

AN EMPIRICAL STUDY FOR MAXIMIZING THE EFFICIENCY OF TRADITIONAL WOOD STOVE

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ABSTRACT

A series of experiments were conducted on the 3-stone single mouth type traditional chula to determine the heat utilization efficiency (HUE) varying the hearth diameter, hearth height and stone height. The effect of the variation of the dimension on the HUE was tested statistically. The best dimension combination of hearth height and stone height for each hearth diameter size of chula was determined.

INTRODUCTION

In Bangladesh biomass fuels are the most dominant fuel in meeting total energy consumption of the country. BEPP(1981) reported that 81.7% of total energy consumption came from biomass (BEPP). This high energy consumption from biomass is a cause of deforestation. In 1947, forest area was 35% and in 1990 it was only 9% of the total area (GOB 1990).

Due to the shortage of wood fuels, use of agricultural residue and animal dung as fuel for cooking is increased. Agricultural residue, wood fuel and animal dung contributed 66.3%, 17.5%, and 16.2% respectively (GOB 1985). World Bank (1982) report shows that about 80% of the total energy is consumed for cooking. This high energy consumption for cooking is due to the low efficiency of traditional chula. The efficiency of the traditional chula is from 5%-11% (Makhijani 1977; Siwatiban 1978; Islam, 1980; Khan, 1989 and Alam 1990). But the farmers are not aware of its low efficiency.

Many researchers worked on the wood stoves and developed different types of improved chula of efficiency 20-40% (Islam 1980, Prashad, 1987 and Khan, 1989). Many organizations are trying to disseminate these improved chulas. But their success is very limited (Islam 1980). The reason may be high construction cost,

unavailability of skilled labour, non acceptance by the rural woman for not changing their traditional system, limitation of fuel used in these chulas etc.

Alam (1990) reported that in the villages 70% of the traditional chula are of 3-stone type. As the maximum farmers are using 3-stone type chula it is necessary to work on the improvement of the efficiency of this type of chula. Hossain et.al (1991) reported that dimension parameter has the significant effect on the efficiency. Therefore this work has been undertaken to select best dimension combination of 3-stone type chula for the different sizes. Because different family size need different sizes of chula.

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METHODOLOGY

The experiments were carried out with 3-stone single mouth type traditional chula to determine HUE varying dimensions. The ranges of dimension parameter were taken according to the observed data from the rural area by Rozario and Chowdhury (1991). The dimension varied as : hearth diameter from 180 to 340 mm; hearth height from 300 to 450 mm; and stone height from 50 to 70 mm. Fuel inlet diameter was kept fixed as 100 mm according to the recommendation of Rahaman and Debnath (1992). A 3- stone type chula is shown in Fig.1. The tests were carried out under the split split plot design the layout of which is shown below in tabular form.

Table 1. Experimental design layout

Hearth diameter of chula, D	Stone height of chula, h	Hearth height of chula, H			
		H ₁	H ₂	H ₃	H ₄
D ₁	h ₁				
	h ₂				
	h ₃				
D ₂	h ₁				
	h ₂				
	h ₃				
D ₃	h ₁				
	h ₂				
	h ₃				
D ₄	h ₁				
	h ₂				
	h ₃				
D ₅	h ₁				
	h ₂				
	h ₃				

In the experiment round bottom pan of the diameter 1.3 times higher than the hearth diameter was used. Mango wood of uniform size (610mm x 45mm x 19mm) was used. Fuel feeding was kept uniform throughout the experiment.

