Ethanol From Sweet Sorghum

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ABSTRACT

This paper details the production of ethanol (ethyl alcohol) from sweet sorghum and its usefulness as a cooking and lighting fuel for rural India, where about 80-90% of total fuel used is for this purpose. There is a growing trend to use liquid fuels like kerosene for these purposes and ethanol seems to be an excellent replacement for it. Also, the production of ethanol from a crop like sweet sorghum does not take land away from food production, since it is a multipurpose crop providing food, fuel and fodder simultaneously. Complete development of indigenous technology of sweet sorghum at NARI which includes breeding, fermentation of its juice, solar distillation of ethanol and finally its use as a cooking and lighting fuel in new and improved stoves and lanterns respectively is outlined. The effect of this technology in giving a boost to energy and economic development of India is also explored.

I. INTRODUCTION

Cooking and lighting energy in rural India constitutes about 57% of the total energy consumed in the country. There is already a major cooking energy crisis in the rural areas with reports suggesting that women in some parts of the country having to walk as much as 5-10 km. everyday to collect firewood. At the same time, sudden and frequent shortages of kerosene in rural areas darken the houses of thousands of people.

The major fuel used for cooking in rural areas is wood. However, studies have shown that an increase in the income of rural population results in a perceptible shift towards liquid fuels like kerosene. This is because of the convenience of liquid fuels over wood. India consumes 6 million tonnes of kerosene every year and spends Rs.13000 million per year in foreign exchange for importing a part of it.

Neither solid nor gaseous fuels can compare with liquid fuels in terms of ease of transportability, high energy density, cleanliness and convenience of use.

Besides, kerosene being the only liquid fuel used for lighting, is also indispensable. Thus it is safe to assume that the use of liquid fuels for cooking and lighting will **increase rather than decrease**. Also with a shortfall in India of about 10,000 MW of electricity for 7th National Plan, the use of kerosene lanterns in rural areas will increase rather than decrease. There is therefore an urgent need to find a renewable replacement for kerosene (a fossil fuel).

One such alternative fuel is ethyl alcohol (ethanol). In the rest of this paper it will be referred to as alcohol. Studies at NARI have shown that it can be easily used for cooking and lighting in new stoves and lamps. At the same time, it can be produced from a locally available renewable source like biomass.

Traditionally, alcohol has been produced mainly from sugarcane and molasses. However, with the debate on food vs fuel from the same piece of land going on, there is a need to use a multipurpose biomass source for alcohol production. One such source is sweet sorghum (**Sorghum bicolor (L.) Moench**). It provides grain from its earhead, sugar and hence alcohol from its stalk and the bagasse is an excellent fodder for animals. Thus it provides food, fuel and fodder. No other crop yields all these things together.

Besides being a multipurpose crop, sweet sorghum has a great tolerance to a wide range of climatic and soil conditions. It is a short duration crop, maturing in 100 to 140 days (as compared to 12 to 18 months for sugarcane). Besides, it is cheaper to grow than sugarcane and requires less water.

This report therefore details the technology development at NARI of alcohol production from sweet sorghum and its use as a cooking and lighting fuel for rural India.

II. COMPONENTS OF NARI PROGRAM

The main components of the project are :

1. Breeding of high yielding sweet sorghum varieties for alcohol production.
2. Fermentation studies.

3. Distillation of alcohol using solar energy.
4. Development of stoves and lanterns running on alcohol.

2.1 Breeding of Sweet Sorghum:

Breeding work at NARI since 1970 has resulted in sweet sorghum varieties which yield in one year (two seasons) about 2-4 tonnes of excellent quality grain, 2000-4000 litres of 95% (v/v) alcohol and bagasse which can supply all the yearly fodder requirements for 3-5 cattle, from one hectare. Figure 1 shows the material flow sheet from 1 ha of sweet sorghum. Figure 2 shows the standing sweet sorghum crop.

