate biomass fuel utilization, routine maintenance, and the relative advantages of the technology compared with traditional cooking practices.

A total of 66 participants attended the training, comprising 57 farmers and 9 development agents. Of the total participants, 45 were women and 21 were men. The training was facilitated by a multidisciplinary team consisting of researchers and technical staff from the renewable energy, agricultural extension, and related technical disciplines.

Table 2. Participants of biomass stove training by study site and sex.

Study site	Farmers: Male	Farmers: Female	DAs: Male	DAs: Female	Total
Gasara	4	10	2	0	16
Kishe	3	8	2	2	15
Kenteri	6	16	1	1	24
Omo Gurude	2	8	1	0	11
Total	15	42	6	3	66

The participation of women was particularly important be-

cause household cooking activities are predominantly under-

taken by women in many rural households. Their direct involvement in training and practical demonstrations can support technology adoption, appropriate use, and dissemination of information within households and communities.

4.2. Performance of the Biomass Stove Under Farmers' Conditions

The biomass stove was demonstrated and evaluated using rice husk and coffee husk. During the field evaluation, 5.5 L of water was used for each test. The stove was also demonstrated for household cooking activities, including cooking potatoes.

Using rice husk, the recorded burning rates were 29, 31, and 8 g/min for the respective test conditions. The corresponding thermal efficiencies were 25.61%, 26.00%, and 24.01%, while specific fuel consumption was 102, 104, and 123 g/L, respectively. Firepower values were 6,305.35, 6,763, and 1,810 W. The time required to bring the water to the recorded endpoint was 13.2, 12.2, and 45 min, respectively.

Table 3. Performance of the biomass stove using rice husk with 5.5 L of water.

Parameter	Test 1	Test 2	Test 3
Burning rate (g/min)	29	31	8
Thermal efficiency (%)	25.61	26.00	24.01
Specific fuel consumption (g/L)	102	104	123
Firepower (W)	6,305.35	6,763	1,810
Time to boil water (min)	13.2	12.2	45
Turn-down ratio	-	-	3

Source: Field evaluation data.

For coffee husk, burning rates of 28, 32, and 11 g/min were recorded for the respective test conditions. Thermal efficiencies were 26.66%, 27.00%, and 25.14%, respectively. Specific fuel consumption was 98, 98, and 123 g/L, while firepower

values were 7,546.67, 8,657, and 2,916 W. The recorded times were 12.6, 10.8, and 45 min, respectively.

Table 4. Performance of the biomass stove using coffee husk with 5.5 L of water.

Parameter	Test 1	Test 2	Test 3
Burning rate (g/min)	28	32	11
Thermal efficiency (%)	26.66	27.00	25.14
Specific fuel consumption (g/L)	98	98	123
Firepower (W)	7,546.67	8,657	2,916
Time to boil water (min)	12.6	10.8	45
Turn-down ratio	-	-	3

Source: Field evaluation data.

The results indicate that the stove was capable of utilizing both rice husk and coffee husk as household cooking fuels. The performance differences between the fuels may be related to differences in fuel characteristics and operating conditions. The results are also consistent with previous studies showing that appropriately designed biomass stoves can effectively utilize agricultural residues such as rice husk and coffee-processing wastes [13-18].

4.3. Mini-Field-Day Participation

Following the training and field demonstrations, a mini-field day was organized to create wider awareness of the technology and obtain feedback from farmers, agricultural experts, and other stakeholders.

A total of 104 participants attended the mini-field day. These included 73 farmers, 7 DAs, 6 SMSs, and 18 other stakeholders. The participation of women, youth, agricultural experts, and other stakeholders helped to broaden awareness and provided an opportunity to discuss the practical applicability and future promotion of the technology.

Table 5. Participants of the biomass stove mini-field day by participant category and sex/age group.

Participant category	Adult men	Young men	Adult women	Young women	Total
Farmers	23	13	26	11	73
DAs	2	3	0	2	7
SMSs	3	1	2	0	6
Other stakeholders	9	5	3	1	18
Total	37	22	31	14	104

The participation of different stakeholder groups is important for scaling up agricultural technologies because successful promotion requires collaboration among farmers, extension personnel, researchers, local administrative offices, and technical service providers.