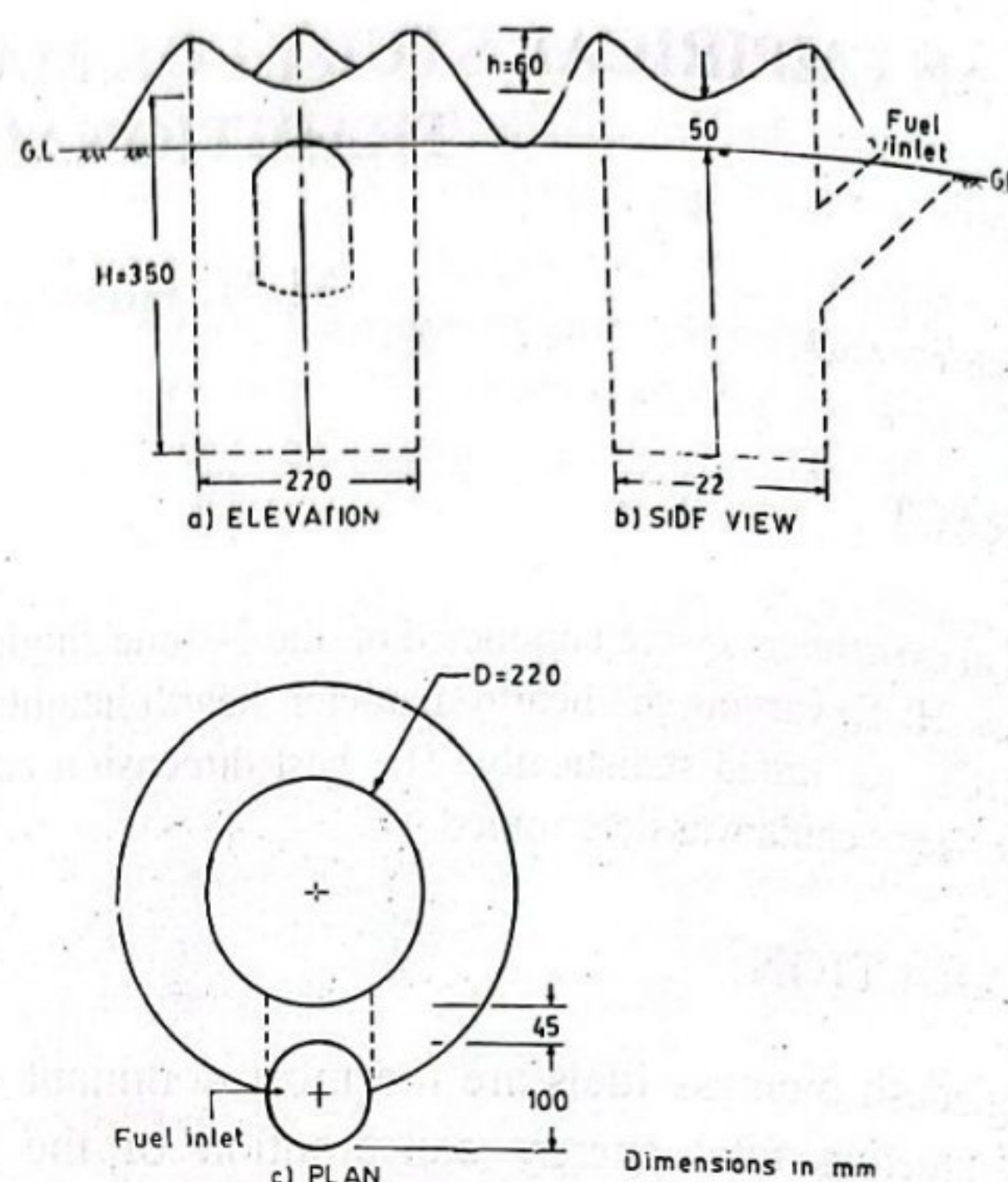


Fig.1 The Plan, Elevation & Side-view of a 3-stone type traditional Chula.

The Heat utilization efficiency was measured by water boiling method using the following formula.

$$\text{HUE} = \frac{\text{Heat output}}{\text{Heat input}} \times 100$$

$$= \frac{(M_w C_{pw} + M_u C_{pu}) (T_2 - T_1) + M_e L}{M_b H_b - M_c H_c} \times 100$$

Where,

HUE = overall heat utilization efficiency of the stove (%)

M_w = amount of water taken (kg)

C_{pw}, C_{pu} = mean specific heat of water and utensil respectively, (kJ/kg°C)

T₁, T₂ = initial and final temperature of water and utensil respectively, (°C)

M_u = mass of utensil (kg)

M_e = amount of water evaporated (kg)

L = latent heat of evaporation (kJ/kg)

M_b = amount of wood burned, (kg)

H_b, H_c = calorific value of the wood and charcoal respectively, (kJ/kg)

M_c = amount of charcoal retained after burning of wood (kg)

Two third of the pan was filled up with water and heated for one hour. Each experiment was replicated thrice.

Statistical analysis were carried out to test effect of dimensions on the efficiency by split split plot design. By using the Duncan's Multiple Range Test (DMRT) statistically alike efficiencies were determined.

RESULTS AND DISCUSSION

The experimental result shows that heat utilization efficiency of the 3-stone one mouth type traditional chula varied from 5.65 to 14.61% with the variation of the dimension parameters.

