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A Study on the Biomass Cook Stoves Used in Kerala and to Develop a Theoretical Design of T-Lud Natural Draft Gasifier Stove as an Option for Kerala's Cooking Culture

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Abstract:
Biomass constitutes the biggest source of energy in rural Kerala. However, its utilization in the domestic sector is mostly inefficient and polluting, resulting in resource wastage, indoor air pollution, which has drastic bad effects on the health of women and children. Traditional cook stoves, predominantly used in the households for domestic cooking, have been a major contributor to these ill effects. Improving stoves is an effective way of improving the environment and serving community. In cities, LPG and the wick type kerosene stoves of 1-3kWth with 60-65% efficiency is used. The best commercially efficient stoves that are available in Kerala is about 30%.
Gasification of wood (or other biomass) offers the possibility of cleaner, better controlled gas cooking for developing countries. Available technology for gasification could utilize a much wider variety and greater quantities of the biomass and provide significant energy while alleviating several pressing environmental concerns. The concept of less polluting, efficient gasifier cook stove has tremendous potential in a state like Kerala. This paper aims to study the different wood based cook stoves used in the state of Kerala and to design theoretically a gasifier based cook stove for house hold usage of Kerala with available biomass sources.

Keywords: *Biomass gasification, gasifier stoves, wood cookstove,*

1. Introduction

Kerala is located at the southern tip of the Indian subcontinent. It forms a 38,864 km^2area of land along the southwest coast of India. In most the regions in Kerala, locally available fuel wood, wood residues, coconut husks, coconut shell, coconut leaves etc. are used as fuel for cooking in wood burning stoves. Other sources of energy which are used for cooking commonly include LPG, Kerosene and electricity.

According to CMIE report, in 1996, 96.78% of rural households of Kerala were dependent on wood for their cooking needs. In 2011, 62.7% of the total households were dependent on firewood and crop residues for their cooking energy needs. Even though Keralite's dependence on wood burning stoves are decreasing day by day, rise in price of LPG, electricity and exhaustion of fossil fuel resources will force them towards developing improved wood based cook stoves in near future. In this paper a study on the common types of wood stoves used in Kerala and a theoretical design of portable single burner T-LUD gasifier based wood stove is done.

2. Kerala's Cooking Culture

In Kerala, people prefer different cook stoves. Many of the households in Kerala uses (about 67.7% - 2011 Census) three-stone-stove, which has only a thermal efficiency of 10%. Though the introduction of improved wood stove, having a thermal efficiency of about 25% - is a way to reduce the consumption of wood fuel - only about 9 % of the households uses such devices in Kerala. The rest of the

people use LPG stoves (17.7%) and Kerosene stoves (1.7%). Many households in Kerala use both LPG and wood stove for their cooking needs. People use wood stoves for boiling water, cooking rice and meat because the time and energy consumption for this cooking process is more, whereas LPG is preferred for frying, roasting etc. as it requires only less time and energy. Thermal cooker and pressure cookers are used by some households for reducing fuel consumption. Pressure cookers allow cooking at a higher temperature, which can be called as a high- temperature cooker, cutting both fuel and cooking time.

Other types of cook stoves though used rarely are Induction type cookers and electric rice cookers. In Kerala, the induction type cookers are being aggressively marketed these days, claiming high thermal efficiency of above 96 % and more economical compared to LPG. These devices are used in more numbers in developing countries, mainly for aesthetic, health and safety reasons, as these doesn't produce a high temperature flame and harmful flues. Among stoves which use electricity for cooking, electric rice cookers are supposed to have higher efficiency. But electric rice cookers are also not much in use in Kerala [4].

3. Common Wood Burning Cook Stoves Used in Kerala

3.1. Three Stone Fire

Figure 1: Three Stone Fire

A three stone fire is the simplest type of stove in which a fire is built directly on the ground using three bricks or stones and placing the cooking pot at the top of the bricks. Three stone fire is easy to build and their cost is very less compared to other wood stoves. One of the most important drawbacks of such stoves is their low efficiency. They are also not easy to control and least safe because of the exposed fire. Tests on three stone fire have shown moderate time to boil, high fuel consumption, and high CO/PM emissions [3]. Fuels used are usually firewood, coconut shell/husks/leaves and wood processed residues.

3.2. Traditional Stoves

Traditional stoves are those are made with either mud (earlier versions) or concrete which are fixed in kitchen space. They usually have one, two combustion chambers which are lined with pottery/brick or concrete. Modern version of these stove have a metal ring support (made of cast iron) for placing cooking pots. The stove is placed under a large chimney space or have separate small chimney outside, for exhaust. They have better thermal efficiency, less smoke and are safer than three stone fire.Cost of the stove may vary from place to place but usually less $20 including installation charge.