4.4. Farmers' and Stakeholders' Perceptions of the Biomass Stove

Feedback was collected from 63 respondents who participated in the demonstration activities. Respondents were asked to assess the utility, suitability, availability and accessibility, maintainability, and portability of the biomass stove.

Table 6. Farmers' and stakeholders' perceptions of the biomass stove.

Attribute	Response category	Frequency (n)	Percentage (%)
Utility	More useful	51	80.95
	Useful	12	19.05
	Less useful	0	0.00
Suitability	More suitable	49	77.78
	Suitable	14	22.22
	Less suitable	0	0.00
Availability and accessibility	Easy	48	76.19
	Moderate	12	19.05
	Difficult	3	4.76
Maintainability	Appropriate	55	87.30
	Moderate	8	12.70
	Inappropriate	0	0.00
Portability	Easy	56	88.89
	Moderate	7	11.11
	Difficult	0	0.00

The results show generally positive perceptions of the technology. For utility, 80.95% of respondents considered the stove more useful, while the remaining 19.05% considered it useful. Regarding suitability, 77.78% considered the stove more suitable and 22.22% considered it suitable.

With respect to availability and accessibility, 76.19% of respondents rated access to the technology as easy, 19.05% as moderate, and only 4.76% as difficult. Most respondents also considered the stove maintainable, with 87.30% rating its maintainability as appropriate. Portability received particularly positive feedback, with 88.89% of respondents rating it as easy and 11.11% as moderate.

The positive feedback indicates that the stove was generally considered applicable to household cooking conditions in the study areas. However, continued technical support, availability of spare parts, and local manufacturing capacity will be important for sustainable adoption and wider dissemination.

5. Conclusion and Recommendation

5.1. Conclusion

Jimma Zone has considerable potential for biomass resources, particularly agricultural and agro-processing residues such as coffee husk and rice husk. Despite this potential, many rural households continue to depend on traditional biomass cooking practices, which can result in inefficient fuel use and household exposure to smoke.

The household biomass stove developed by JAERC was demonstrated and evaluated under farmers' conditions in selected districts of Jimma Zone. The stove successfully utilized both rice husk and coffee husk as cooking fuels. With 5.5 L of water, the recorded water temperatures reached 96 °C after 8.4 min using rice husk and 95 °C after 7.7 min using coffee husk

under the respective demonstration conditions.

A total of 66 participants, including 57 farmers and 9 DAs, received training on the operation and maintenance of the stove. Women accounted for 45 of the 66 trainees. A subsequent mini-field day involved 104 participants, comprising 73 farmers, 7 DAs, 6 SMSs, and 18 other stakeholders.

Feedback from 63 respondents indicated generally positive perceptions of the stove. Most respondents rated the stove positively in terms of utility, suitability, availability and accessibility, maintainability, and portability. These findings suggest that the biomass stove has potential for wider promotion in areas where suitable biomass residues are available.

5.2. Recommendation

Based on the demonstration and evaluation results, the following actions are recommended:

The household biomass stove should be promoted and scaled up in suitable biomass-producing areas of Jimma Zone.

Farmers and extension personnel should receive practical training on stove operation, safe use, routine maintenance, and fuel preparation.

Linkages among research centers, extension offices, local manufacturers, private enterprises, and farmers should be strengthened to support sustainable technology dissemination.

Small and medium enterprises and local technical workshops should be encouraged and trained to manufacture, repair, and supply the biomass stove and its spare parts.

Further demonstrations should focus on areas where coffee husk, rice husk, and other suitable biomass residues are readily available.

Continuous farmer feedback should be incorporated into future design improvements to enhance the efficiency, usability, durability, and accessibility of the stove.

Abbreviations

DA	Development Agent
DAs	Development Agents
FRG	Farmer Research Group
SMS	Subject Matter Specialist
SMSs	Subject Matter Specialists
WBT	Water Boiling Test

Author Contributions

Kumale Sadeso: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing

Abdusalam Aliyyi: Data curation, Investigation, Methodology, Validation, Writing – review & editing