The effect of hearth diameter, hearth height and stone height on the HUE is represented in the Fig. 2 to Fig.4. Fig.2 shows that HUE increases with the increase of hearth diameter up to 260mm and then started to decrease with further increase of diameter. With the increase of hearth height up to 350mm HUE also increases and then decreases with further increase of H (Fig.3).

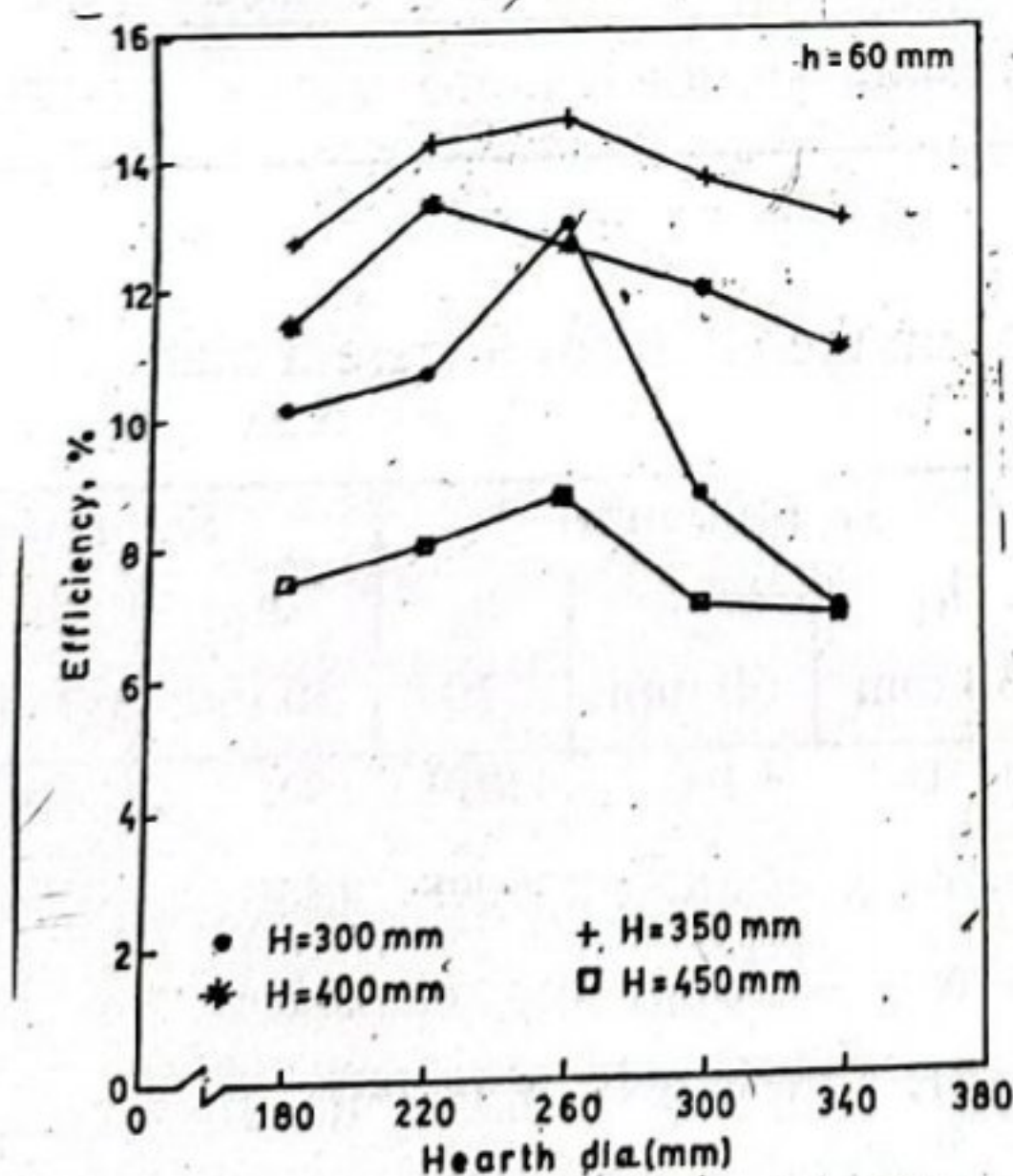


Fig.2 The effect of hearth dia. and hearth height on the HUE of 3 stone type Chula.

