



ISSN (E): 2277- 7695

ISSN (P): 2349-8242

NAAS Rating: 5.03

TPI 2020; 9(8): 119-126

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[www.thepharmajournal.com](http://www.thepharmajournal.com)

Received: 13-06-2020

Accepted: 15-07-2020

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## Performance evaluation of improved cook stoves

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DOI: <https://doi.org/10.22271/tpi.2020.v9.i8b.5012>

### Abstract

An experiment has been carried out on various types of cook stoves including traditional cook stoves, sukhad model, udairaj and improved udairaj models, with which the water-boiling test has been performed to find the thermal efficiency, specific fuel consumption and power rating. The results revealed that Udairaj cook stove and traditional cook stove was found to have the highest and lowest thermal efficiency of 23.4% and 15.4% among the cook stoves tested. Udairaj and improved udairaj cook stoves have similar power rating and lowest specific fuel consumption in the range of 0.811 kW to 0.849 kW and 1.232 kg/kWh to 1.225 kg/kWh respectively, whereas traditional cook stove was found to have the lowest power rating of 0.559 Kwh and highest specific fuel consumption of 1.799 kg/Kwh. Finally, both udairaj and improved udairaj cook stoves have a better thermal efficiency, power rating and specific fuel consumption than traditional cook stoves.

**Keywords:** Improved cook stoves (ICS's), udairaj, improved udairaj, specific fuel consumption thermal efficiency and power rating

### 1. Introduction

About 70 to 80% of the total energy used in communities is used for domestic cooking; with firewood, cattle dung and agricultural crop waste (Shukla, 1988) <sup>[10]</sup>. The bio fuels are in traditional cook stoves that are low efficiency. Smoke emanated from traditional cookers pollutes the environment within the house causing negative effects on women and children's health. The uncertain growth in the use of non-commercial energy resources, for meeting rural energy needs, available at almost zero private cost, has resulted in serious environmental problems, including deforestation, soil erosion and loss of fertility and these in turn because lowering of productivity and economic stagnation. With this in view, the Ministry of non-conventional sources launched the National Programme on Improved Cook stoves during 1984-85 and around 30 million improved stoves are installed in the country. India consumes about 130 million tonnes of firewood every year, whereas the production from forests is only 70 million tonnes. The gap of 60 million tonnes leads to denudation of the existing forest.

At domestic, industrial and community levels cook stoves are used to cooking energy that are made up with mud for three styles. For traditional cook stoves there is no vent to remove the smoke. An improved cook stove is the solid biomass fuel burning system for the immediate use of heat in domestic cooking which is produced by combustion. Improved cook stove is not only used to improve biomass combustion thermal efficiency but also to remove the smoke and other inerts, the main cause of indoor air pollution, safe from the kitchen (Chandel *et al.*, 1993) <sup>[1]</sup>. Rathore *et al.* (1999) <sup>[6]</sup> observed that on an average 950 kg of fuelwood could be saved through one local improved cook stove in a year and also observed that improved consumption of fuelwood exposed that an escalation of 1% of thermal efficiency of traditional cook stoves could result in saving of energy equivalent to 4 million tonnes of coal in the country every year. The consumption of firewood is indeed associated with forest degradation leading to many environmental and health problems.

The chulahs used at the household level give off smoke, which not only makes the kitchen uncomfortable to work in but also is very harmful to health. Apart from these disadvantages, the open chulahs consume more fuel, and the smoke discolours and damages the walls Singh, B.P (1993) <sup>[11]</sup>, Garg and Jagwani (1993) <sup>[2]</sup>. This smoke nuisance can be avoided by the use of a chimney placed over the chulah, which takes the smoke safely out of the kitchen, thus making the chulah smokeless. The main advantage of using a smokeless chulah is that since the chulah is covered, less fuel is consumed Karthikeyan *et al.* (1991) <sup>[3]</sup>, Mathur and Verma (1993) <sup>[4]</sup>. Besides, there is no risk to anyone's health due to smoke.

The smokeless chulah is easy to build and is fuel-efficient too. Improved chulahs program has been in operation in India from 1983 by the Ministry of Non-Conventional Energy Sources with the objectives of efficient use of fuelwood in rural and semi-urban areas, preventing deforestation, elimination of smoke from the kitchen.

Different models are developed and promoted by MNES sponsored institutions like IISc, Bangalore, College of Technology and Engineering, Udaipur, CAST FORD and TNAU, etc. Single pot, Double pot stoves, Metallic stoves, Ceramic/ refractory lined chulahs, etc. was developed and promoted. District agencies of Non-conventional Energy Development Corporations are taking a major part in implementing this programme. Several NGOs are also actively participating in implementing and propagation of the installation of improved chulahs. Still, there are so many villages, which are unaware of these programmers, and there is a lot of work to be done to reach these technologies to every village in Andhra Pradesh. The present review covers an overview of the history of cook stoves development, classification of cook stoves, inherent defects of traditional cook stoves, salient features of improved cook stoves and previous research work related to performance evaluation of different cook stoves and possible reasons for success or failure of stove programs.

