Distillation of Ethyl Alcohol from Fermented Sweet Sorghum Solution by Solar Energy

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*(This report was submitted to DNCES, New Delhi in **June 1984**. Since then lot of work both on sweet sorghum (http://www.nariphaltan.org/sorghum.pdf); solar distillation http://www.nariphaltan.org/ethanoldist.pdf) and low concentration(50% w/w) ethanol stoves (www.nariphaltan.org/ethstove.pdf) has been done at our Institute.* ***This report to our knowledge was the first attempt anywhere in developing technology for solar distillation of ethanol using sweet sorghum.***

ABSTRACT

The proof of concept for solar distillation of ethanol from sweet sorghum juice has been established. Heat and mass transfer data for a laboratory single effect solar still has been generated. It is found that it will require 8 stills to distill 70% ethanol/water mixture starting from 7% ethanol in fermented solution.

Various vacuum distillation units have been tested and analyzed. It is possible to distill 40-60% ethanol by solar energy using these units. An average day (5 kWhr/m^2-day insolation) yields 1.4 kg/m^2-day of 40% ethanol. The amount of ethanol distilled is inversely proportional to its percentage and directly proportional to the solar radiation. Consequently linear regression equations for these relationships have been established.

A simple method of predicting the percentage of ethanol distilled by knowing the solution temperature has also been developed. The efficiency of the distillation unit for distilling 40% ethanol is about 13% and compares extremely favorably as compared to 2-3% obtained from existing fossil fuel fired ethanol distillation plants.

The energy output/input analysis for production of ethanol for sweet sorghum has been done (Table 1 and 2). This ratio is 3.94 and thus shows that ethanol production from sweet sorghum has a highly positive energy balance. On an average one can produce about 2000 liters/ha of ethanol per year, from the present sorghum lines bred at the Institute.

Table 1. Energy input in growing and crushing sweet sorghum (Plot size 2800 m^2)

Sr. No.	Operation	Device	Number & system	Time (hrs.)	Energy unit	Total Energy MJ	Ref.
	AGRICULTURE						
1.	Land preparation	Tractor	13 liters Diesel	3.15	37.7 MJ/lit.	490	22
	Tractor production energy					110	22
2.	Furrow opening	Muscle	1 man	7	1.05 MJ/hr	7.35	26
		Power	2 bullocks	7	2.66 MJ/hr	18.62	26
3.	Small row op.	Agricart	1 man + 2 bullocks	7 + 7	-do-	+ 7.35 18.62	26
4.	Sowing	Muscle	2 women	7	0.84 MJ/hr	11.76	26
5.	Weeding	Muscle	15 women	7	0.84 MJ/hr	88.2	22
6.	Irrigation	Ele. Motor 10 HP	1.2 million liters of water	10	27 MJ/hr	270	22
	Prod. of Elec. for motor running				11.4 MJ/kWh	850	22
	FERTILIZERS						
7.	Carbofuran		5 kg		454 MJ/kg	2270	27
	Urea		100 kg		35 MJ/kg	3500	27
	Superphosphate	18% P_2O_5	130 kg		2.48 MJ/kg	323	27
	Muriate potash	60% K_2O	40 kg		4.8 MJ/kg	192	27
8.	**Pesticides**						
	Thiodan		125 ml		100 MJ/kg	12.5	27
	Metasystox		120 ml		100 MJ/kg	12.0	27
9.	Application of fertilizer + insecticide	Muscle Power	13 women 2 men	7 3.5	0.84 MJ/hr 1.05 MJ/hr	76.44 7.35	26 26
10.	**Harvesting**	Muscle	14 women	7	0.84 MJ/hr	82.32	26
	CRUSHING						
11.	Crushing	Elec. crusher	3 H.P.	34.6		278.7	22
12.	Elec. Prod.				11.4 MJ/kWh	882.5	22
13.	Labour for crushing	Muscle	1 man	12.2	105 MJ/hr	12.82	26
	TOTAL					9521.6 MJ	