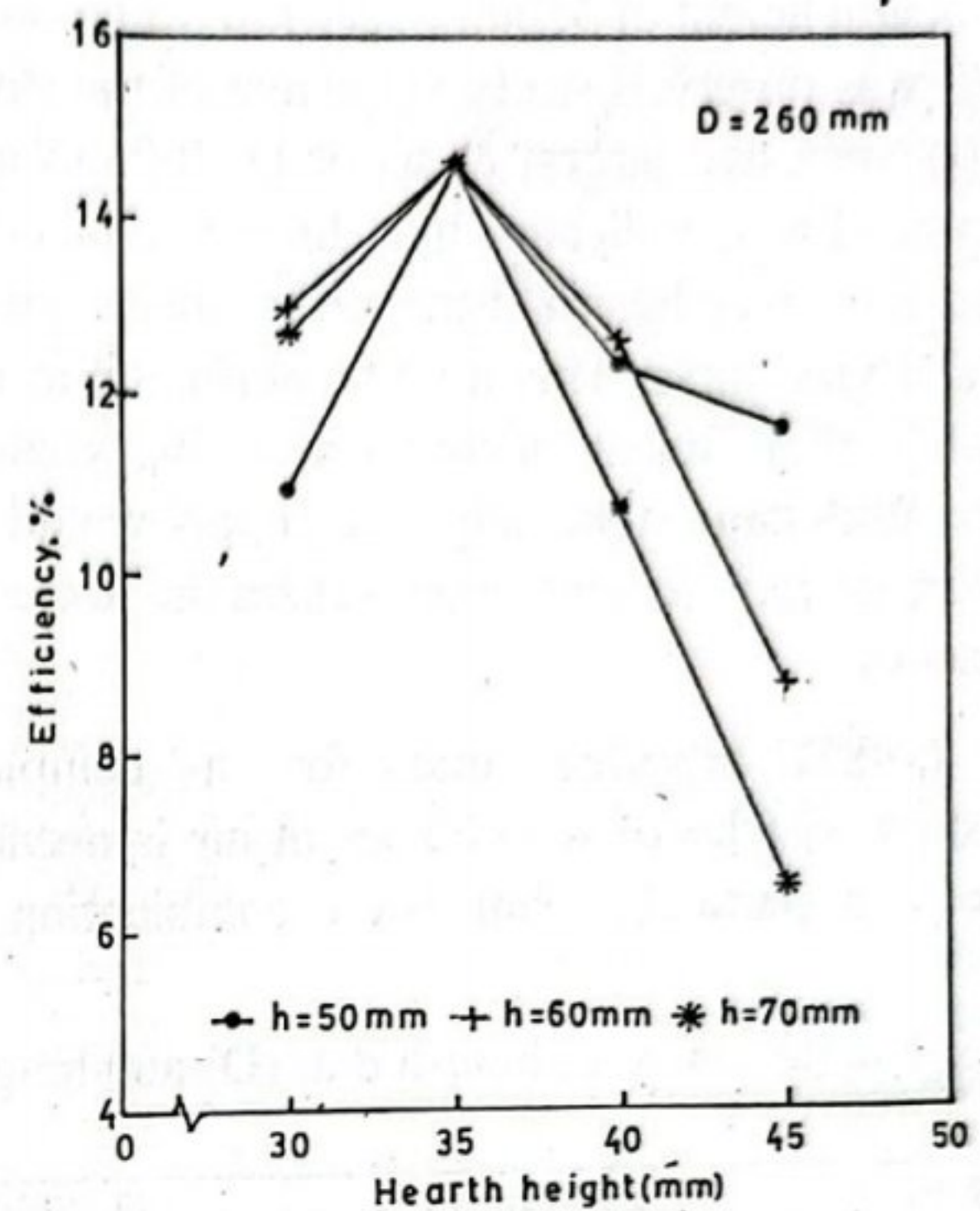


Fig. 3 The effect of hearth height and stone height on the HUE of 3 stone type Chula.