Rathore *et al.* (1999) <sup>[6]</sup> made a performance evaluation of Chetak & Udairaj ICS in terms of saving in fuel and extent in minimization of indoor air pollution. It was observed that on an average 950 kg of fuelwood could be saved annually from one such cook stove. ICS have not only reduced fuel consumption at the village level but also helped in minimization of indoor air pollution. In five selected villages, study on indoor air pollution was also extended and better health of beneficiaries using ICS was observed.

Rathore *et al.* (2001) <sup>[7]</sup> evaluated the performances of the Chetak (Single-pot) and Udairaj (Double-pot) by standard water boiling test. The thermal efficiencies of these stoves was found to be in the range of 21.78% and 29.08%. These designs was found to fulfil the needs of rural and tribal people and have been recommended for large-scale adoption.

Manju Mehta *et al.* (2003) <sup>[5]</sup> developed and evaluated the performance of nine different cook stoves and compared them with the traditional cook stove. Each cook stove was evaluated in terms of fuel-burning rate, ash produced and charcoal produced. In the first category (traditional and priyagni and little modification in them) higher fuel burning rate was observed in the traditional cook stove. In the second category (U shaped cook stoves with grates), the highest amount of heat was generated. The third category (U shaped cook stoves with grate and flame concentration plate) model required the least amount of fuel i.e. 1.44 kg/hr and provided only 0.085 kg charcoal and 0.001 kg of ash per kg of fuel used.

Rathore *et al.* (2003) <sup>[8]</sup> developed a single pot stove called "chetak" and a double pot stove called "Udairaj" having an average service life of 5years. Chetak stoves have been installed in 63 farmhouses and udairaj stoves in 33 farmhouses of 4 villages in Udaipur district both the stoves was evaluated for water boiling test and average thermal efficiency was worked out to be 21.3% for chetak and 25.5% for Udairaj stoves. ICS affected more than 50% saving in fuel and 60% saving in cooking time. Pollutants emitted by the chetak stove are significantly lower than the traditional stove.

Rathore *et al.* (2005) <sup>[9]</sup> assessed the performance of the

Chetak and Udairaj cook stoves and found the merits of an improved cooking stove over the traditional cook stove. The thermal efficiencies of cook stoves was in the range of 20-25% as compared to 8-10% traditional cook stoves and save the homemakers from the ill effects of the gases associated with the burning of wood. The average thermal efficiency of the two stoves was 25.54%. The fuel consumed, the time taken for cooking the meal and smoke constituents of improved cook stoves was compared with those of the traditional stove. The Chetak and Udairaj stoves was found to be superior to traditional stoves on all evaluated parameters and quite suitable for rural areas.

Syedul Islam *et al.* (2008) <sup>[12]</sup> developed an improved version of cook stove by incorporating a perforated screen in the stove cavity, an ash port by the side of the stove and reducing pot rest height from 8 to 2 cm of the ground traditional stove. In the improved stove, fuel efficiency was increased by 40% compared to the traditional ground stove. The time required for initial firing in an improved cook stove was less than 1 min, as compared to the traditional stove that was 3 minutes. The fuel consumption is improved ground stove was about 35% less than that in the traditional ground stove.

A study was undertaken to establish the best cook stove to recommend in the rural areas. Experiments were conducted on different models of cook stoves viz traditional cook stove, sukhad model, udairaj and improved udairaj models to find the thermal efficiency, power rating and specific fuel consumption by conducting water boiling test.

## 2. Materials and Methods

The study was undertaken to evaluate the performance of different cook stoves. This section deals with installation and maintenance, construction details, the experimental procedure for conducting a water-boiling test to determine thermal efficiency, the procedure to determine the power rating of different types of improved cook stoves.

### 2.1 Installation and maintenance of ICSS

Improved cook stoves maybe were constructed through a skilled mason. The internal structure should be made using good quality first-class bricks laid with cement mortar and cured for one day. Pure Portland cement packed in polythene bags and good quality fine and coarse sand should be used. The AC pipe of 7.5 cm diameter and approximately 3 m length may be fixed properly at the stove end and made waterproof at the ceiling/roof. The skeleton may be plastered with a 12 mm thick cement plaster and cured properly for 15 days. To avoid cracking of the plaster, fuel burning may be gradually increased to full scale over a period of 3 days. A mud plaster may be applied on the outer surface to avoid skin burns. In the case of double pot, ICSS both the pots should be used simultaneously. The chimney pipe and connecting tunnels should be clean periodically to ensure the efficient operation of the stove.

### 2.2 Construction details of ICSS

#### 2.2.1 Udairaj cook stove

Table.1 shows the major specifications of cook stove. The cook stove is made of cemented bricks. The chimney is used as an AC pipe with a diameter of 7.5 cm and a length of 3m, for creating a smoke removal draft and providing adequate secondary air for combustion. For the fire from the first pot to the second, a linking tube is supplied. The first pot is 24 cm in diameter. The stoves have a wood burning average of 1 kg/h.

