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ALCOHOL DISTILLATION BY SOLAR ENERGY

(this work was a direct outcome of small scale solar still developed in 1984)

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ABSTRACT

Ethanol (alcohol) from a multi-purpose crop like sweet sorghum is an attractive alternative to kerosene for cooking and lighting in developing countries. This paper reports the successful use of solar energy for distillation of alcohol. A flat plate solar collector system with a collector area of 38 m^2 was coupled to a pilot-scale distillation plant with a capacity of 1.8 l/h of 95% v/v ethanol. Data collected on this system over 4000 hours of operation shows that the average daily insolation was 6 kWh/m^2.day. The average daily solar collection was 1.68 kWh/m^2.day and the collection efficiency was 28%. The average specific ethanol production rate was 0.63 l/ m^2.day and the yearly solar load was 65%. A correlation was developed between the specific alcohol production rate and the solar load for different insolation levels. The economics of using flat plate systems for alcohol production was not favorable at the prevailing collector prices. However, low cost solar systems like solar ponds could be a viable alternative.

KEYWORDS

Solar distillation; Alcohol production; Sweet sorghum; Pilot plant; Solar ponds.

INTRODUCTION

Ethanol (ethyl alcohol) as a liquid fuel for cooking and lighting is an attractive alternative to kerosene in developing countries. Besides being a biomass-derived fuel and hence renewable, ethanol can also be used in new types of cooking stoves and lanterns (Rajvanshi, 1989). Ethanol has been traditionally produced from sugarcane, cereal grain etc. However with the debate on food vs. fuel, it is extremely attractive to use sweet sorghum, a multi purpose crop. It can provide grain from its earheads for human consumption and ethanol from its stalk from the same piece of land (Rajvanshi, 1989).

Distillation takes up about 70-85% of total energy consumed in ethanol production (Ladisch, 1979). Traditional fuels used have been bagasse, charcoal and wood. Bagasse is an excellent raw material for paper and hence it is a waste to use it as fuel. Solar distillation of ethanol does provide a solution for energy conservation in ethanol production. This paper presents the data generated for a study of pilot solar distillation plant to produce ethanol (hereafter referred to as alcohol) using sweet sorghum as the raw material.

EXPERIMENTAL METHODS

Raw materials

Sweet sorghum [Sorghum bicolor (L) Moench] cultivar NSS-1 (bred at NARI) was used as raw material. This variety produces between 60-80 tons/ha-year of stripped stalks (two crops per year) (Nimbkar, 1987). The juice was fermented using strains of Saccharomyces cerevisiae (NCIM No. 3319). The fermentation efficiency obtained was 80-90%. The details of juice extraction, fermentation etc. are given elsewhere (Rajvanshi, 1988).

Pilot Plant characteristics

The pilot plant has two main components comprising of ***solar energy system*** and ***alcohol distillation plant.***

Solar Energy System. Details of this system are given in Table 1.

TABLE 1 Solar Energy System Details

1. Type of system	Forced circulation closed loop
2. No. of flat plate solar collectors	19 (Area ~ 38 m^2)
3. Solar collector	Aluminum fins with copper tube risers mechanically bonded and coated with selective Ni Coating $\alpha/\varepsilon = 9$; $\alpha_s = 0.9$
4. Flow rate through each collector	2 lpm (litres per minute)
5. Arrangement of collectors	2 banks in series – parallel combination
6. Angle of inclination	25 degrees to horizontal
7. Hot water storage capacity	2150 liters

Distillation Plant. The distillation plant was designed to produce 1.8 l/h of 95% v/v ethanol. Since it was to be run by solely heated water, the system was designed to run at 70^0C hot water storage temperature and partial vacuum. The plant essentially consists of a packed-bed distillation column made of G.I. pipe. It is 5.5 m tall and 0.15 m I.D. and packed with Raschig rings of 1.25 cm diameter. The reboiler and condenser are shell and tube heat exchangers with heat transfer areas of 0.236 m^2 and 1.29 m^2 respectively. The feed preheater is a concentric-tube heat exchanger made of copper. Figure 1 shows the schematic of the distillation plant and figure 2 shows the photographs.