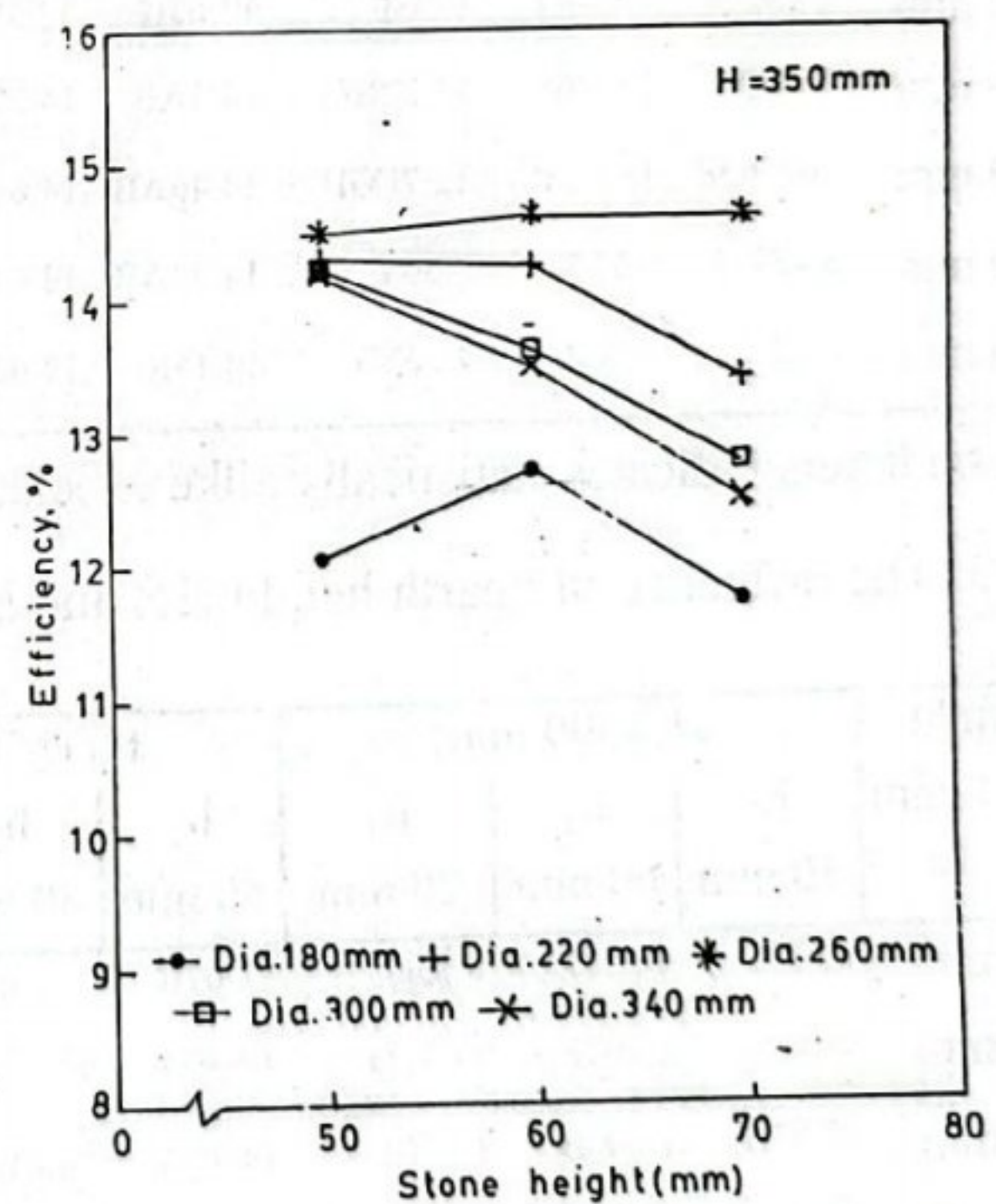


Fig. 4 The effect of stone height and hearth dia. on the HUE of 3 stone type Chula.

For the hearth height of 350mm very low variation of the HUE was observed with the change of the stone height between two largest chula of D=300mm and D=340mm. Fig.4 indicates that higher efficiency occurred for larger hearth diameter at smaller stone height and vice versa. This may be attributed to the availability of sufficient air due to their big volume capacity. With large stone height air supply would be more than the requirement which causes the decrease of efficiency.

Molle (1982) reported that for a complete combustion of 1 kg of wood 5 kg of air is needed. Therefore, a particular dimension combination is

needed to get this sufficient air supply to the chula for complete combustion. Less supply of air creates incomplete combustion, on the other hand more supply of it creates heat loss to the surroundings and causes a decrease of HUE.

The effect of D, H and h on HUE was tested statistically and found highly significant at 1% level. By using Duncan's Multiple Range Test (DMRT) it was found that the best combination of dimension parameter, giving maximum HUE are D=260 mm, H=350 mm and h=60 and 70 mm. The different dimension combination for the statistically alike HUE is shown in Table 2.

Table 2. The influence of hearth dia. (D) and height (H), and stone height (h) on the HUE of traditional chula.