**Table 1:** Major Specifications of different cook stoves

Sl. No.	Description	Traditional	Sukhad	Udairaj	Improved udairaj
1	Body size, cm	27x35x22	80x42x20	80x48x25	70x40x22
2	Firebox diameter				
	❖ First pot, cm	-	20	24	18
	❖ Second pot, cm	-	17	20	14
3	Firebox opening				
	❖ Shape	Rectangle	Square	Rectangle	Rectangle
	❖ Size, cm	22x17	17x17	24x16	18x16

### 2.2.2 Sukhad cook stove

Sukhad stove is constructed with locally available material and AC pipe/pipe pieces, cowl, etc. for chimney and connecting tunnel. The body of the stove on the floor is about 80 cm X 42 cm. the first firebox platform is 20 inches high, with a pot seat of 3 cm wide. The platform was raised by the second pot hole. The first and second pot hole diameters are 20 cm and 17 cm. A tunnel, which connects the pot tough, is a tube cut in size from an AC tube with a diameter of 7.5 cm and a length of 26 cm. it is kept at 30° inclined in the tube. This system allows moving heat to the second pot faster and more explicitly. Baffling effect on the hot gases in the second pot hole is provided by setting the chimney tunnel inclined downwards and reduction in it is the cross-sectional area. The chimney tunnel is cut to size from an AC pipe of 5 cm diameter and 13 cm long. To support the chimney pipe (7.5 cm diameter and 3 m long) and help its easy replacement and cleaning a separate collared pipe piece 10 cm long (excluding collar) is fixed with cook stove body at the front or rear corner to suit the site.

**2.2.3 Improved Udairaj cook stove** is similar to that of udairaj cook stove except that the diameters of first and second pot holes are changed to 18 cm and 14 cm to suit the local requirements.

**2.2.4 The traditional cook stove** is constructed with bricks on three sides with an opening at the front which is commonly used in rural areas is selected for the study.

### 2.3 Improved Cook Stove - Testing

The testing of an improved cook stove involves a systematic approach to the evaluation of the useful and adverse characteristics of a particular model. It allows a better understanding of the processes of combustion, heat transfer, and fluid flow taking place in the stove for heat utilization. Without testing, it is not possible to quantify the observations on the parametric studies for further evaluation. It will permit the comparison of the results of tests conducted at different places. Thus testing is one of the most important tools from the points of view of quality control and design. It also helps in the dissemination of the technology, by demonstrating to the user the relative advantages of efficient models.

#### 2.3.1 Criteria for testing

Keeping in view the above discussion, a versatile test procedure should have the following features

- The test should be simple and easy to perform, at different stages such as in the laboratory, factory, and field.
- The results of the test should be easy to interpret by the different actors such as developers, research scientists, implementers, public opinion makers, planners, and users.

- Results should be reproducible, within reasonable limits.
- The test should be versatile so that it applies to a wide range of end-use applications.
- It should be able to simulate cooking, as closely as possible.
- It should be able to predict the effect of different parameters that influence the performance of the stove.

#### 2.3.2 Water Boiling Test (WBT)

The basic method of the University of California Berkeley (UCB) is used for the water-boiling test. Water boiling tests have been performed by the volunteers in Technical Assistance (VITA), USA, for the thermic performance of wood burning stove as defined in international standards for the quality testing of wood – burin stoves. Experiments were conducted during various stoves. The water-boiling test is laboratory test that allows two or more stoves to be compared under controlled conditions or the same stove under different conditions.

The water-boiling test is a simplified version of the University of California Berkeley (UCB). Water boiling test as outlined in the International Standard on testing the efficiency of wood-burning stoves, prepared by Volunteers in Technical Assistance (VITA), USA, was conducted for arriving at the overall thermal efficiency of a wood-burning stove. The experiments were carried out on different days to estimate the efficiency of different stoves. The water-boiling test is a laboratory test, which can be used to compare the performance of two or more stoves under controlled conditions, or the same stove under different conditions. It simulates the boiling/simmering type of cooking to some extent only. As a result, it does not necessarily reflect the stove performance, when food is cooked.

The four stoves selected for conducting tests are

1. Traditional
2. Sukhad
3. Udairaj
4. Improved Udairaj

#### 2.3.3 Materials used for water boiling test (WBT)

- The scale of at least 6kg capacity and 1-gram accuracy.
- Thermometer accurate to 1/10 of a degree.
- Timer.
- Testing pots.
- Small shovel/spatula to remove charcoal from the stove.
- Air-dried fuelwood.
- Measuring jar of 0.5-liter capacity.

##### 2.3.3.1 Fuel

The fuelwood cut into convenient sizes, 4-5 cm diameter and 30 – 40 cm long is taken from a complete sun-dried single lot. Before initializing the test, the considered amount of fuelwood is weighted in a minor lot of 1 kg each. The calorific value of calorific value of fuelwood is 3500 kcal/kg.

