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Techno-economic evaluation of masonry type animal feed solar cooker in rural areas of an Indian state Rajasthan

N.L. Panwar [a,*], Surendra Kothari [b], S.C. Kaushik [a]

[a] Centre for Energy Studies, Indian Institute of Technology, Hauz Khas, Delhi 110016, India
[b] Department of Renewable Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur 313001, Rajasthan, India

HIGHLIGHTS

- Considerable amount of energy can be saved on annual basis.
- This also helps to save the time and money of rural farmer.
- AFSC helps to reduce the greenhouse gas.

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ABSTRACT

Utilisation of animal draft power in agricultural operation and milk production is highly dependent on the feed and fodder. Properly cooked feed is digestive in nature and enhance milk production. Solar energy is promising option for slow cooking. Keeping this in view a masonry animal feed solar cooker (AFSC) was developed. It helps in the number of ways to improve the living standard of rural farmers and also reduce the CO_2 emission by replacing conventional fossil fuel. The AFSC can replace the 100 per cent biomass and save about 424.80 kg of CO_2 on annual basis and save about 24 INR per day. Usually women prepare animal feed in rural areas, hence cooking with AFSC save time and this time can be spear to take care of her family or in agricultural operation. This paper presents fuel replacement and reduction of carbon dioxide on annual basis and economic evaluation of AFSC.

1. Introduction

In developing countries, cooking energy requirement is meeting out through firewood, which resulted in deforestation, fuelwood shortage, increased costs of fuels and adverse environmental effects. Many researchers work out the environmental effects of fossil fuels, sustainable energy consumption, energy efficiency, conservation, and renewable energy sources in rural areas of developing countries (Boehmer-Christiansen, 2000; Brunicki, 2002; Elliott, 2004; Shove, 2004; Tingem and Rivington, 2009; Panwar et al., 2009,2011; Huttunen, 2009). Cooking with conventional energy sources is environmentally inefficient because they released CO_2 while burning, which adversely affects natural carbon (C) cycles and irreversible accumulation in the atmosphere. Therefore, transitions towards less CO_2 intensive energy systems are urgently needed in order to mitigate climate change (Budzianowski, 2012). Cooking with solar energy is a promising option to conserve the natural resources and considerable time can also save. The saved time can be utilised to perform extra agricultural activity. In Rajasthan, plenty of solar radiations are available and almost 300-days clear sky observed throughout the state.

Rajasthan having 342,239 sq km of the geographical area, which is 10.4% of the country's geographical area. Versatile agricultural practices opted into the state, and animal husbandry, and livestocks are contributing a lot in state economy, especially of rural economy. In the western part of the Rajasthan state that falls under arid and semi-arid regions, animal husbandry and livestock considered as a major economic activity. It also played major role in generating employment and reducing poverty in rural areas. Significantly, livestock provides a large portion of draft power for agriculture (Binswanger and Quizon, 1988). The dairy cattle population is more compared to other cattle into the state, and it provided a range of benefits, including nutritious milk for home consumption, extra milk for sale and manure to help maintain soil fertility.

Such benefit is possible only when properly, digestive and nutritive feed is given to milking animals. The common ingredient of animal feed is present in Table 1. It was found that in rural areas within the state using firewood, cow dung cake and agricultural

* Corresponding author. Tel.: +91 294 2471068; fax: +91 294 2471056.
E-mail address: nlpanwar@rediffmail.com (N.L. Panwar).

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Nomenclature

C_0	capital cost of AFSC (Rs.)
α	repair and maintenance fraction of capital cost (%)
d	discount rate (%)
t	life span of AFSC (years)
n	number of feed can be cooked in a year
p	money value of the fuel saved per cooked (Rs.)
FC	fuel combusted per year
HHV_{fc}	higher heating value of fuel (MJ/kg)
CCC_{fc}	carbon content coefficient of fuel (kg C/MJ)
OF_{fc}	oxidation factor of fuel
MW_{CO_2}	molecular weight of carbon dioxide
MW_C	molecular weight of carbon

waste burnt for the boiling of animal feed (Nahar et al., 1996a,b; Panwar et al., 2011). This traditional practice is not ensuring the proper cooking/boiling because animal feed required slow cooking. Solar cooking is the most suitable device to prepare the feed as it is offered in evening time only (Panwar et al. 2010, 2012). There is a very little study available on animal feed cooker and its cost economics. Keeping this in view an attempt has been made to evaluate the techno economics of animal feed solar cooker (AFSC) particularly for Indian state Rajasthan.