Husen Aba Gisa: Data curation, Investigation, Methodology, Validation, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Abebaw S. E. Household fuelwood consumption and its implication for carbon dioxide emission. *New Energy Exploitation and Application*. 2024; 3(2).
- [2] Awopeju O. F. Health effect of biomass fuel smoke. In: *Health and Environmental Effects of Biomass Fuel Smoke*. IntechOpen; 2020. <https://doi.org/10.5772/intechopen.94611>
- [3] Beyene A, Kassahun Y, Addis T, Assefa F, Amsalu A, Legesse W, Kloos H, Triest L. The impact of traditional coffee processing on river water quality in Ethiopia and the urgency of adopting sound environmental practices. *Environmental Monitoring and Assessment*. 2012; 184(11): 7053-7063. <https://doi.org/10.1007/s10661-011-2479-7>
- [4] Franca AS, Oliveira LS. Coffee processing solid wastes: Current uses and future perspectives. In: *Agricultural Wastes*. Nova Science Publishers; 2009. Chapter 8.
- [5] Merete W, Haddis A, Alemayehu E, Ambelu A. The potential of coffee husk and pulp as an alternative source of environmentally friendly energy. *East African Journal of Sciences*. 2014; 8(1): 29-36. <https://doi.org/10.4314/cajs.v8i1.4>
- [6] Thenepalli T, Ramakrishna C, Ahn JW. Environmental effect of the coffee waste and anti-microbial property of oyster shell waste treatment. *Journal of Energy Engineering*. 2017; 26(2): 39-49. <https://doi.org/10.5855/energy.2017.26.2.097>
- [7] Jimma Zone Agricultural and Rural Development Office (JZARDO). *Annual Report for the Year 2007/08*. Jimma, Ethiopia; 2008.
- [8] Balmes JR. Household air pollution from domestic combustion of solid fuels and health. *Journal of Allergy and Clinical Immunology*. 2019; 143(6): 1979-1987. <https://doi.org/10.1016/j.jaci.2019.04.016>
- [9] Derebe B, Alemu A, Asfaw Z. Fuelwood dependence and alternative energy sources in Ethiopia: A systematic review. *Discover Sustainability*. 2025; 6: 99. <https://doi.org/10.1007/s43621-024-00721-5>
- [10] Grabher HF, Erb K, Singh S, Haberl H. Household energy systems based on biomass: Tracing material flows from source to service in rural Ethiopia. *Ecological Economics*. 2024; 217: 108057. <https://doi.org/10.1016/j.ecolecon.2023.108057>
- [11] Liyew KW, Ejigu NA, Habtu NG. Analysis of energy supply, energy policies, and the final energy end-use consumption of the residential sector in Ethiopia. *Heliyon*. 2024; 10(15): e34809. <https://doi.org/10.1016/j.heliyon.2024.e34809>
- [12] Alem Y. Clean cooking in the Global South: A critical synthesis of causal evidence and a future research agenda. *South African Journal of Economics*. 2026; 94(4): e70037. <https://doi.org/10.1111/saje.70037>

- [13] Tesfay A, Kahsay MB, Geleta AB. Improved cook stoves to meet Sustainable Development Goal in Ethiopia. *Energies*. 2024;17(5): 1011. <https://doi.org/10.3390/en17051011>
- [14] Fetene MA, Tikunch DB. Evaluation and modeling the performance of rice husk gasifier cook stove for household energy use. *Journal of Energy*. 2024; 73(3): 17-35. <https://doi.org/10.37798/2024733521>
- [15] Ebissa DT, Getahun E. Evaluation of biomass-based cook stoves in Ethiopia: A transition strategy from conventional to modern cook stoves. *Environmental Progress & Sustainable Energy*. 2025; 44(1): e14531. <https://doi.org/10.1002/ep.14531>
- [16] Mekonnen A, Beyene A, Bluffstone R, Dissanayake S, Gebregziabher Z, LaFave D, Martinsson P, Toman M. Improved biomass cookstove use in the longer run: Results from a field experiment in rural Ethiopia. *Environment and Development Economics*. 2025; 30(5): 339-359. <https://doi.org/10.1017/S1355770X25000117>
- [17] Tesfay AH, Tsegay K, Kahsay MB, Hailu MH, Adaramola MS. Performance comparison of three prototype biomass stoves with traditional and Mirt stoves for baking Injera. *Energy, Sustainability and Society*. 2024; 14: 11. <https://doi.org/10.1186/s13705-024-00443-6>
- [18] Kole AT, Zeru BA, Bekele EA, Ramayya AV. Design, development, and performance evaluation of husk biomass cook stove at high altitude condition. *International Journal of Thermofluids*. 2022; 16: 100242. <https://doi.org/10.1016/j.ijft.2022.100242>