Table 2. Energy output from sweet sorghum (RM line)

(Plot size 2800 m^2)

Material	Quantity	Unit Energy	Total Energy MJ	% of Total	Ref.
Grain	700 kg	14.5 MJ/kg	10150	27	27
Alcohol	290 lit.	22.3 MJ/liter [a, b, c]	6467	17.3	22
Bagasse	1494 kg	14 MJ/kg at 20% M.C.	20916	55.7	27
		TOTAL	37533	100	

a) This is the maximum possible alcohol obtainable from RM lines with 10-14% fermentable sugars and 50% conversion rate for alcohol.

b) Actual bagasse is 1868 kg. at 50% moisture content (M.C.).

c) Besides being a high energy output quantity, sweet sorghum bagasse is an excellent fodder for animals. Thus the quality of energy is far superior to simply burning.

The use of 40-60% ethanol as an excellent cooking fuel has been established. A wickless stove has been designed, fabricated and tested to use this percentage and the efficiency of this stove has been found to be between 30-35%. Since 1984 we have developed extremely efficient stoves and lanterns to run on 50 %(w /w) ethanol/water mixtures.

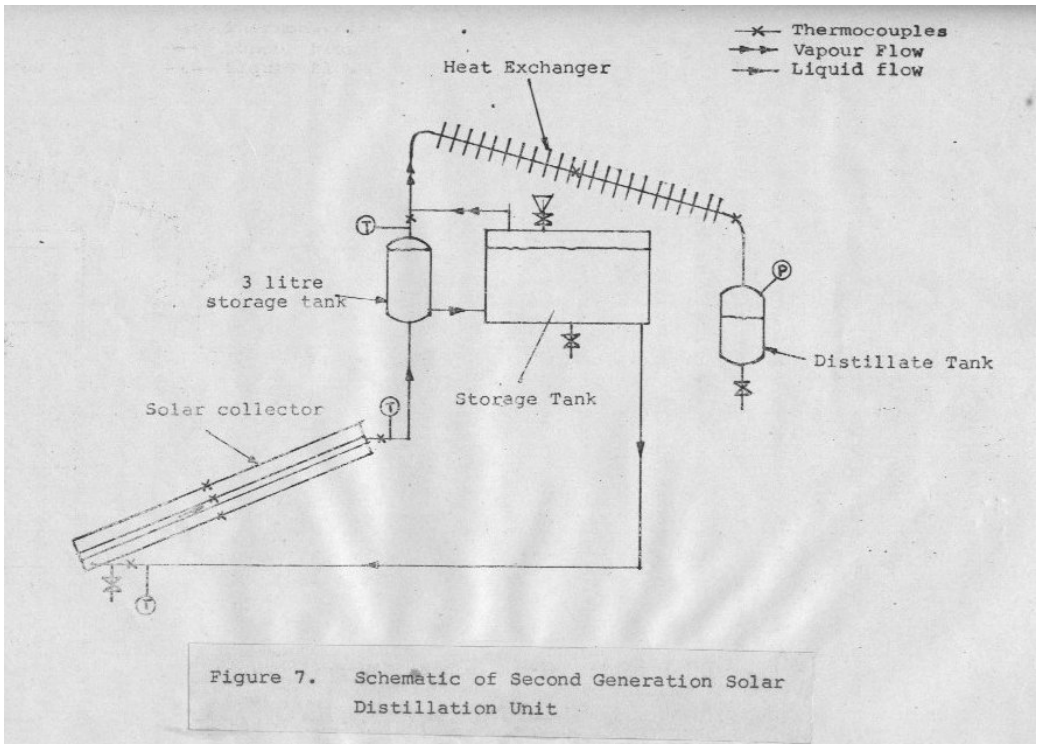

Figure 7. Schematic of Second Generation Solar Distillation Unit