The main component of the breeding work at NARI was crossing the American varieties (used for syrup making) with the local grain yielding ones. Thus about 20 U.S. sweet sorghum varieties were obtained (as part of a USDA-funded project at NARI) and crosses made with local varieties. Initially the project was for development of sweet sorghum for sugar production and as an offseason substitute for sugarcane. However, with our emphasis from 1981 onwards on renewable sources of energy, the focus has been shifted to developing dual purpose varieties and hybrids for alcohol and grain.

Fig. 2: Standing Sweet Sorghum Crop

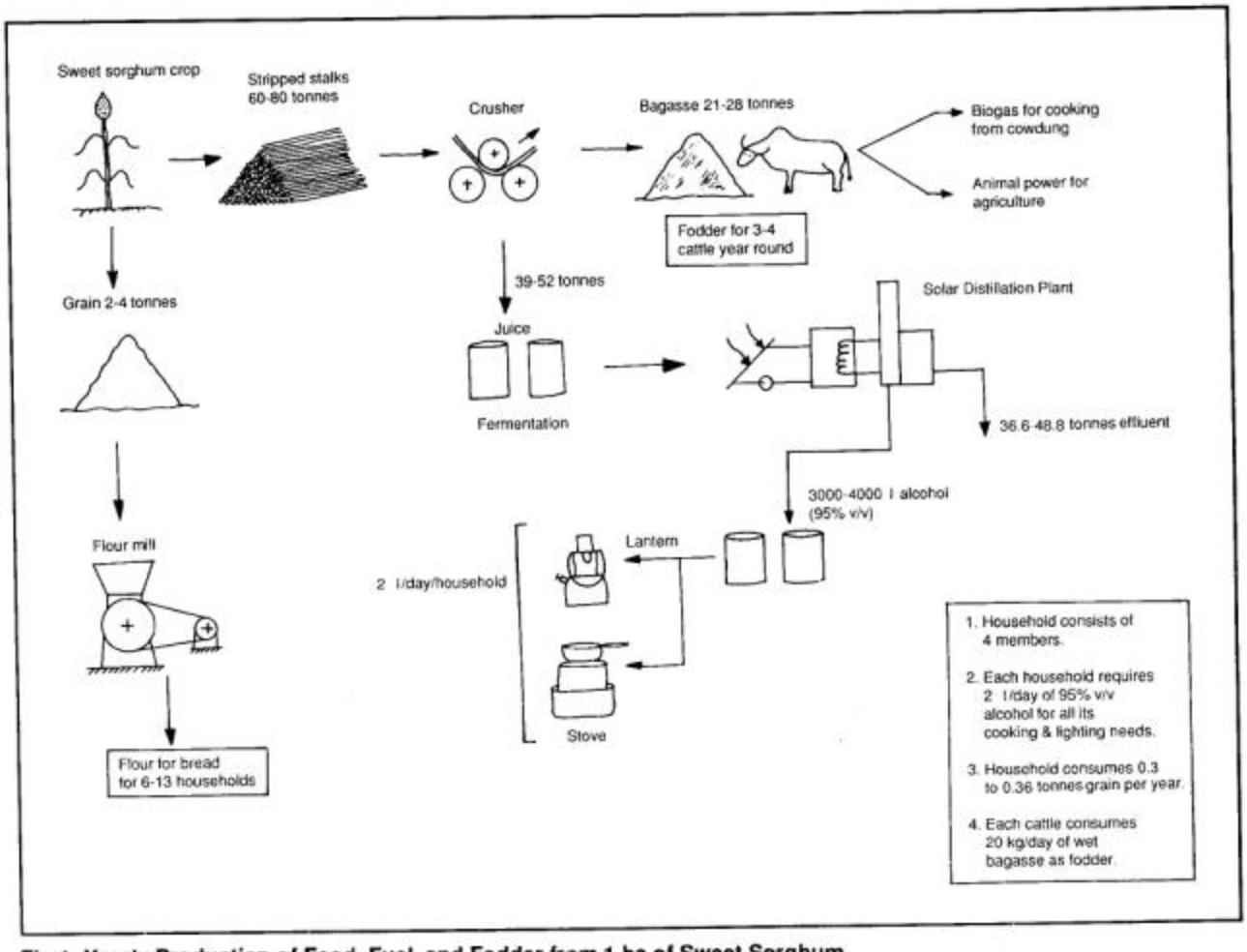

Fig.1: Yearly Production of Food, Fuel, and Fodder from 1 ha of Sweet Sorghum

There are approximately 20 varieties and two hybrids which have been developed so far as a part of this project. One of our varieties NSS-1 and hybrids NSSH-1 have been successfully released and at present about 500 ha of land has been brought under each of these in the state of Maharashtra and Gujarat. The crop has so far been utilised mainly as fodder for cattle. However, with the setting up of alcohol plants it is envisaged that the acreage under this crop will increase. Majority of the area planted has been in the rainfed regions with annual rainfall of less than 500 mm, with supplementary irrigation.

2.2 Fermentation Studies:

Fermentation studies were conducted on juice of our sweet sorghum varieties using strains of **Saccharomyces cerevisiae.** A total of 16 strains were screened and NCIM 3319 was found to be best suited for fermentation. The average fermentation efficiency obtained was 90% and the fermentation was completed between 48-72 hours. The juice contains an average of 10-11% (w/w) total fermentable sugars and the alcohol yields are about 6% (v/v). Thus our varieties can produce about 1000-2000 l/ha/season of 95% (v/v) alcohol.

