

Research Article

Participatory Popularization and Demonstration of Household Biomass Stove in Selected Districts of Jimma Zone of Oromia Region, Ethiopia

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Abstract

Participatory popularization and demonstration of household biomass stove was conducted mainly in coffee producing districts of Jimma zone (namely, Manna, Gomma, Gera, and Shabe Sombo districts). The main studies of this research were to popularize the stove, to create wider demand on stove, to create and strengthen linkage among possible actors, to enhance multiplication and dissemination of the stove and to collect relevant feedback from the farmers. Water boiling test of the stove was carried out by using coffee husk and 3.5 L of pot at different phase. From WBT using 3.5 L of pot, thermal efficiency, specific fuel consumption, fire power and time to boil water during hot start phase were 29%, 125 g/L, 9,899 watts and 7.7 min whereas during cold start phase were 28.53%, 127 g/L, 8,868.84 watts and 8.9 min respectively. For the success of the activity, training program was organized for the farmers, development agents, and other agricultural experts. A total of 97 participants attended the training, with 85.2% being farmers and the rest were agricultural experts (development agents and subject matter specialists). To share experiences among the participants and access their feedbacks, mini-field days were conducted with 91 (58.2% female and 41.8% male) participants. Following a field demonstration, a focus group discussion with 26 farmers revealed a positive perception of the stove across all assessed attributes. This universally positive response strongly recommends further production and dissemination of the stove through coordinated stakeholder efforts.

Keywords

Biomass Stove, Demonstration, Dissemination, Household, Water-boiling Test

1. Introduction

1.1. Background and Justification

Coffee is the second most traded commodity in the world market after oil, accounting for an estimated export worth of 36.3 billion USD [1] and it is the main source of foreign currency earnings for over 80 tropical countries including Ethiopia [2]. Coffee is cultivated in about 80 countries across

the globe and entangles huge business worldwide [3]. Coffee production is an important sector of the agro-industry in Ethiopia, accounting for about 29% of the value of all exports in [4].

Coffee generates large amount of coffee by-products/residues during processing [5]. Depending upon the method of coffee cherries processing, different residues

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are obtained. Coffee husks are the major solid residues from the handling and processing of coffee. In Ethiopia, enormous amounts of coffee husk and pulp are generated from coffee processing industries annually. According to the author, for every 2 kg of coffee beans produced approximately 1 kg of husks are generated [6, 7]. The residue from dry coffee processing is burnt while those from wet processing are dumped into the rivers, both being disposed into landfills and surface water [8]. The residue from the wet coffee processing factories particularly coffee processing effluents is causing considerable pollution to the wetlands.

Southwestern Oromia region mainly Jimma zone, is enriched with coffee husk which is generated from small-scale industries and from the rural areas of coffee producer farmers [9]. Coffee processing firms in the zone generate huge amount of solid wastes (coffee pulp and husk). During the processing of coffee bean to the final product, there are a number of wastes generated that are harmful to health of human being (i.

e it causes environmental pollution). Because of these problems, these residues should be handled in an appropriate way in order to avoid environmental impact as these wastes are easily dumped in to water bodies and unsanitary landfills due to their threat to the environment [10].

In spite of the toxic components, coffee husk and pulp are very much rich in organic components and could be used as substrates after bioprocessing to produce enzymes, aroma compounds, edible mushroom plant hormones, organic fertilizer and feeds [11]. Proposed alternative uses for coffee husks include employing this solid residue as a supplement for animal feed, direct use as fuel, and fermentation for the production of a diversity of products (enzymes, citric acid and flavoring substances), use as a substrate for growth of mushrooms and use as adsorbents [12]. However, these materials have been poorly utilized and managed or left to decompose or burned in open fields or dumped in the environment including water bodies [13].



Figure 1. Coffee husk decomposed in the fields of Jimma zone while data collection.

Some people burn the generated coffee husk, while others dispose it on the field. Moreover, smoke released from the biomass causes acute respiratory infections [14]. Yet, these activities cause and aggravate pollution of air, the environment, and water [15].



Figure 2. The coffee husk burning manner in Jimma zone during data collection.

Those agricultural wastes are increasing from time to time without efficient uses and causing environmental pollution, problems on health farmers' holdings, state and private owned plantations. Problem of air pollution while the rural community life in the study areas depends on firewood collection from the forests causing deforestation, environmental degradation, wood scarcity and interns causes problems of health on rural communities.

