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Performance evaluation of Chinese model (HX-20) updraft institutional gasifier stove in context of Nepal

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Abstract
Gasifier stove can act as a simple and energy efficient device for cooking purpose which can improve cooking and kitchen environment. It is more worthy if it is used for institutional purpose like in hotels, hospitals, schools and barracks etc. where cooking is used for a large number of people. The research work presented in this paper is focused on evaluation of Chinese model (HX-20) updraft gasifier stove with locally available feedstock such as rice husk, wood chips and pellets (mixture of saw dust, straw and rice husk).The performance was evaluated in term of thermal efficiency, flame temperature and specific fuel consumption at laboratory. The efficiency of stove with wood chips, rice husk and pellet were found 17.76%, 15.51% and 19.91% respectively and specific fuel consumption of wood chips, rice husk and pellet were 0.539kg/kgh, 0.495 kg/kgh and 0.675 kg/kgh respectively. The study also showed that there was problem with rice husk due to excess formation of tar.

Keywords
Thermal efficiency – updraft institutional stove – pellet – wood chips

1. Introduction

1.1 Background

Biomass is widely regarded as a potential renewable energy resource of “CO2 zero emission” and is especially important in developing countries (often more than 90% in developing countries but 10-15% all around world), and more and more attentions have been focused on biomass utilization under the conditions of global warming and energy shortage. Biomass combustion provides basic energy requirements for cooking and heating of rural households and for process in a variety of traditional industries in the developing countries. In general, biomass energy use in such cases is characterized by low energy efficiency and emission of air pollutants [1]. Historically, Nepal’s rural population have been meeting the energy need from the traditional sources like fuel wood and other biomass resources. The economy of the rural population is largely based on agricultural activities. Biomass resources play major role in the overall energy sector of Nepal and will be continued to be main sources of energy for most of the rural areas at least for some decades in future.

Wood fuel (branches, twigs, barks, split,logs etc), agricultural residues and animal waste are easily available and relatively cheaper indigenous source of energy for almost all rural areas of Nepal. The traditional resources alone meet 87.1% of total energy demand of our country whereas fossil fuel and petroleum product meet only 10.17% of total annual energy demand. Large amount of national income is being spent to import fossil fuel whereas we are obtaining biomass energy (which contributes about 87.1% of total energy demand) at very cheap or almost free of cost. If the indigenous sources of energy are utilized properly, huge amount of outgoing dollar can be saved. In the case of developing countries like Nepal, it is glaring that the proper and efficient use of biomass fuel can play an important role [2].

Biomass fuels currently used in traditional energy systems could potentially provide a much more extensive energy service than at present if these were used efficiently. For example, improved stove design can enhance the efficiency of biomass use for cooking by a factor of 2 to 3. Thus, the energy service provided by biomass in this case could be potentially provided by one third to half of the amount of biomass used currently, amount of biomass saved through efficiency improvement can be used to provide further energy services. According to a study, the total potential of saving biomass used for domestic cooking through substitution of the traditional stoves by improved ones in six Asian countries (China, India ,Nepal, Pakistan, Philippines and Srilanka) is about 277 million tons/year the saving amounts to about 36% of the biomass consumption for cooking in these countries at present. In the last few decades many improved wood stoves have been developed in different parts of the world. Huge resource has been invested to replace the traditional stoves by improved cook stoves in Nepal too. In Nepal, the government has been supporting a program to introduce improved cook stoves (ICS). The general objective of the program is to establish a sustainable framework and strategy to make technically available and socially appropriate ICS in rural communities based on local capacity building and income generation. This program has been currently promoting ICS in 33 mid-hill districts of our country [3].

A large number of improved wood fired cooking stoves have been developed in different countries; most of these basically aim to overcome the two major drawbacks of traditional stoves, namely low efficiency and indoor pollution. Gasification of biomass (use of the producer gas) appears to be an interesting option for its clean and efficient use for cooking.

1.2 The Research Problem

Over two billion people cook badly on inefficient wood stoves that waste wood, cause health problems and destroy forests. Electricity, gas or liquid fuels are preferred for cooking when they can be obtained but their availability depends on having a suitable infrastructure and they are often not available in developing countries like Nepal. Gas can be obtained from wood and biomass in gasifiers developed in this century, use of non-woody fuels for gasification can avoid deforestation . Generally non woody are seasonal so the there must be a unique system that work on multi fuel (locally available feedstock).