Figure 2: Traditional Stoves

3.3. Parishad Aduppu - Parishad Stove

The Parishad Aduppu was developed in 1986 by KSSP, Trivandrum inCo-operation with the Technical Back-up Unit, Department of Mechanical Engineering, College of Engineering, Trivandrum, Kerala.

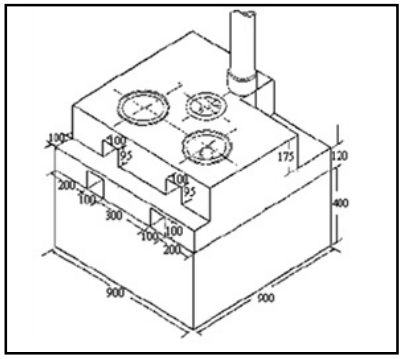

Figure 3: Schematic of Parishad Stove

The Parishad stove is a three-pot, mud-brick smokeless stove with chimney for a medium size family (5-8 members). It can accommodate vessels 16-25 cm. in diameter. The model was developed over a period of time maintaining the traditional cooking requirements of the rural households of Kerala and nearby areas. While coconut fronds and fuel wood are the main fuels, other agri-residues can also be used. The stove has two pottery lined combustion chambers, pottery tunnels, metal grates and asbestos chimney pipe [7].

The stove is built on a high platform suitable for cooking in a standing position. Anormal brick laying technique using mud mortar along with other standard items mentioned above is employed. The two front fire-boxes are designed to meet the requirements of fast cooking using high power in the initial stage followed by low cooking power for simmering. The stove is designed for cooking in the standing position with sufficient area on top for keeping cooked food materials. Parishad stove has thermal efficiency in the range of 25 – 30% thus reducing the firewood expenditure to 1/3 of the normal.

Figure 4: Aluva Smokeless Stove

3.4. Aluva Aduppu –Aluva Smokeless Stove

Aluva aduppu is a smokeless stove named after the industries in Aluva (Ernakulam district) who first initiated its manufacturing. Aluva aduppu is a smoke less, chimney based, low efficiency stove made using concrete, bricks and steel. It's now commonly used in Kerala due its wide popularity and aesthetic design. Stove making industries in Aluva are also doing custom designs of these stoves for a variety of consumers from common households to large restaurants. Even though, this stove aesthetically attractive and smokeless, little consideration has been given to the thermal characteristics which can improve the performance and efficiency of the stove.

3.5. Portable Energy Efficient Wood Stove – Jayaprakash Stove

Figure 5: Portable JP Stove by IRTC

Jayaprakash's (JP) stove is a double chambered efficient portable stove, available for household as well as for community cooking. This portable stove is made of bricks, cement, clay, cast iron. The base of the bottom chamber is made of iron grill on which the fuel is kept. Below the grill is an air chamber. When the fuel burns, smoke mixed with un-burnt hydrocarbons reaches the upper chamber, which has been provided with air inlet holes. Complete combustion takes place here and the combined heat gets available to the cooking vessel above the second chamber. The fuel opening has been provided at the front of the device and can be regulated using shutter, which in turn controls the flow of air. The air which flows through the opening during combustion causes an updraft when the fuel is burnt. This triggers secondary combustion as the carbon particles, which were left unburned will now get burned due to the additional air.

Apart from its efficiency, lower cost and portability are also significant features of this stove. The combustion efficiency is in the range of 37.67% when wood is used as a fuel and 29.48% when coconut shell is used (Test report by Integrated Rural Technology Centre, Mundur, Palakkad). IIT Guwahati also tested the same and observed the thermal efficiency of 29.28%. It can use coconut shell or wood as a fuel.