### 2.3.3.2 Vessels

The vessels used should fit into the pot hole and sealed properly to avoid leakage. Proper size lids of the same material as that of vessels shall be required to cover the vessels during the test to fit on it without any air gap in between. Before filling in water to the vessel, its inner and outer surface should be well cleaned and dried and should be free of any foreign material deposit. The lids should also be cleaned.

### 2.3.3.3 Water

Clean portable water should be used for the water-boiling test. A known quantity of water is filled in to vessel, to occupy its two-thirds of volume. The initial temperature of water in both pots is noted using a laboratory (mercury-in-glass) thermometer.

### 2.3.3.4 Igniting the fuel

The fire is started by igniting small pieces of chopped fuelwood or with minimum (10-15 ml) kerosene with the help of matchstick. As soon as the fuel wood catches fire in the first pot, hole. Vessels containing water are placed properly on the pot seats at this movement time of starting the test is noted down.

### 2.3.3.5 Boiling

- Allow the combustion of fuel in such a way that the flame becomes steady. This can be done by adjusting the chimney damper/fuel-wood pieces in the hearth.
- Note down the temperature rise of water at regular intervals.
- When water starts boiling in the first pot, note down the time at this stage simmering the sound of the boiling water and its temperature will indicate the boiling point.
- A similar procedure should be adopted for the second pot. Note the timing to reach boiling point in the second pot and remove lids.
- Keep constant fuel feed rate until the duration of the test is over. Note down timing and final temperature.
- Extinguish the fire in the hearth immediately at the end of the test duration. Take out coal (residue) and weigh it.
- Measure the quantity of residual water, separately in both the pots. Calculate quantities of water evaporated in the two pots separately, by subtracting the quantity of residual water from the initial quantity of water taken in the vessels.
- The test should be repeated after allowing sufficient time for the cooling of ICS.

## 2.4 Thermal efficiency

The model calculation of thermal efficiency of ICS is

$$E = \frac{H_1 + H_2}{F \times CV} \times 100$$

Where: F = Amount of fuelwood burnt in kg  
 C.V = fuelwood Calorific value 3500 kcal/kg  
 H<sub>1</sub> = Sensible heat (kcal)  
 H<sub>2</sub> = Latent heat (kcal)  
 E = Thermal efficiency (%)

### 2.4.1 Precautions

- Overfeeding of fuel-wood should be avoided.

- Wood pieces should be placed on the hearth floor in such a way that proper aeration is maintained for smoke-free, burning of the fuel and steady flame.
- A gap of 3-4 hrs, should be kept in between the repetition of the test so that the ICS comes back to ambient temperature.

## 2.5 Power Rating

The power rating of the cook stove is the measure of the total energy produced for 1 hour by fuelwood.

$$\text{Power Rating } P.R = \frac{F \times C.V \times E}{860} \text{ KW}$$

Where

F = Fuel burning rate (kg/hr)

C.V = Calorific value of fuel wood (3500 kcal/kg for casuarinas wood)

E = Thermal efficiency (%)

## 3. Results and Discussion

### 3.1 Variation of water temperature with time

The water temperature increases with an increase in heat input and reaches maximum boiling temperature and then decreases with a decrease in heat input. Variation of water temperature with time in each pot of different cook stoves for the burning and recovery periods is presented in fig.1-4. It was observed that the temperature of the water was high in the first pot of the double pot cook stoves in comparison to traditional cook stoves. The temperature in the range of 63-87 °c was also observed in the second pot of improved cook stove suggesting the availability of additional heat for cooking in the second pot of ICS. From the experimental results, it was observed that the variation of water temperature depends on the following factors

- Initial water temperature
- The volume of water taken
- Prevailing wind conditions
- Feeding and burning rate of firewood.

Vengatesan *et al.* (1991) <sup>[13]</sup> made similar observations on a high-efficiency smokeless wood-burning stove.

