COMPARATIVE PERFORMANCE OF LARGE SIZE ANIMAL FEED SOLAR COOKERS

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ABSTRACT

The solar cookers available are suitable for cooking food twice a day and their cost is high, while animal feed is to be boiled only once a day. Therefore, it was felt that a very low-cost, suitable solar cooker should be designed for boiling of animal feed. Considering this, a simple novel solar cooker using locally available materials, such as clay, pearl millet husk,and horse excreta/cow dung and vermiculite-cement has been designed, developed, and tested. It has a width to length ratio of 3:1 to avoid azimuthal sun tracking. The stagnation temperatures were 120°C and 110°C in a solar cooker made of vermiculite-cement and in a solar cooker made of clay etc. respectively. The cooker saves about 22.5 MJ of fuel equivalent per day. There are 300 clear days at Jodhpur. Therefore, it will save 6750 MJ of fuel equivalent per year. The payback periods are in increasing order with respect to fuel: electricity, charcoal, firewood, LPG, and kerosene. The shorter payback period suggests that the use of large size non-tracking solar cookers is economical.

Key words: Animal feed solar cooker, solar energy, energy conservation, large size animal feed solar cooker

1. INTRODUCTION

Cooking accounts for the major share of energy consumption in developing countries. Fifty percent of the total energy consumed in India is for cooking [1]. Most of the cooking energy requirement is met by non-conventional fuels such as firewood, (75%) agricultural waste and cowdung (25%) cakes in rural areas. During the survey of rural arid areas, it was found that huge amount of firewood, cowdung cake and agriculture waste are burnt for boiling of animal feed [2]. In rural areas firewood crisis is far graver than that caused by rise in oil prices. Poor villagers have to forage 8 to 10 hours a day in search of firewood as compared to one to two hours' ten years ago. One third of India's fertilizer consumption can be met if cow dung is not burnt for cooking and instead is used as manure. The cutting of firewood causes deforestation, which leads to desertification. Fortunately, India is blessed with abundant solar radiation [3]. The arid parts of India receive maximum radiation i. e. 7600-8000 MJm^{-2} per annum, followed by semi arid parts, 7200-7600 MJm^{-2} , per annum and least on hilly areas where solar radiation is still appreciable i.e. 6000 MJm^{-2} per annum. Therefore, the animal feed solar cooker seems to be a good substitute for boiling with firewood.

The first solar furnace was fabricated by naturalist George Louis Leclere Buffon (1707-1788). But Nicholas-de-Saussure (1740-1799) was first in the world to use the sun for cooking. Augustin Mouchot, a French physicist, described a solar cooker in his book "La Chaleur Solaire" published in Paris, in 1869. He has also reported in the same book earlier work on solar cooking by English astronomer, Sir John Herschel, in South Africa, between 1834 and 1838. Adams, an army officer, made India's first solar cooker in 1878 and he cooked food in it at Bombay, India [4]. Since then different types of solar cookers have been developed [5-14].

Solar cookers available are suitable for cooking food twice a day and, their cost is high, while animal feed is to be boiled only once a day. Therefore, it was felt that a very low-cost suitable solar cooker should be designed for boiling of animal feed. Considering this, a small, simple novel solar cooker using locally available materials - clay, wheat husk and horse excreta - has been designed, developed and tested [15]. The performance of this cooker was very good, but its capacity was to boil only 2 kg of animal feed per day while in western Rajasthan, farmers have 4 to 5 cattle and generally boil 10 kg of animal feed per day. Therefore, Nahar *et al.* [16] have developed a large size animal feed solar cooker made of clay etc. By observing its success it was felt that more durable solar cooker should be designed by using cement and vermiculite and further improvement should be made to improving its efficiency during the winter by providing a low cost reflector. The performance and testing of this cooker has been compared with the solar cooker made of clay etc. and the one made of vermiculite cement without reflector.

2. DESIGN

Animal feed solar cooker made of clay etc.

A pit of dimensions 1980x760x100 mm^3 has been dug in the ground. The clay, pearl millet husk and animal dung have been mixed in equal proportion with water to form a paste. The bottom of the pit has been filled up to a depth of 50 mm by this paste. It was left to dry in the air for a couple of days. The sides of solar cooker have been made by the same material. Pearl millet husk insulation (150 mm) has been provided at the bottom, and 24 standard wire gauge (swg) galvanised steel absorber has been put over the insulation. The absorber has been painted with blackboard paint. Two glass covers (4mm thick) on a removable angle iron and wooden frame have been provided over it. A technician's help has been taken for fixing the glass and acrylic sheets on a suitable angle iron and wooden frame. Three aluminium utensils can be kept inside the cooking chamber for boiling animal feed. The body of the cooker has been fabricated by an unskilled village lady.