On the other hand; utilization of coffee husk and pulp is an option to alleviate the problems [16]. For example, in different region of Ethiopia as well as in Jimma zone, this biomass has been consumed by households in place of firewood with inefficient open fire stoves [8]. However, most of these stoves were designed by considering only wood fuel and are unsuitable for using agricultural residue biomass. Additionally these cook stove have low thermal efficiency, low portability,

continues feed of biomass and has high outdoor and indoor air pollution. In other way, direct utilization of this type of biomass as a source of energy is not suitable because it has low density, high smoke, and low energy intensity [17].

To reduce these problems, household biomass stove has been developed and evaluated in Jimma Agricultural Engineering Research Center by using water-boiling test (WBT) and coffee husk. The results indicated that coffee husk by using household biomass stove has 9.98 g/min of average burning rate during simmering test, 34.53% of thermal efficiency during hot start test and was 9393.66 Watt firepower during hot start test.

Household biomass stove also is energy-efficient cooking devices designed to reduce fuel consumption and indoor air pollution. In rural areas where traditional cooking practices prevail, promoting improved biomass stoves contributes to better health outcomes, environmental conservation, and reduced workload especially for women.

Moreover, in the areas of Climate-Smart Agriculture (CSA) that aims to increase agricultural productivity, adapt and build resilience to climate change, and reduce greenhouse gas emissions [18], household biomass stove can also contribute in using agricultural wastes as heat energy, reducing deforestation by minimizing usage of firewood, lowering greenhouse gas emission, improving soil health by providing biochar, and supporting gender equality.

Table 1. Summary of the role of biomass stove in sustaining climate smart agriculture.

Contribution	How biomass stoves merits
Waste management	Use agricultural residues as fuel
Forest conservation	Reduce wood demand
Emission reduction	Cleaner, efficient combustion
Soil health	Produce and apply biochar
Farmer welfare	Better health, more farm time
Economic opportunities	Save money, new income streams
Gender empowerment	Reduce women's workload

Thus, undertaking participatory popularization and demonstration of household biomass stove technology that can reduce the problems related to environmental pollutions and ensure the effort of climate smart agriculture was undertaken with the participation of farmers and other stakeholders in Jimma Zone.

1.2. Research Objectives

The objectives of this study were to evaluate and popularize the household biomass stove through scaling-up, to create

wider demand on household biomass stove technologies, to create and strengthen linkage among possible actors, to enhance the multiplication and dissemination of the stove and to collect the relevant feedback from end-users.

2. Research Methodologies

2.1. Description of the Study Area

Jimma zone is one of the Oromia regions in Ethiopia. It is located on distance of 355 kilometers from capital city of Ethiopia Finfinnee in a direction of country's southwestern part. It is bordered on the south by South-west region of Ethiopia, in north-west by Ilu Ababor zone, on the north by East Wollega zone, and on the north-east by West Shewa zone. Jimma Zone is divided into 20 districts (hosting a total population of over 2.2 million) with an agro-ecological setting of highlands (15%), midlands (67%) and lowlands (18%). The zone is one of the major coffee growing areas of Oromia region well-endowed with natural resources contributing significantly to the national economy of the country. Jimma Zone reliably receives good rains, ranging from 1,200 - 2,800 mm per annum [19].

2.2. Materials

Raw materials necessary for production of the stove were listed below and the prototypes were manufactured in Jimma Agricultural Engineering Research Center metal workshop.

Table 2. List of raw materials and their description.

List of materials	Unit	Quantity
Sheet metal 2 mm	Pcs	16
Flat iron	Pcs	8
2.5 electrodes	Pcs	20
Anti-rust	Gal	4

2.3. Methods

2.3.1. Site Selection, Farmers' Identification and FREG Organization

For effective implementation of the study, appropriate site and farmer's selection was carried-out by multidisciplinary team of researchers, agricultural experts from district office and development agents. Thus, four districts namely Gera, Gomma, Mana, and Shabe Sombo districts were selected from Jimma zone purposely based on existence of coffee husks. Potential kebeles suitable for popularization of this stove were selected so that one kebele from each district. Next female

households who have coffee husks and willing to participate in popularization the biomass stove were identified purposely. Accordingly, one farmer's research and extension group with twenty (20) members was organized based on their willingness to be FREG member and suitability to participate from each kebele.

2.3.2. Technology Multiplication and Distribution



Figure 3. Number of manufactured household biomass stoves.