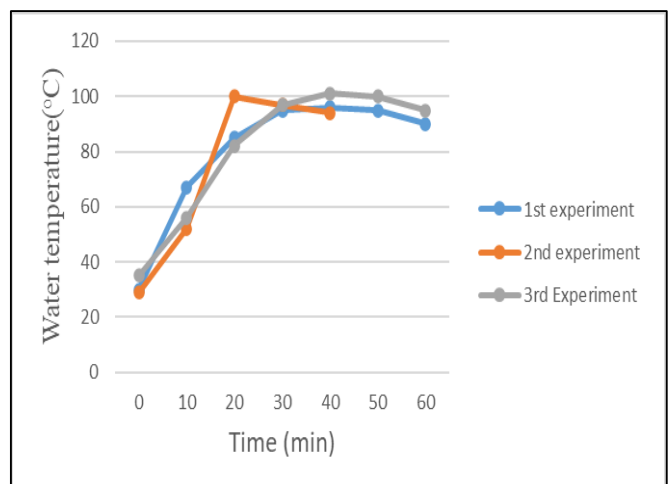
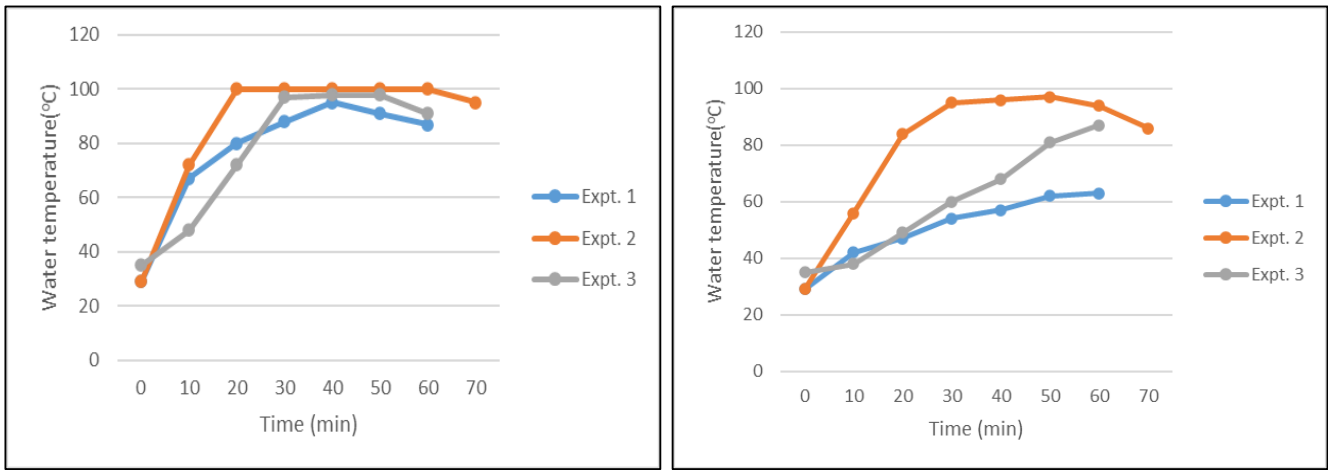
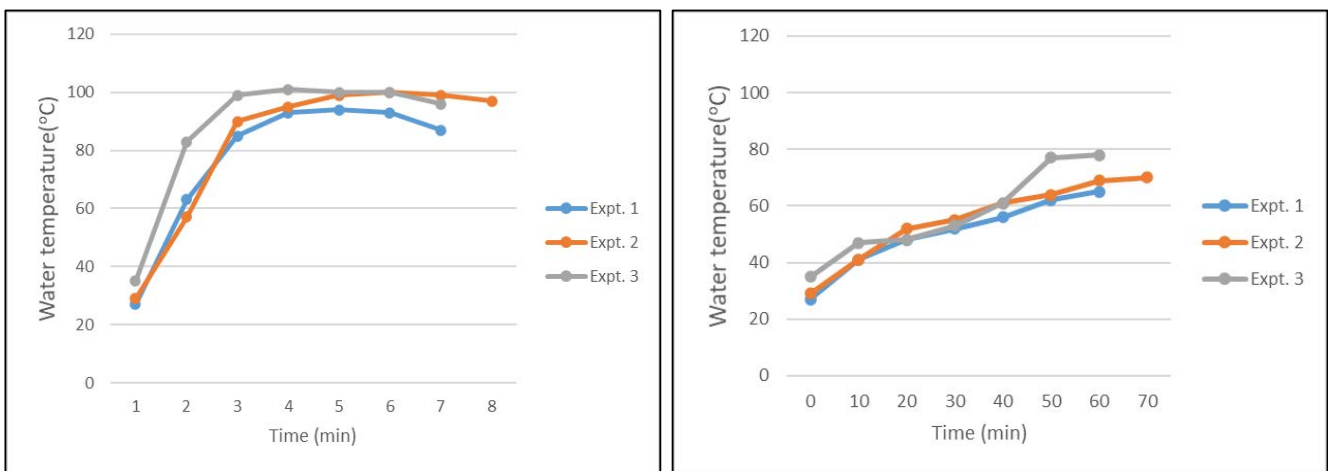