2.3 Solar Distillation of Alcohol:

Energywise, distillation requires about 70-85% of the total energy consumed in alcohol production. The existing alcohol distillation in India and in other developing countries is fuelled by biomass such as bagasse, wood etc. or by steam from sugar factories (which again are bagasse based). Bagasse is an excellent raw material for paper. A large number of paper mills based on bagasse have been set up in India. Hence the use of bagasse as a boiler fuel is a waste of precious raw material. Use of solar energy to distill alcohol appears to be one way to avoid this.

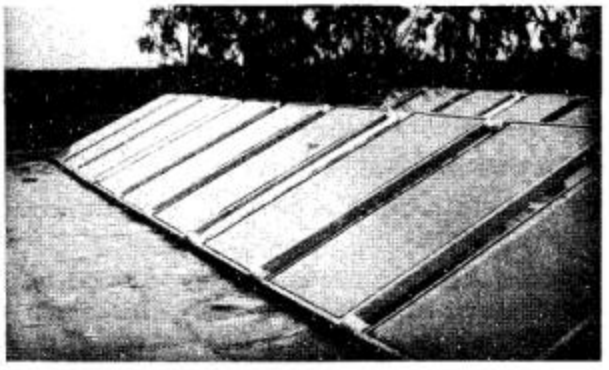

Fig. 3a: Solar Collectors

Consequently, a pilot solar distillation plant has been set up at NARI campus (Figs. 3a & 3b). It is a completely instrumented facility and is being used for scaling up this technology. This pilot plant consists of 38 m^2 of flat plate solar collectors coupled to a hot water storage tank of 2150 litre capacity. The distillation column is of packed bed type and has been specifically designed to run at distillation temperatures of 50-70° C (easily obtainable from solar collectors).

The system till March 1989 has logged about 4000 hours of operation. Data collected show that about 67% of total yearly distillation heat load comes from solar energy while the rest is provided by fossil fuels (presently electric heaters). However, the plant has also been modified to run on a biomass powered producer gas unit (developed at NARI). The fuel for this gasifier is dried sweet sorghum bagasse.