2. Methodology

The survey was conducted to know how the feed preparation practices in rural areas. It was found that people are using traditional cookstove which has low thermal efficiency about 10% to cook the feed. Usually, farmer feeding such prepared feed to milking animals for higher milk production. They prepared 10 kg of feed for three animals and six kilograms of firewood is required for preparing the same on the traditional cook stove, and it is fully replaced by AFSC, and its fuel replacement is compared with other conventional fuels such as diesel, kerosene and liquefied petroleum gas (LPG). The construction cost of an AFSC is presented in Table 2. The technical specification of animal feed cooker is presented in Table 3.

The AFSC was developed by Department of Renewable Energy Engineering, College of Technology and Engineering, Udaipur (27° 42′ N, 75° 33 E) under All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro Based Industries as illustrated in Fig. 1.

The economic assessment of such a cooker is adopted from Kandpal and Mathur (1986) and Kandpal and Garg (2003). The net present value, minimum number of feed to be prepared for break even number and the payback period has been taken into account for economic assessment.

The following assumptions were made for economic assessment of AFSC

a. Discount rate (d) 10%
b. Repair and maintenance (α) 5% of capital cost of cooker
c. Number of meals in a year (n) 300
d. Life span (t) 5 year

The net present worth can be calculated as follows:

$$NPV = \left(\frac{np - C_0\alpha}{d}\right)\left[\frac{(1+d)^t - 1}{(1+d)^t}\right]$$

The minimum number of feed to be cooked by AFSC so as to be economic, can be calculated as follows:

$$n_m = \frac{C_0}{p}\left[\alpha + \frac{d(1+d)^t}{(1+d)^t - 1}\right]$$

The payback period (PP) can be calculated as follows:

$$PP = \frac{C_0}{(np - \alpha C_0)}$$

Annual CO_2 emission from the different fuels was estimated with the help of fuel analysis approach as proposed by North

Table 1
Ingredients commonly used in animal feeds.

Maize, sorghum, bajra (millet)	Soybean meal	Horse gram chuni
Rice bran, wheat bran	Groundnut (Peanut) meal	Black gram chuni
Rice bran extractions	Rapseed meal, Sesame meal	Pigeon Pea Chuni
Tapioca	Sunflower meal, cotton seed meal	
Molasses	Copra meal, Guar meal	Di calcium phosphate (DCP)
	Meat meal, meat cum-bone meal	Bone origin
	Fish meal	Mineral based

Table 2
Cost of an animal feed cooker (Rs. 50 US^{-1} as on March 2012).

S. No.	Material and on as on/misc. charge	Cost (Rs.)
1.	Bricks (100 nos.)	350
2.	Sand (300 kg)	200
3.	Cement (2 bags)	500
4.	Glass	400
5.	Reflector	500
6.	Wooden frame	900
7.	Colour, paint etc.	250
8.	Vessel	550
9.	Rubber got and handles etc.	200
10.	Aluminium tray	650
11.	Labour charges	500
Total		**5000**

Table 3
Technical specification of a solar cooker animal feed.

Dimensions of cooker	
Hot box	650 mm × 650 mm × 170 mm
Overall dimension	920 mm × 920 mm × 270 mm
Dimensions reflector	
Reflector mirror	800 mm × 800 mm
Overall dimension	900 mm × 900 mm
Material for outer casing of cooker	Bricks and cement
Emissivity of absorber plate	0.90
Material of absorber plate	Aluminium
Thickness of glass covers	
Inner glass cover	3 mm
Outer glass cover	3 mm
Spacing between glass cover	15 mm
Emissivity of glass covers	0.88
Specific heat of water	4200 J kg^{-1} °C^{-1}