Traditional combustion of biomass material produces low conversion efficiency and high emission. The total efficiency of traditional cooking stove is only about 10-12% on direct combustion process. In the last few decades, many improved wood stoves have been developed in different parts of world. Huge resources have been invested to replace the traditional stoves by improved cook stoves in Nepal as well. However, it has been not effective to an expected extent.

A gasifier produces gas from biomass wastes such as wood chunks, corn stake, cobs, straws etc. the gas burns cleanly with high heat release and high combustion intensity than conventional stove burner. The gasifier may be user-friendly because of simple construction, low cost fuel, easy operation, clean and fast heating.

It is possible to produce gas from biomass in practice. Therefore, biomass gasifier has been developed in different parts of the world since nineteenth century (Reed,2001; Kaupp and Goss,1984;Stassen,1995;Foley and Barnard,1983). But the gasifiers fabricated so far are generally too big for domestic as well as institutional uses. A downdraft gasifier stove for domestic cooking has been manufactured in China (Gao, 1994). In Nepal, Nepal Academy of Science and Technology (NAST) has developed a briquette gasifier stove by adopting the design of Asian Institute of Technology (AIT), Thailand (Singh and Shakya,2001). Basnyat (2004) has fabricated a gasifier primarily intended for cardamom drying. Similarly, Simkhada (2005) has developed an domestic gasifier. Recently, crossdraft gasifier for institutional cooking purpose has developed at CRE and many countries of the world are working to build institutional type of gasifier for large and continuous cooking purpose [4].

In such a scenario, an idea crop up that the gasifier stove useful to be operated for institutional purpose with multi fuel can be sustainable in Nepal. Such a technology can be appropriate for institutional cooking purpose for hostels, roadside restaurants, barracks etc to reduce the drudgery faced by the rural population of the country and also improve the health of the rural women who are primarily involved in cooking. Due to the above issues it is necessary to study in the area of institutional gasifier.

1.3 Objectives of the Study

The main objective of this study is to perform testing of Chinese (HX-20) model of updraft institutional gasifier stove with locally available feed stock.

The specific objectives of this study are given below:

- To study the technical aspect of existing institutional gasifier stove.

- To compare energy efficiency, specific fuel consumption using locally available different feed stock.

2. Methodology and Testing Procedures

2.1 Problem Formulation

Problem formulation is an activity which defines the cognitive gap between what is and what is desirable and delineates the resources for closing it. Problem formulation is the creative and probably the more important step towards overcoming a problematic state than problem-solving. A research is aimed towards obtaining the solution of energy efficient cooking in the institutional sector.

2.2 Performance Evaluation of Chinese Model (HX-20) Gasifier Stove

For performance evaluation, locally available feed stock (wood chips, rice husk and pellet) were selected and tested in the existing Chinese (HX-20) model of institutional gasifier at CEEN with the help of laboratory tests listed below:

- Proximate analysis of different feed stock
- Calorific value determination of different feed stock
- Water boiling test 4.22 with different feed stock

3. Experimental Setup

3.1 Apparatus Setup

The main focus of this research work is to evaluate the performance test of the Chinese model institutional biomass gasifier stove and explore its opportunity to be used in context to Nepal as well as look for modification with locally available biomass in Nepal. The stove is basically a forced draft, updraft gasifier coupled to a gas burner which is shown in Figure 1 has a combustion space of 270 mm diameter and 690 mm depth with ash removal opening at the bottom and pellet, rice husk, saw dust of biomass can be used as fuel. The stove is a top-lit updraft gasifier with air for gasification (primary air) provided from the bottom region and the gas generated in the process of gasification burnt on top with secondary air to ensure complete combustion and minimum emissions.