2.3.3. Stakeholder Analysis

Stakeholder analysis was a critical step when planning the popularization or dissemination of new technologies. Effective collaboration and understanding of each stakeholder's perspective were a crucial for the successful implementation of the activities. In our case, stakeholder analysis was conducted before commencing on actual implementation of the activities. Five potential stakeholders were identified with

Techniques

Multiplication of household biomass stove was undertaken at Jimma Agricultural Engineering Research Centers' metal workshop. Thus, twenty (20) household biomass stove were manufactured and thus, distributed to each farmer research and extension group.

their roles and responsibilities for successful implementation of the study. Training program was organized for these stakeholders by Jimma Agricultural Engineering Research Center. Below table summarizes the key stakeholder groups involved in the popularization of household biomass stoves and highlights their respective roles in facilitating implementation of the activities.

Table 3. Identified key stakeholder and their roles.

Key stakeholder	Their roles in biomass stove popularization
Farmers	Provide coffee husk Adopting and sustained use of the stove provide feedbacks on of the stove Provide feedback on environmental and cultural appropriateness of the stove Influencing demand through preferences and willingness to pay
Local communities and leader	Facilitate in training and demonstration of the stove Influence communities acceptance of the stove Support community based dissemination of the stove Provide feedback on performance of the stove
District office of agriculture	Provide secondary data Support in appropriate site selection Facilitate in all implementation of the activities Support in wider dissemination of the information on the stove Help in awareness creation, distribution of the stove Provide feedback on the stove
Metal technicians and manufacturers	Manufacture quality of biomass stove Support in awareness creation Support in distribution of the stove

Key stakeholder	Their roles in biomass stove popularization
Researchers from Jimma Agricultural Engineering Research Center	Select suitable site and organize farmer research and extension group Provide training and organize mini-field day Provide household biomass stove Making stoves accessible to end users through established linkage Conduct research on stove performance Collect feedback from the farmers and other stakeholders

2.3.4. Awareness Creation and Communication Methods

Multidisciplinary team of researchers and technicians was established at Jimma Agricultural Engineering Research Center (JAERC) to jointly work in capacity building, planning, implementing, monitoring and evaluating the activities. Training and mini-field day were used to create awareness of the farmers, development agents, subject matter specialists and other participants on different areas of the stove. Farmer-to-farmer approach, group discussion, practical demonstration, experience sharing, interactive lectures or presentation with visual aids were used to ensure communication and learning systems among all participants.

2.4. Type of Data and Data Collection Methods

Measurements, semi-structured questionnaire and different participatory rural appraisal (PRA) approach such as focus group discussion, interview and observation were used to collect quantitative and qualitative data. Data type that were used in this study are technical performance of the stove, total number of training and mini-field day participants, number of distributed stove, farmers' perception, and feedback.

2.5. Method of Data Analysis

Quantitative data was analyzed by using simple descriptive statistical tools such as, percentage, mean and frequency distribution whereas qualitative data was analyzed by narration.

3. Results and Discussion

3.1. Technical Performance of the Household Biomass Stove

Table 4. Water boiling test of the stove by using coffee husk with 3.5 L pot.

Parameters tested	Unit	Cold start	Hot start	Simmer
Burning rate	g/min	33	37	7
Thermal efficiency	%	28.53	29	27.74
Specific fuel consumption	g/lit	127	125	152
Firepower	Watt	8868.848	9899	193.3
Time to boil Pot water	Min	8.9	7.7	45
Turn-down ratio	-	-	-	5

Source: Own computed data

3.2. Training of Farmers, Development Agents and Subject Matter Specialists

Before implementation of the activity, training was given for the farmer's especially female households, development

agents, subject matter specialists and selected experts from district agricultural and natural resource management office. This training aimed to introduce the concept, benefits, and practical usage of household biomass stove to build local capacity for dissemination and sustained adoption of this technology.

Table 5. Summary of the training participants.

Participants	Site (districts)								
	Gomma		Gera		Shabe		Manna		Total
	Male	Female	Male	Female	Male	Female	Male	Female	
Farmers	3	17	2	18	5	15	1	19	80
DAs	2	1	1	1	1	2	2	2	12
SMSs	1	0	1	0	1	1	0	1	5
Total	6	18	4	19	7	18	3	22	97

A total of 97 stakeholders were participated on training from four training sites. Among training participants, around 82.5% of participants were farmers and the rest were woreda's and kebele's agricultural expert including development agents and subject matter specialists. From the total trained participants, about 79.4% of were female participants and 20.6% were male participants. During this training program, different extension materials manuals and leaflets were prepared

and organized in Afan Oromo and English languages on stove's importance and operation methods. Thus, around 8 small manuals and 28 leaflets utilized and distributed for the FREG members and development agents of respective districts. Moreover, twenty (20) manufactured biomass stoves were distributed to the organized farmers with the arrangement being one stove for every four female households.

Photos taken during the training



At Manna district



At Shabe district



At Gomma district



At Gera district

Figure 4. The photos taken during mini field training at Jimma zone.