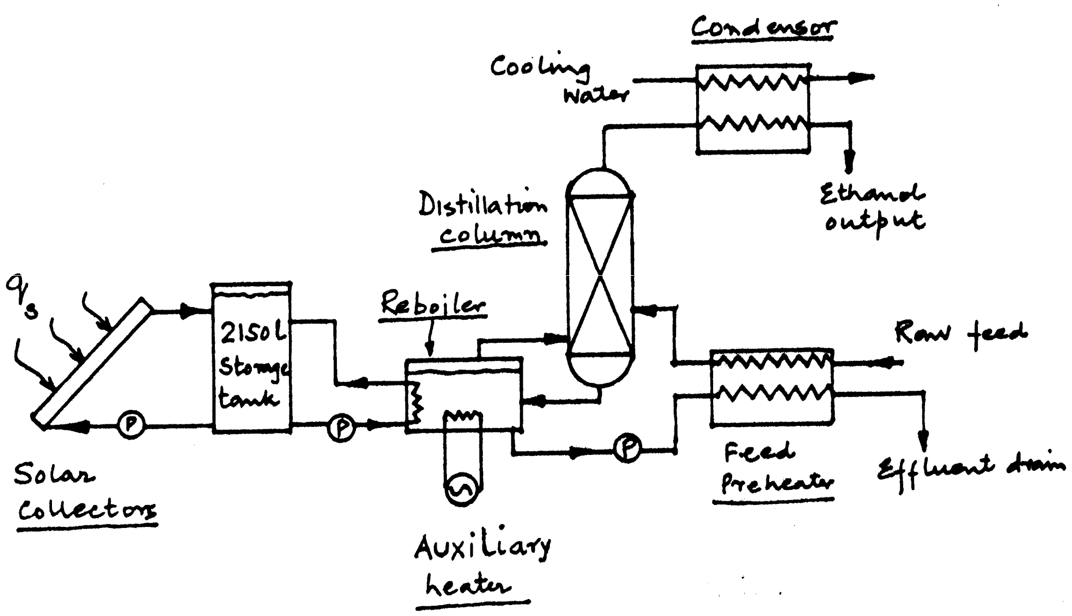

Fig. 1 Schematic of the Solar Distillation plant

Fig. 2. Solar distillation plant

RESULTS AND DISCUSSIONS

The solar distillation plant has logged over 4000 hours of operation. The results are summarized in Table 2.

TABLE 2 Results of Solar Distillation Plant

Particulars	Average	Range
Solar system		
1. Insolation, kWh/m^2.day	6.00	4-8
2. Daily solar collection, kWh/m^2.day	1.68	0.6-2.5
3. Solar collector efficiency, %	28	25-35
4. Solar energy collection time, h/day	--	5-6
5. Storage hot water temperature, ^0C	--	55-85
6. Solar load (yearly average), %	65	---
Distillation Plant		
1. Ethanol content of feed, % v/v	6	5-8
2. Feed flow-rate, l/h	25	13-30
3. Ethanol Recovery, %	85	75-90
4. Product flow-rate, l/h of 95% v/v	1.25	1.0-1.5
5. Reboiler Temperature, ^0C	--	42-62
6. Specific ethanol production rate, $1/m^2$ (collector area). day	0.63	0.16-0.95
7. Ethanol yield from sweet sorghum, l/ha. year	--	3000-4000

Figure 3 shows the histograms of alcohol output and the daily heat collection by the solar collectors for different months. During the month of July (being a rainy month), the solar load was zero and so the plant was run on an auxiliary electric heater.