Hearth ht h mm	H ₁ (300 mm)			H ₂ (350 mm)			H ₃ (400 mm)			H ₄ (450 mm)		
	h ₁	h ₂	h ₃	h ₁	h ₂	h ₃	h ₁	h ₂	h ₃	h ₁	h ₂	h ₃
D mm	50 mm	60 mm	70 mm	50 mm	60 mm	70 mm	50 mm	60 mm	70	50 mm	60 mm	70 mm
D ₁ 180 mm	8.33UV	10.13Q	8.76T	12.07IJ	12.7PGH	11.73JKL	10.73P	11.43LMN	9.63R	7.90WX	7.43Y	6.46J
D ₂ 220 mm	9.96QR	10.67P	11.22NO	14.3AB	14.27AB	13.40CD	13.75C	13.32DE	10.30Q	8.80T	8.0VWZ	8.2UVW
D ₃ 260 mm	10.97OP	13.0KP	12.7FGH	14.49AB	14.61A	14.60A	13.40HI	12.64PGH	10.7AP	11.6KLM	8.76T	6.50J
D ₄ 300 mm	8.48TU	8.73T	7.50Y	14.23AB	13.63CD	12.77PG	11.8JKL	11.93JK	10.23Q	10.02QR	7.00Z	5.92N
D ₅ 340 mm	6.08\	6.96Z	7.66XY	14.18R	13.00KY	12.50GH	11.3MNO	10.95OP	10.07Q	9.17S	7.83ZJ	5.65J

Common letters indicates statistically alike efficiency

Table 3. The influence of hearth height (H) and stone height (h) on the HUE for different diameter of chula

Hearth ht h mm	H ₁ (300 mm)			H ₂ (350 mm)			H ₃ (400 mm)			H ₄ (450 mm)		
	h ₁	h ₂	h ₃	h ₁	h ₂	h ₃	h ₁	h ₂	h ₃	h ₁	h ₂	h ₃
D mm	50 mm	60 mm	70 mm	50 mm	60 mm	70 mm	50 mm	60 mm	70	50 mm	60 mm	70 mm
D ₁ 180 mm	4.33R	10.13E	8.76G	12.07B	12.70A	11.73BC	10.73D	11.43C	9.63F	7.90I	7.43J	6.46K
D ₂ 220 mm	9.96P	10.67P	11.22D	14.30A	14.27A	13.40C	13.75B	13.32C	10.30F	8.80G	8.00H	8.20H
D ₃ 260 mm	10.97B	13.00B	12.7BC	14.49A	14.61A	14.60A	13.40C	12.64BC	10.73E	11.60D	8.76F	6.50G
D ₄ 300 mm	8.48P	8.73F	7.50G	14.23A	13.63B	12.77C	11.80D	11.93D	10.23E	10.02E	7.00H	5.92I
D ₅ 340 mm	6.00I	6.96H	7.66G	14.18A	13.00B	12.50C	11.30D	10.95D	10.07E	9.17F	6.83H	5.65I

For each row of different dia. Common letters indicates statistically alike efficiency

Different family will use the different hearth diameter size of chula on the basis of their family members. So by using DMRT for each hearth diameter best combination of hearth height and stone height were determined giving maximum efficiency (Table 3).

Best dimension combination for different hearth diameter sizes is shown in Table 4 as a summary table.

Table 4. Best combinations of the dimension

Hearth diameter (mm)	Hearth height (mm)	Stone height (mm)	Minimum HUE (%)
180	350	60	12.7
220	350	50, 60	14.3
260	350	50, 60, 70	14.61
300	350	50	14.23
340	350	50	14.18

For all sizes of chula best hearth height is 350 mm. For large chula of size 300 & 340 mm stone height is 50mm and for small chula of 180mm diameter stone height is 60mm. But in case of D=260mm for all three stone heights, the HUE is statistically alike and in case of D= 220mm for h= 50 & 60 mm the HUE is statistically alike.

The maximum HUE was observed to be 12.7, 14.3, 14.61, 14.23 & 14.18% for the hearth diameter of 180, 220, 260, 300 and 340mm respectively. Many researchers reported, as mentioned earlier, that HUE of traditional chula ranges from 5-11% i.e. on average 8%. This work shows that proper dimension combination gives HUE from 12.7 to 14.61% (on av. 14%). Although this increase of HUE seems to be small but with this development wood fuel consumption will decrease by $(100-8 \times 100/\text{HUE})\%$. Taking average HUE 14% this decrease becomes 43%. Therefore, without involving any extra cost only by making the chula with proper dimension biomass fuel consumption can be decreased by 43%.

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