Animal feed solar cooker made of vermiculite cement

The body of cooker is made of cement and exfoliated vermiculite in the ratio of 1:5. The outer and inner dimensions of the cooker are 1925x750x200 mm^3 and 1750x550x100 mm^3 respectively. The 24 swg galvanised steel sheet is put up in the base of the cooker and painted with black board paint. Top of the cooker is provided with two plane glass cover (4 mm thick). One reflector of metalised polyester film is provided having a width to length ratio of 3:1 to avoid azimuthal sun tracking. Three cooking utensils made of 22 swg aluminium and each having dimensions 550x450x75 mm^3 are provided for the boiling of animal feed.

Actual installation of the above animal feed solar cookers is shown in Fig.1.

3. PERFORMANCE

The cooker was tested by measuring stagnation plate temperature and it was observed as high as 120°C as compared to 110°C observed in solar cooker made of clay. Different types of animal feed e.g. crushed barley (local name "Jau Ghat"); clusterbean split, cluster bean powder, gram powder, etc., have been tried. Three aluminium cooking utensils each having 3.0 kg of crushed barley/cluster bean with 8.0 litres of water were put inside the cooking chamber at 9.00 AM and it was cooked perfectly by 2.00 PM. These animal feeds are commonly used in the Thar desert, western Rajasthan. The animal feed is generally given to the animals between 4.00 PM to 8.00 PM.

The efficiency of an animal feed solar cooker has been obtained by the following relation.

$$\eta = \frac{(m_1 + m_2\, c_p)\,(t_2 - t_1)}{A \int^{\theta} H\, d\theta} \qquad (1)$$

Where,

A	Absorber area, m^2
c_p	Specific heat of cooking utensils, K Cal.Kg^{-1} °C
H	Solar radiation, KCal m^{-2} hr^{-1}
m_1	Mass of water in cooking utensils, kg
m_2	Mass of cooking utensils, kg
t_1	Initial temperature of water in the utensils, °C
t_2	Final temperature of water in the utensils, °C
θ	Period of test, hr
η	Efficiency of solar cooker

The efficiency of solar cooker for animal feed from the eq. 1 has been found to be 26.4%.

Fig.1 Animal feed solar cookers made of vermiculite cement and clay etc.

4. ENERGY CONSERVATION AND PAYBACK PERIODS

The solar cooker is suitable for boiling 10 kg of animal feed per day. The cooker saves about 22.5 MJ of fuel equivalent per day. There are 300 clear days at Jodhpur. Therefore, it will save 6750 MJ of fuel equivalent per year.

The payback periods have been computed by considering equivalent savings in alternate fuels viz. firewood, coal, kerosene, liquid petroleum gas (LPG) and electricity. The payback periods have been calculated by considering the compound interest, maintenance cost and inflation in fuel prices and maintenance cost per year.

The payback periods have been computed by following relation [17,18].

$$N = \frac{\log [(E-M)/ (a-b)] - \log [(E-M)/ (a-b) - C]}{\log [(1 + a)/ (1 + b)]} \qquad (2)$$

Where,

a	Compound interest rate per annum
b	Inflation rate in energy and maintenance per annum
C	Cost of the cooker, Rs.
E	Energy savings per year, Rs
M	Maintenance cost per annum, Rs.
N	Payback periods, yr

The economic evaluation and payback periods have been computed by considering the following:

Interest rate a = 10%

Maintenance M = 5%

Inflation rate b = 5%.

The cost of a solar cooker for animal feed is only Rs.3500.00 (1.0 US $ = Rs. 46.00). The exact payback periods have been computed from eq. 2 and shown in Table 2. The payback period is least, i.e. 0.67 years (less than nine months), with respect to firewood and maximum i.e. 4.22 years with respect to kerosene because it is subsidised by the government. The payback periods are in increasing order with respect to fuel: electricity, charcoal, firewood, LPG, and kerosene. The shorter payback periods suggest that the use of large size non-tracking solar cooker is economical.

5. CONCLUSION

Performance of a solar cooker for animal feed made of cement-vermiculite is very good. It is durable, the efficiency of the solar cooker is 26.4%, and its capacity is 10 kg per day. The cost of cooker made of vermiculite-cement is only Rs.3500.00. That can be recovered within 0.67 to 4.22 years depending upon the fuel it replaces. The payback periods are in increasing order with respect to fuels firewood, coal, electricity, LPG and kerosene. The very short payback periods suggest that the use of solar cooker for boiling of animal feed is very economical. The use of a solar cooker will save a lot of conventional fuels, viz. firewood, cowdung cakes and agricultural waste, which are at present burnt for boiling of animal feed.

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