2.4 Development of Lanterns and Stoves Running on Alcohol:

As discussed in the introduction, cooking and lighting constitute the major energy use in rural areas of devel-

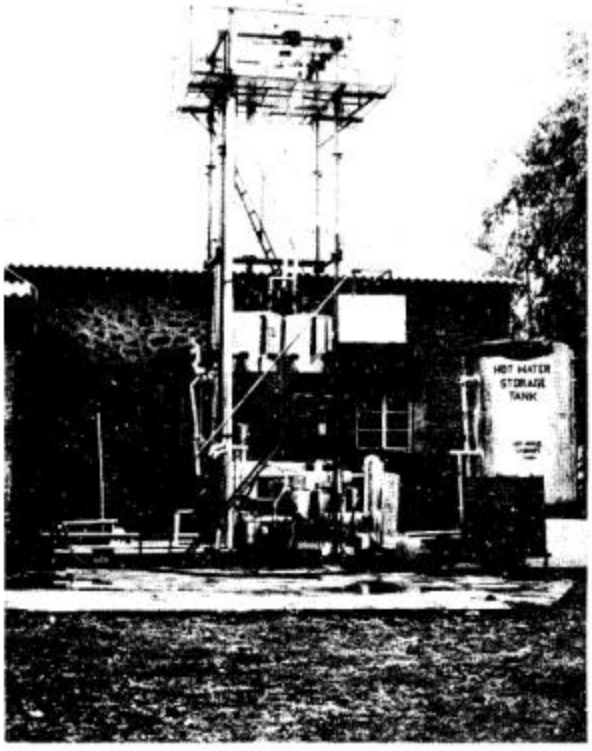

Fig. 3b: Alcohol Distillation Plant (30-50 lpd)

oping countries. Hence development of devices like lanterns and stoves running on alcohol was essential as a part of an overall rural alcohol economy.

a) **Improved lanterns:** About 60% of total kerosene consumed in India is for lighting purposes. There are guesstimates indicating that about 15-20% of the total population have only kerosene lanterns as light sources. Since the project is aimed at finding a substitute fuel for kerosene, development of alcohol lantern was undertaken. Two types of lanterns have been developed : pressurised and non-pressurised. The pressurised alcohol lanterns produce light output equivalent to that of a 100 W light bulb (Figure 4a). Details of these lanterns are given in publication No.NARI-LAN-1 (1989).

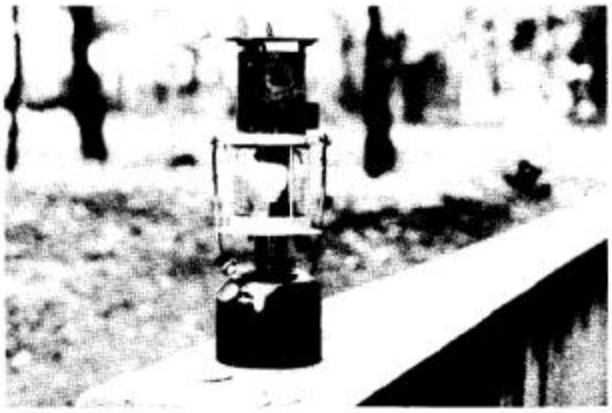

Fig. 4a: Alcohol Lantern

b) **Cooking stoves:** A wickless alcohol stove has been developed (Figure 4b), which runs on alcohol concentrations of 45% (v/v) and above. Its heating capacity is 3 KW [for 95% (v/v) alcohol concentration] and it has an arrangement by which weak solution of alcohol left after combustion is drained off. The thermal efficiency of this stove is between 30-35%.

Efforts are also underway to modify the existing wick stoves to run on alcohol. Consequently, changes in the wick materials and geometry of the existing stoves were effected and tests were conducted. Results showed that wick stoves could run only with alcohol percentages of 80% (v/v) and above with 50-60% power reduction vis-a-vis kerosene stoves.

III. IMPLICATIONS FOR THE STATE OF MAHARASHTRA

In Maharashtra, grain sorghum is planted on 6.65 million hectares. This produces about 4.65 million tonnes of grain/year. If all this land can be brought under sweet sorghum, the following can result.

Fig. 4b: Alcohol Stove

Alcohol (95% v/v)	: 27000 million litres/year
Grain	: 13 million tonnes/year
Bagasse	: 84 million tonnes/year

The above alcohol production can meet all the petrol requirements of automotive industry of India by 2000 A.D. Besides it can also completely replace the kerosene consumed in the state of Maharashtra. The bagasse produced will also have the capability to supply about 80% of the fodder needs of all the cattle in Maharashtra. Hence the implications for the state are tremendous.