3.6. Biomass Gasifier Stoves as an Option for Kerala

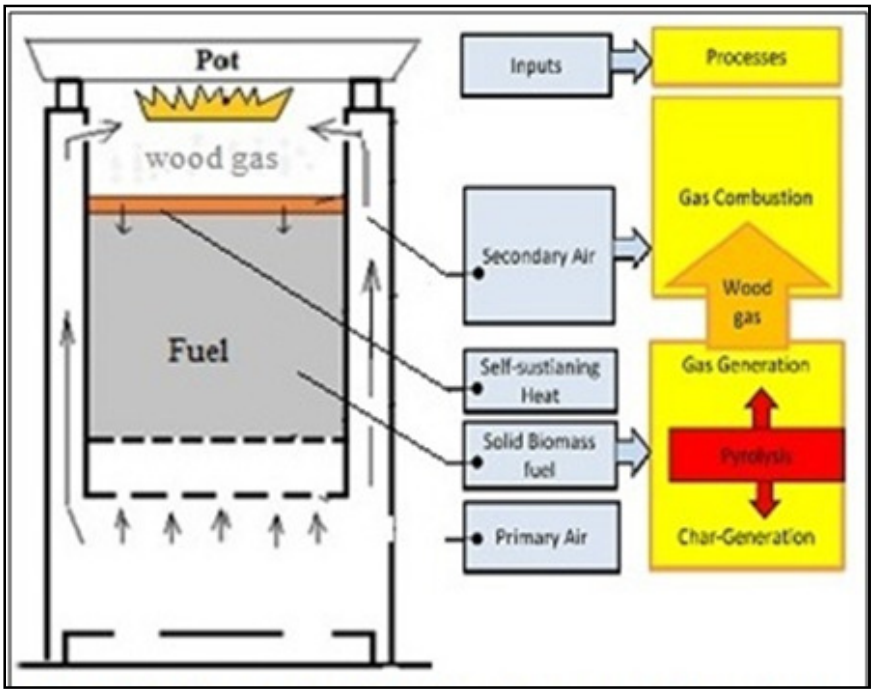

Figure 6: Natural Draft (ND) micro – gasifier Stove

Gasification is the thermochemical conversion process of converting solid fuels, such as wood, agricultural residues and coal, into a combustible gas. A biomass gasifier consists primarily of a reactor or container into which fuel is fed along with a limited (less than stoichiometric, or amount required for complete combustion) supply of air. Heat for gasification is generated through partial combustion of the feed material. The resulting chemical breakdown of the fuel and internal reactions result in a combustible gas usually called producer gas. The heating value of this gas is about 10-15 % of the heating value of natural gas. Beginning in 1985 – 1988, Thomas B. Reed in America and Paal Wendelbo in Norway and Africa worked independently and devised what is now known as top-lit updraft (TLUD) gasifier technology for cookstoves with batches of biomass fuel [9]. "Gasifiers" are defined as devices in which the dry biomass is transformed into combustible gases in processes distinctly separate from the eventual combustion of the volatile gases.

T-LUD Gasifier stove is one particular stove design that can be used to potentially reduce harmful emissions production from solid-fuel combustion and the charcoal produced can be used as biochar (an organic soil enhancer). Gasifier stoves also have better thermal efficiencies (25-35%) compared to three stone stoves, which will reduce the wood consumption drastically. Serious studies has been conducted in Indian Institute of Science, Bangalore and many other research institutes for developing better gasifier based cookstoves both natural draft and forced draft (with fans). Some models are available in the market in different parts of India.

Biomass is certainly ought to play a key role in the fuel scenario as Kerala is noted for its abundant natural resources. Even now, about 70% of our households in the rural areas use firewood as the main cooking fuel. Majority of people are forced to use the smoky, sooty, firewood chulha and it is the ambition of every housewife to switch to a more convenient, sootless, smokeless hazardous stove. But the biomass based cook stove will be the only option for the people with low income, for a long time to come. The improved chulha with higher efficiency and less smoke can only be a partial solution to the problem.Gasifier stoves can be a better option due its

increased thermal efficiency (as high as 40%) for coconut derived products like coconut shell. Using coconut products will also increase its appreciation in Kerala.

4. Theoretical Design of Wood Gasifier Stove

A Theoretical design of the cook stove was done based on natural draft principle. A gasifier cook stove design with single burner for a typical rural Kerala household of 5 members is calculated. Coconut shell is taken as fuel as it is widely available and has better calorific value. All the important parameters regarding theoretical design of a wood gas stove are as follows:

Energy needed (Q):

The present wood gas stove is a natural draft wood gasifier stove. The present design carried out on the basis of energy required for an average size family. Assuming a 14.2 kg cylinder of LPG meets the needs of a family of five for 25-27 days.

Calorific Value of Liquefied Petroleum Gas is 45.84MJ/kg and average cooking hours per day is taken as 190 min [8].

Total energy available from a 14.2 kg LPG cylinder = 14.2*45.84 MJ = 650.928 MJ.

Energy usage for cooking per day = 650.928 /26= 25.04MJ

Energy usage for cooking per hour, Q = 25.04 / 3.16 = 7.924 MJ/hr

Q = 7.924 MJ/hr……(1)

Fuel combustion rate (FCR):

The energy input, taken as the fuel consumption rate, FCR, refers to the energy/fuel quantity to be fed into wood gas stove.

$FCR = \frac{Q}{C.V \times \eta_g}$ …… (2)

The calorific value (C.V) of coconut shell is usually between 18-22MJ/kg [11] and the gasifier efficiency is taken as 25%.

$FCR = \frac{7924}{21000 \times 0.25}$ = 1.509 kg/hr.

Reactor Diameter (D):

This refers to the size of the reactor in terms of the diameter of the cross-section of the cylinder where rice husks are being burned. This is a function of the amount of the fuel consumed per unit time (FCR) to the specific gasification rate (SGR) of coconut shell. SGR is assumed to be 90kg/m^2-hr.