Fig 1: Variation of water temperature with time in traditional stove

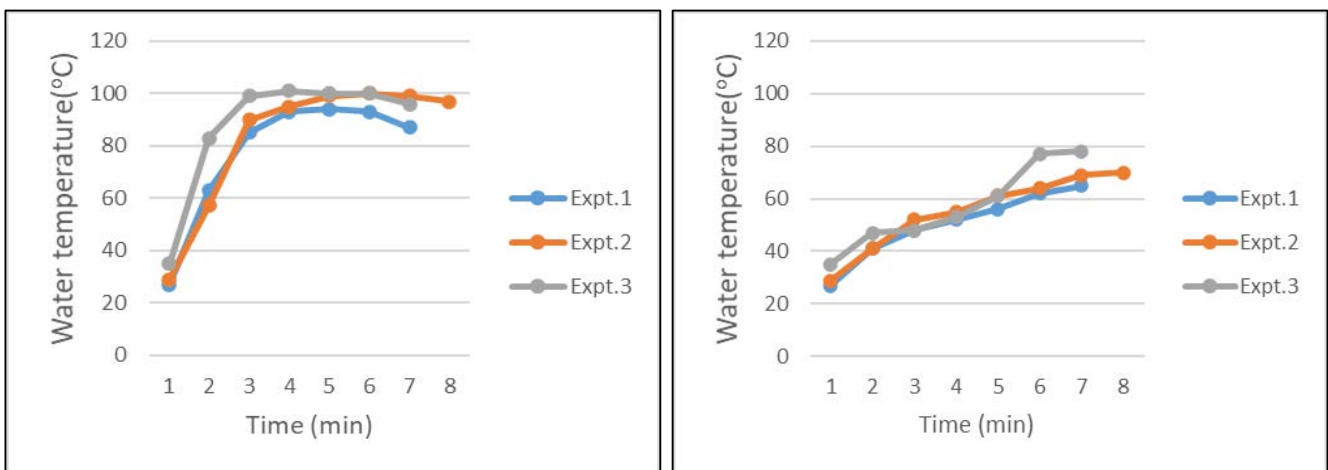




**Fig 2:** Variation of water temperature with time in Sukhad stove (a) 1<sup>st</sup> pot temperature (b) 2<sup>nd</sup> pot temperature



**Fig 3:** Variation of water temperature with time in udairaj cook stove (a) 1<sup>st</sup> pot temperature (b) 2<sup>nd</sup> pot temperature



**Fig 4:** Variation of water temperature with time in improved udairaj (a) 1<sup>st</sup> pot temperature (b) 2<sup>nd</sup> pot temperature

**3.2 Determination of burning rate, thermal efficiency and power rating of different cook stoves**

The average firewood-burning rate of 1 kg /hr was observed for all the cook stoves. Improved udairaj stove was found to have highest thermal efficiency and power rating of 26.1% and 1.06 kW during the first experiment and udairaj stove was

found to have highest thermal efficiency and power rating of 23.36% and 0.84 kW during the second experiment and 24.3% and 0.811 kW during the third experiment (Table.1). It is known that with an increase in the burning rate the heat transfer efficiency decreases while combustion efficiency

increases. The factors that affect the thermal efficiency of an improved cook stove are

- **Fuel factors:** Physical and chemical proportions of fuel such as calorific value, density, volatile matter, moisture, ash, etc.
- **Operational factors:** Feeding and burning rates, size of the fuel charge, geometry of cooking vessels, mode of fuel supply, cooking time etc.
- **Environmental factors:** Air temperature, water temperature, wind velocity, atmospheric pressure, relative humidity and the kitchen environment.

- **Stove factors:** Fuel/air ratio, the mass of the stove, age of cook stove, etc.

The heat transfer from the fire to the cooking vessel takes place by radiation and convection and its subsequent transfer to food in the vessel is governed by conduction and convection. The thermal properties of the cooking vessel such as thermal conductivity, thermal diffusivity, heat transfer coefficient and emissivity have an important bearing on the heat transfer from the fire to the wood. Geller *et al.* (1983) estimated that the material of the cooking vessel has a strong influence on the heat transfer efficiency

**Table 1:** Burning rate, thermal efficiency and power rating of different models of cook stoves

S. No.	Stove model	Quantity of water taken (l)	Quantity of water evaporated (l)	Burning rate (kg/hr)	Sensible heat (Kcal)	Latent heat (Kcal)	Output (Kcal)	Input (Kcal)	Thermal efficiency (%)	Power rating (kW)
Experiment – 1										
1.	Traditional	3.5	0.44	1.07	227.5	237.6	465.1	3230	14.39	0.54
2.	Sukhad									
	Pot-I	3.5	0.3							
	Pot-II	3.0	0.1	0.857	333	183.6	516.6	3075	16.8	0.599
3.	Improved Udairaj									
	Pot-I	3.5								
	Pot-II	2.0	0.7	1.0	385	528.66	913.66	3500	26.1	1.06
4.	Udairaj									
	Pot-I	3.5	0.57							
	Pot-II	2.0	0.065	1.27	332.5	342.9	675.4	2975	22.7	0.784
Experiment – 2										
1.	Traditional	3.0	0.61	1.27	213	329.4	542.4	3000	18.08	0.629
2.	Sukhad									
	Pot-I	1.5	0.495							
	Pot-II	1.0	0.15	1.27	172.5	348.3	520.8	2850	18.27	0.6047
3.	Improved Udairaj									
	Pot-I	3.5	0.585							
	Pot-II	2.0	0.10	1.0	355	369.9	724.9	3230	22.44	0.841
4.	Udairaj									
	Pot-I	3.5	0.77							
	Pot-II	2.5	0.01	1.016	303	421.2	724.2	3100	23.36	0.84
Experiment – 3										
1.	Traditional	2.0	0.57	1.2	132	307.8	439.8	3175	13.8	0.508
2.	Sukhad									
	Pot-I	2.0	0.54							
	Pot-II	1.5	0.1	1.2	204	345.6	549.6	2950	18.6	0.637
3.	Improved Udairaj									
	Pot-I	2.0	0.635							
	Pot-II	1.5	0.05	1.2	190.5	369.9	560.4	3050	18.3	0.648
4.	Udairaj									
	Pot-I	2.0	0.9							
	Pot-II	1.5	0.035	1.33	196.5	504.9	701.4	2875	24.3	0.811