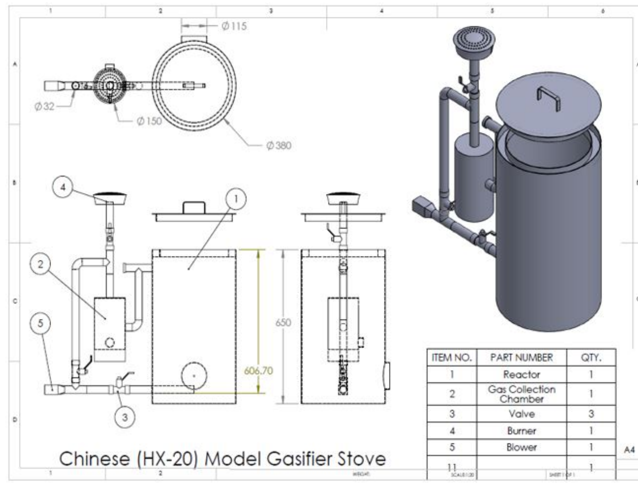

Figure 1: Assembly drawing of Chinese model (HX-20) gasifier stove

3.2 Experimental Procedure

Wood chips, rice husk and pellet were loaded into the metallic combustion chamber (reactor, hopper) from the top to calculate the performance of the different fuel types. Water was filled into the water seal to prevent leakage from the top. The fuel was lit on top by sprinkling small amounts of liquid fuel (say. diesel or kerosene), de-volatilization of biomass leads to ignition of particles in the top most layer. This in turn leads to similar processes in the subsequent layers of biomass particles. This flame front propagates into the fuel bed against the air stream like a premixed flame propagation. The air that passes from the bottom through the bed aids flaming combustion of the biomass piece and the gases move upward through the bed behind by the propagating pyrolysis front. This leads to reduction reactions and the gases that issue from the top region are fuel rich. The amount of air entering the stove was controlled by the regulating switch of blower and the air damper provided at the primary air inlet. Secondary air from the blower mixes and burns with this combustible gas ensuring complete combustion with minimum emissions and maximum possible heat transfer to the vessel.

4. Results and Discussion

The performance evaluation of the Chinese (HX-20) model institutional gasifier stove located at CEEN was done using different biomass fuel sources (wood chips, rice husk and pellet). The results obtained during the test that performed are discussed below:

4.1 Proximate Analysis Test

The proximate analysis is one of the combustion characteristics of any fuel which will give a preliminary picture of the fuel and its quality. The proximate analysis was conducted using Japanese Industrial Standard JIS 8811. In this research we perform a Proximate analysis for three different feed stocks. The results obtained from the tests are shown in table below:

Table 1: Result of proximate analysis

Sample	Moisture %	Ash %	Volatile matter%	Carbon Content%
Wood chips	12.93	0.48	85.79	0.81
Rice husk	10.68	11.28	75.33	2.70
Pellet	10.36	13.17	73.13	3.34

4.2 Calorific Value Test

The calorific value of the different materials used was determined experimentally by using a Bomb calorimeter and following the standard methodology in the College of Applied Science (CAS). The calorific value obtained from test at Center for Energy and Environment Nepal (CEEN) are listed below:

Table 2: Result of calorific value test at CEEN

S.N	Sample	Calorific Value(MJ/kg)
1	Wood chips	20.967
2	Rice husk	16.518
3	Pellet	16.721

4.3 Performance analysis of Chinese model (HX-20) updraft institutional gasifier stove

Three tests were carried out for each fuel type for the performance evaluation of the IGS. The three tests were analyzed simultaneously, however here we have discussed only average of the tests result.