$D = \left(\frac{1.27 \times FCR}{SGR}\right)^{0.5}$ …….(3)

$D = \left(\frac{1.27 \times 1.509}{90}\right)^{0.5}$ = 0.1459 m = *14.59 cm.*

Height of the reactor (H):

This refers to the total distance from the top and the bottom end of the reactor. This determines how long would the stove be operated in one loading of fuel. Basically, it is a function of a number of variables such as the required time to operate the gasifier (T) (assumed to operate for 1.5 hr), the specific gasification rate (SGR), and the density of coconut shell-fuel.

The height of the reactor can be computed using the formula:

$H = \frac{(SGR \times T)}{\rho_{fuel}}$…….(4)

Density of coconut shell ranges from 550-650 kg/m^3.

$H = \frac{(90 \times 1.5)}{650}$ = 0.2076 m = *20.76cm*

Time to consume coconut shell (T):

This refers to the total time required to completely gasify the rice husks inside the reactor. This includes the time to ignite the fuel and the time to generate gas, plus the time to completely burn all the fuel in the reactor. The density of the coconut shell (ρ), the volume of the reactor (Vr), and the fuel consumption rate (FCR) are the factors used in determining the total time to consume the coconut shell fuel in the reactor.

$T = \frac{\rho_{fuel} \times Vr}{FCR}$…… (5)

$T = \frac{650 \times \left(\pi \times 0.1459^2 \times 0.2076\right)}{1.509 \times 4}$ = 1.49 hrs.

Amount of Air Needed for Gasification (AFR):

This refers to the rate of flow of air needed to gasify coconut shell. As shown, this can be simply determined using the rate of consumption of coconut shell fuel (FCR), the stoichiometric air of coconut shell (SA), and the recommended equivalence ratio (ε) for gasifying coconut shell of 0.3.

SA is in the range of 6:1 to 6.5:1 that is 6kg of air for 1kg of coconut shell.

$AFR = \frac{(\epsilon \times FCR \times SA)}{\rho_{air}}$…….. (6)

$AFR = \frac{(0.3 \times 1.509 \times 6)}{1.2}$= 2.26 m^3/hr.

The theoretical design results in a gasifier stove of 21 cm height and 15 cm reactor diameter. As a matter of fact, the height of the reactor depends on the time, for which we intend to use the stove with one batch of fuel. So size can be reduced if there provision for continuous feeding. According to cooking practice prevailing in Kerala, women stand while cooking and the LPG

stove/Kerosene/wood stove are placed on a concrete structure about 1 m above ground. So it will be better to design a stove of height, less than 25 cm.

5. Design Options Stove for Gasifier Stove

Economic aspects are one of the important factors while designing a product like biomass stove. Most of the stoves mentioned above are not affordable for rural poor communities, who are the potential users of such stoves. Even portable JP stove produced by IRTC, Palakkad costs about $ 60. A combination of metal body like the JP stove and ceramic combustion chamber like a mud stove is a good option for reducing the price and for improving the life span of the stove. Combustion chamber must be insertion type, which can be removed if damaged.

Rice husk based gasifier stove is an option for Palakkad district as the district itself is named as the granary of Kerala. Coconut shell is a good option as a fuel due to its calorific value and availability. Fuel wood, coconut husk etc. are other potential wood options. Fire wood and other fuels are also easily available in the market at a rate Rs.4-5/kg (6-8 cents). The stove must be designed to use at least any two of the fuels and should have provision for continuous feeding compared to the batch feed gasifier stove that are commonly used in northern parts of India, as cooking of rice take more than an hour.

A portable gasifier stove based on natural draft principle will be a better option for introducing in to the market, as it will be a low cost option for the poor in rural areas and a secondary cooking option for the urban. In the future, stoves can be designed concentrating more on force draft less polluting and efficient model, 2-3 burner house hold unit and community stoves.

6. Results and Discussions

Study on different stoves shows that there is a need for improved fuel efficient stoves in Kerala. Theoretical design of gasifier resulted in developing a combustion chamber of height 21 cm and diameter 15 cm which suits the living condition of Kerala. Fire wood, coconut shell, agri-residue based gasifierstove will be a better option for Kerala conditions as it is smokeless as well as fuel efficient. A continuous feed with metal body and ceramic – insert type combustion chamber can reduce the cost of production and increase the life of stove.Force draft gasifier stoves are less polluting and efficient compared to natural draft option, sacrificing the cost. Future studies may concentrate on gasifier based community stoves and multi burner natural draft stoves.

7. Acknowledgment

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8. Abbreviations

T-LUD – Top Lit Up Draft; CMIE – Centre for Monitoring Indian Economy ; LPG – Liquefied Petroleum Gas; CO – Carbon Monoxide; PM – Particulate Matter; KSSP - Kerala Sasthra Sahitya Parishad; IRTC – Integrated Rural Technology Centre ; IIT – Indian Institute of Technology

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