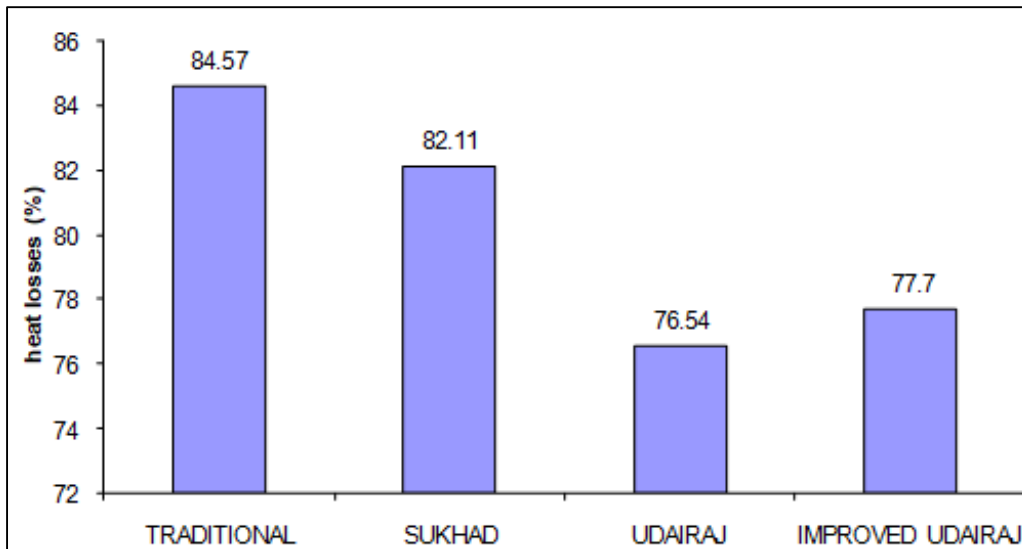
### 3.3 The thermal efficiency of different cook stoves

Water boiling tests were conducted on different models of cook stoves to determine thermal efficiency. From the experimental results, udairaj stove was found to have a highest average thermal efficiency of 23.4% and the traditional stove was found to have the lowest averaged thermal efficiency of 15.4% (Table.2. and Fig.5).

The reasons for low thermal efficiency with traditional cook stoves are perhaps heat losses and low conservation of heat due to only one pot. Rathore and Jain (2001)<sup>[7]</sup> made similar observations on “Chetak” & “Udairaj” models of improved cook stoves.

**Table 2:** The average thermal efficiency of different cook stoves

Experiment	Traditional	Sukhad	Udairaj	Improved Udairaj
1	14.4	16.8	22.7	26.1
2	18.08	18.27	23.36	22.4
3	13.8	18.6	24.3	18.3
Average	15.4	17.89	23.45	22.26



**Fig 5:** The average thermal efficiency of different cook stoves

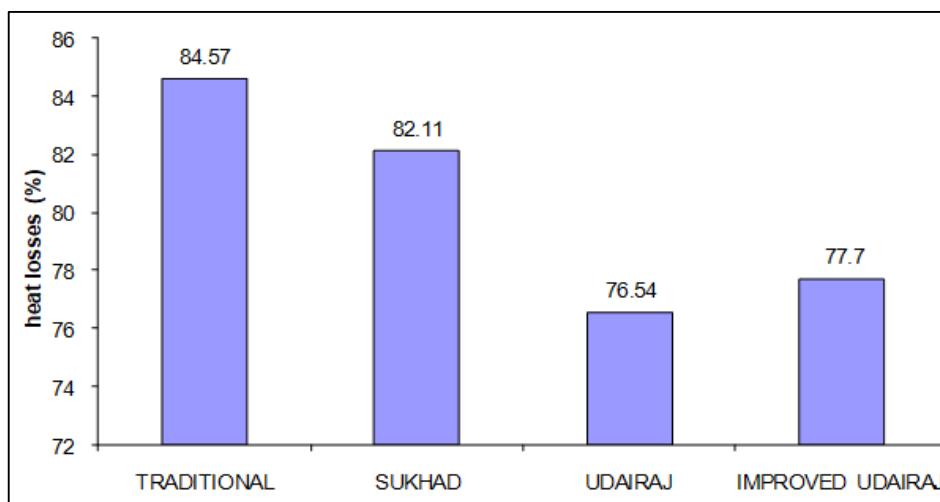
**3.4 Heat losses in different cook stoves**