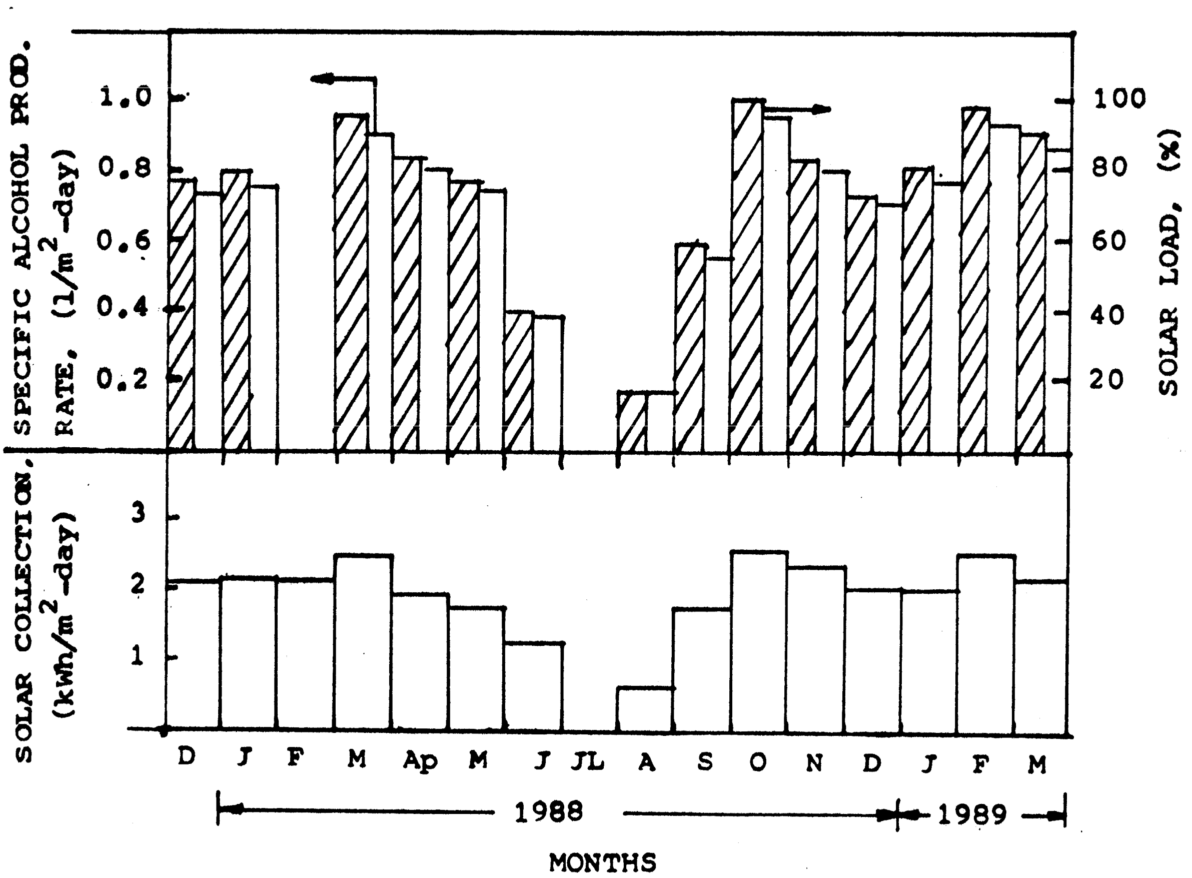

Fig. 3. Histograms of alcohol production rate and solar collection

It is also instructive to look at the relationship between specific alcohol production rate and solar load for various insolation levels. Figure 4 shows such a relationship. This relationship can help the designer to initially estimate the size of collector field required for a given alcohol production rate. It should be pointed out that this figure is valid for the system described in the present study. With changes in alcohol technology or the solar collectors, a different relationship, though with similar methodology, can be developed.

Economic analysis of the system reveals that solar distillation of ethanol using flat plate collectors is not an economically viable proposition (Rajvanshi, 1989 DNES). The collector costs are 80% of the total plant cost. However, this study has also shown that it is feasible to run the plant at reboiler temperatures as low as 42^0C. Thus low temperature solar collector systems like solar ponds could become a viable alternative. Since the present solar pond prices are only about $1/10^{th}$ that of flat plate solar collectors (Srinivasan, 1988), solar distillation of ethanol using solar ponds can become economical.

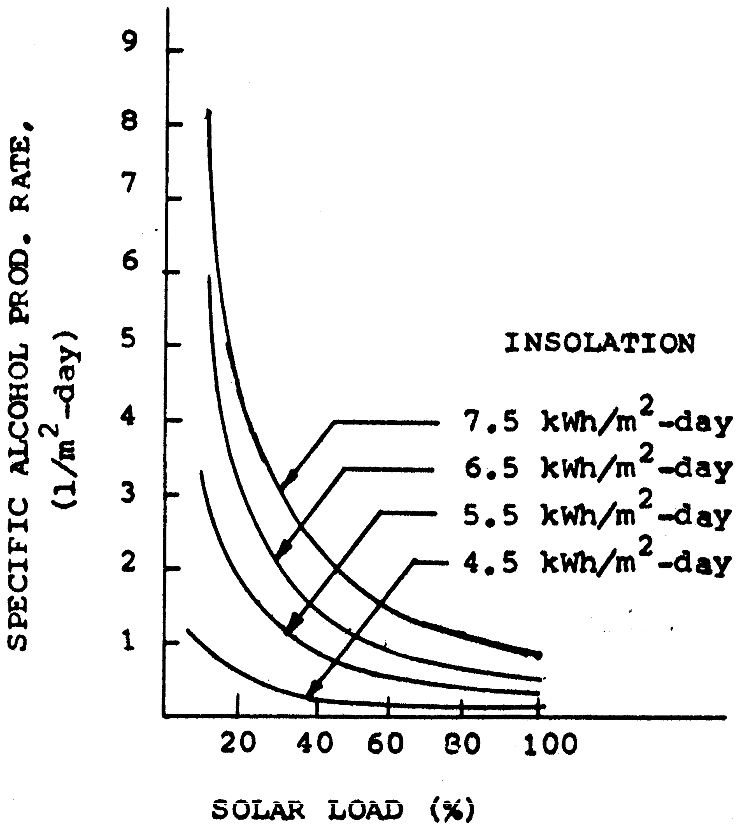

Fig. 4. Correlation of alcohol production rate with solar load

CONCLUSIONS

Based on this study, the following conclusions can be drawn :

1. The concept of solar distillation of alcohol has been successfully tested on a pilot scale and found to be technically viable.

2. The specific ethanol production rate varies from 0.16 to 0.95 l/m (collector area).day. The yearly average is 0.63 l/m.day at a corresponding solar load of 65%.

3. Solar distillation of alcohol using flat plate collectors is economically not viable. However, use of solar ponds can make the scheme economically attractive.

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