3.3. Knowledge Sharing Mini-field Days Conducted to Display the Stove

Mini-field day was one of the mechanisms of research and extension to get feedbacks on demonstrated technologies at

farmers' field or on station. In this case, mini-field days have been organized with different stakeholders to further popularize biomass stove and to collect feedbacks on demonstrated technologies. This event was conducted with 91 stakeholders including farmers, development agents, subject matter specialists, woreda's agricultural officers at all districts.

Table 6. Summary of participants on mini-field day.

Description of participants	No. of participants by gender disaggregation		Total
	Male	Female	
Farmers	21	47	68
Development agents	7	3	10
Subject matter specialists	2	2	4
Woreda's agricultural officers	8	1	9
Total	38	53	91

The photos during mini-day

**Figure 5.** The photos taken during mini field training at Buno Bedelle zone.

3.4. Farmer's Perception and Feedbacks

After field demonstrations, focus group discussion (FGD) was conducted at farmer's field to assess their perception toward different attributes of the stove. Accordingly, it was collected from twenty (24) respondents.

Table 7. Summary of farmer's feedback on household biomass stove.

Description their criteria responded	Number respondents and their perception level in percentage (%)				
	Very poor	Poor	Moderate	Good	Very good
Efficiency in reducing fuel consumption				8.3	91.7
Efficiency in reducing smoke emission				12.5	87.5
Cooking Performance in fasting cooking times				-	100
Consistency in transmitting heat energy				4.2	95.8
Gender sensitivity of biomass stove					100
Compatibility to the aspect of climate smart agriculture					100
Affordability			4.2	12.5	83.3
Ease of maintenance and operation				16.7	83.3
Ease of transport					100

Source: From FGD result

Fuel Efficiency: Majority of interviewed farmers responded that biomass stove was more fuel-efficient compared to existing cooking stove, leading to cost savings and reduced fuel consumption.

Smoke Reduction: Farmers appreciated the reduced smoke emissions from biomass stove while cooking, highlighting improvements in indoor air quality and a healthier cooking environment.

Cooking Performance: Many farmers praised the stove's cooking performance, noting faster cooking times and consistent heat distribution.

Affordability: Most farmers also positively perceived the stoves' affordability due to its small size and low initial cost.

Ease of maintenance and operation: Majority of the farmers responded that, the stove could easily maintain and operated by local technicians with minimum training.

Ease of Transport: Many farmers commended the portability of biomass stove due to its lightweight and convenient size for transportation between indoor and outdoor cooking areas.

Contributing in climate smart agriculture: Biomass stoves could play a vital role in sustaining climate-smart agriculture by promoting the efficient use of coffee husks, reducing deforestation, lowering greenhouse gas emissions, and improving soil fertility through biochar production, improving health of rural communities by utilizing agricultural waste, saving time and resources. Because of all these all of the respondents positively perceived to biomass stove.

Gender aspect of the biomass stove: Since day-to-day management of food preparation is carried out by women and female children, this technology is intended to solve women problems in their daily activities. Because of this, majority of respondents were positively perceived the stove.

4. Conclusions and Recommendation

Household biomass stove was successfully evaluated and popularized in potential districts of Jimma zone by using coffee husk biomass. From WBT using 3.5 L of pot, thermal efficiency, specific fuel consumption, fire power and time to boil water during hot start phase were 29%, 125 g/L, 9899 watts and 7.7 min whereas during cold start phase were 28.53%, 127 g/L, 8868.84 watts and 8.9 min respectively. Training and mini-field day were used as awareness creation methods toward the farmers, development agents, subject matter specialists and other stakeholders during popularization of biomass stove. To this end, training was provided to around 97 participants whereas mini field day was organized with 91 participants from all districts. As feedback from popularized biomass stove performances were increasing and more demand was created by the farmers for this stove. The questions raised by farmers are looking the way to have easily accessible to biomass stove. Therefore, collaboration and

coordination among key stakeholder in household biomass stove production is paramount importance to enhance dissemination and distribution of this stove to wider users.

Abbreviations

CSA	Climate Smart Agriculture
DA	Development Agriculture
FGD	Focus Group Discussion
FREG	Farmers Research Extension Group
JAERC	Jimma Agricultural Engineering Research Center
PRA	Participatory Rural Appraisal
SMS	Subject Mater Specialist
WBT	Water Boiling Test
USD	United States Dollar

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Author Contributions

Daniel Bekele: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing-review & editing

Adem Tibesso: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Supervision, Validation, Writing - original draft, Writing - review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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