Heat losses in cook stoves include convection heat losses, radiation heat losses, the heat lost through flue gases and the heat gained by vessel and stove. Convection and radiation are the major heat losses and heat losses can be estimated by deducting the percentage of thermal efficiency from a hundred. From the experiments conducted, udairaj cook stove was found to have the lowest heat losses of 76.54% and traditional cook stove was found to have the highest average

heat losses of 84.57% (Table.3. and Fig.6). From the experimental results it was observed that due to the increase in heat transfer area by providing a second pot hole in the improved cook stove, the heat losses are reduced. Heat losses can also be reduced by providing insulation on the outer surface of the stove and by using low thermal conductivity material for construction. Karthikeyan *et al.* (1991) <sup>[3]</sup> made similar observations on a low-cost high-efficiency mud stove.

**Table 4.7:** Average heat losses of different cook stoves

Experiment	Traditional	Sukhad	Udairaj	Improved Udairaj
1	85.6	83.2	77.3	73.9
2	81.92	81.73	76.64	77.6
3	86.2	81.4	75.7	81.7
Average	84.57	82.11	76.54	77.7



**Fig 6:** Average heat losses of different cook stoves

## Conclusions

Based on experimental data and results, the following specific conclusions were drawn from the study

- Udairaj cook stove was found to have the highest thermal efficiency of 23.4% whereas traditional cook stove was found to have the lowest thermal efficiency of 15.4% among the cook stoves tested.
- Udairaj and Improved udairaj cook stoves was found to have a similar power rating in the range of 0.811 kW to 0.849 kW whereas traditional cook stove was found to have the lowest power rating of 0.559 kW.
- Udairaj and Improved udairaj cook stoves was found to have the lowest average specific fuel consumption in the range of 1.232 kg/kWh to 1.225 kg/kWh whereas traditional cook stove was found to have the highest specific fuel consumption of 1.799 kg/kWh.
- Overall, it was found that, although both udairaj and improved udairaj cook stoves are better than traditional cook stove in terms of thermal efficiency, power rating and specific fuel consumption, improved udairaj model stands out, as it is easy to construct due to prefabricated concrete top used for the installation.

## References

1. Chandel SS, Aggarwal RK. Identification of Design Parameters of Traditional Cook stoves of Himachal Pradesh. *ANTIKA*, a publication on improved chulha. 1993; (4):15-20.
2. Garg BML, Jagwani SK. Development of low cost Metal-clad ceramic/refractory Lined chulhas (New Generation chulhas). *ANTIKA*, a publication on improved chulha. 1993; 4:8.
3. Karthikeyan G, Balakrishna Reddy K, Sethumadhavan R, Vasudevan R. Low cost High Efficiency Mud Stove for Domestic Cooking. Technical Paper Presented at IIT, Madras, 1991, 49-52.
4. Mathur AN, Verma LC. Improved Community Chulha-Successful adoption, *ANTIKA*, a publication on improved chulha. 1993; 4:43-46.
5. Manju Mehta, Sangwan V, Sharma DN. Performance Evaluation of Different Models of Cook stove to Improve Household Environment. *Journal of Agricultural Engineering*. 2003; 40(2):8-12.
6. Rathore NS, Paneri KL, Rajesh Meena. Improved Cook stoves for Minimization of Indoor Air Pollution and Energy Conservation. Project Implemented by Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, 1999.
7. Rathore NS, Sudhir Jain. Durable Improved Cooking Stoves For Rural And Tribal Families. *Agricultural Engineering Today*. 2001; 25:47-52.
8. Rathore NS, Kurchania AK, Sudhir Jain, Mathur AN. Durable Improved Cook stoves. All India Co-ordinate Research Project on "Renewable Sources of Energy" Central Institute of Agricultural Engineering, Bhopal. 2003.
9. Rathore NS, Sudhir Jain. Durable and Improved Cooking Stoves for Rural Areas. *Agricultural Engineering Today*. 2005; 29:1-2.
10. Shukla AR. Current Issues and Challenges. *ANTIKA*, A publication on improved chulha. 1988, 6-7.
11. Singh BP. Model Village. *ANTIKA*, a publication on improved chulha. 1993; 4:54.
12. Syedul Islam, Abdul Quasem, Abdur Rahman, Mohammad Nasim, Abdul Baqui, Farah Nazkhan. Efficient Utilization of Conventional Fuel through the Improvement of Traditional Stove. *Agricultural Mechanization in Asia, Africa, and Latin America*. 2008; 39(2):19-22.
13. Vengatesan S, Nagabushana Raju K, Sethumadhavan R. and Vasudevan R. High Efficiency Smokeless Wood Burning Stove, Technical paper presented at Entrepreneurship Development Programme at IIT, Madras. 1991, 43-47.