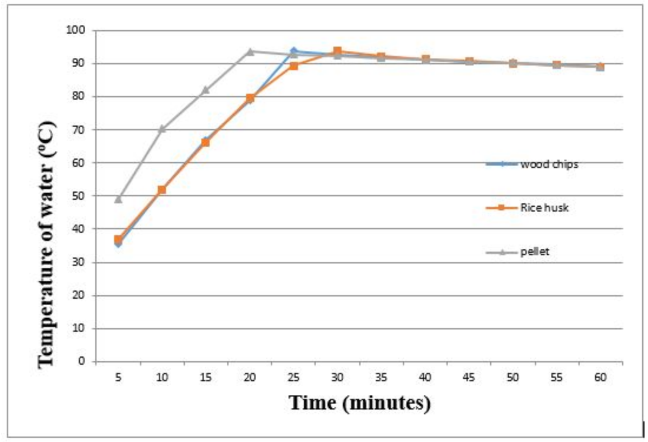

Figure 2: Result of water boiling test

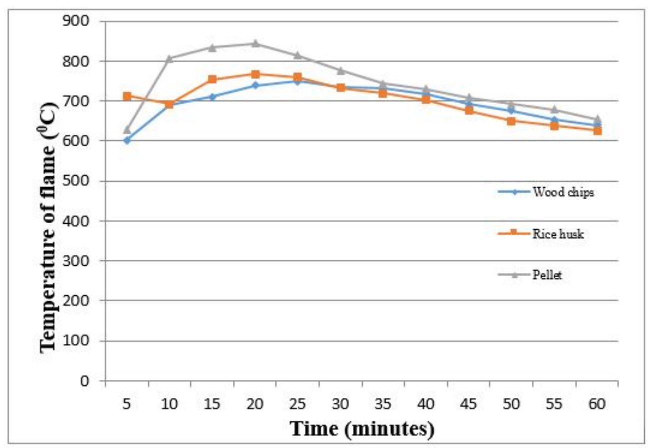

Figure 3: Graph of Flame temperature Vs time with different feed stock

4.4 Comparison of the performance of Chinese model (HX-20) gasifier stove with different feedstock

The figure 4 shown below is the thermal efficiency and specific fuel consumption of existing Chinese (HX-20) model gasifier stove with different feed stock (wood chips, rice husk and pellet).

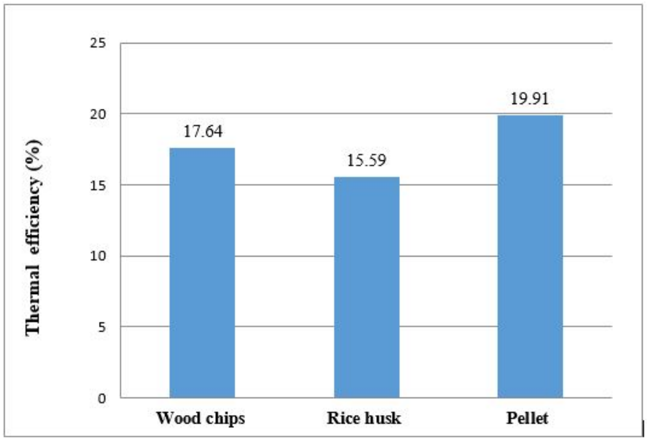

Figure 4: Thermal efficiency of different feed stock

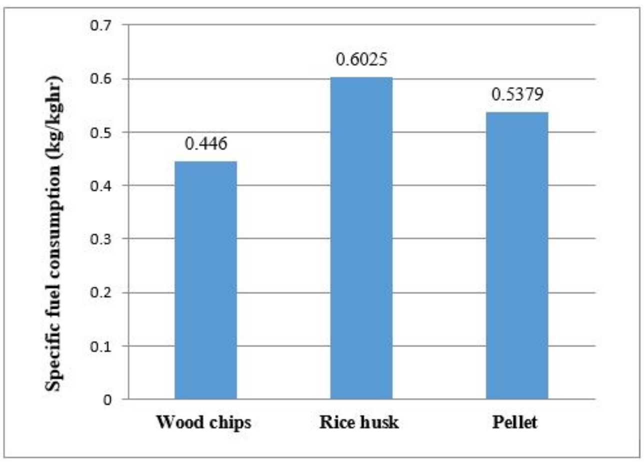

Figure 5: Specific fuel consumption of different feed stock

5. Conclusion

The efficiency of the Chinese model (HX-20) updraft institutional gasifier stove was found to be different with different type of feedstock. For example for the three different fuel wood chips, rice husk and pellet were found 17.76%, 15.51% and 19.91% respectively. And specific fuel consumption of wood chips, rice husk and pellet were 0.539 kg/kgh, 0.495 kg/kgh and 0.675 kg/kgh respectively. This Chinese model gasifier works satisfactory for all the fuel in the term of thermal efficiency and specific fuel consumption. But rice husk has problem due to high rate of formation of tar .

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