IV. ECONOMICS OF ALCOHOL PRODUCTION FROM SWEET SORGHUM

An economic analysis for a 5000 litres/day (lpd) mini-distillery has been done. Figure 5 shows the details of the sensitivity analysis. The assumptions are:

1. 150 tonnes/day stripped stalks are required.
2. 42 tonnes/day bagasse is produced out of which 15% is used in boilers.
3. Bagasse selling price is Rs.100/tonne.
4. Distillation plant cost is Rs.40 lakhs.
5. Utilities use 350 KW.
6. Electricity cost is Rs.1/KWhr.
7. Interest on capital is 12% p.a.
8. O & M is 20% of the capital cost/year.
9. The plant will run for 300 days/year.
10. The cost of cultivation of sweet sorghum is Rs.10,000/ ha/year (2 seasons).

Note that this analysis has been done for biomass-based boilers for distillation. The existing solar collectors are extremely costly and hence their cost has not been taken into account. However, solar ponds do provide heat very economically (even cheaper than biomass-

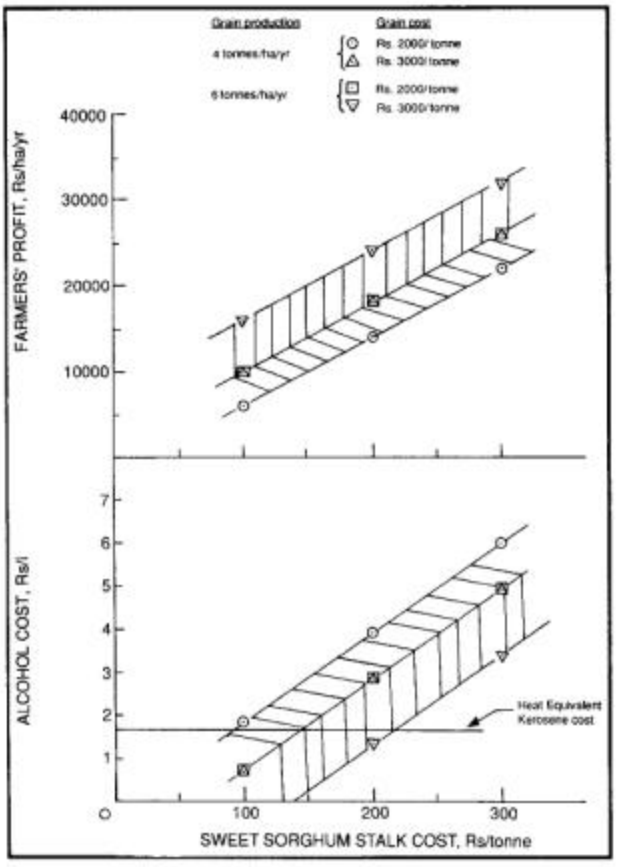

Fig. 5: Economic Analysis of Alcohol Production from Sweet Sorghum

based boilers) and is the subject of ongoing research at NARI.

V. ONGOING RESEARCH AND DEVELOPMENT

The above description of the work which has been done in this project at NARI is just laying the basic ground work. Much work needs to be done to widely spread this technology. Sweet sorghum is a relatively new crop in India and hence great efforts are required to popularise it. Thus the following R&D is proposed, or is underway.

1. Breeding of better sweet sorghum varieties to increase the yields of alcohol per hectare. A program has been initiated in NARI in this direction.
2. Effluent treatment of distillery waste. Since a large number of such plants will be put up in rural areas, this is a priority item. A small R&D program in this direction in two areas : (a) development of effluent incineration technology and (b) anaerobic digestion of the effluent to yield biogas; has been initiated.
3. Setting up of one mini-distillery of 5000 lpd based on the above technology. A complete techno-economic feasibility report has been prepared based on our R&D. It is hoped that in the near future this distillery can be set up. 5000 lpd alcohol will provide all the cooking and lighting needs of 2500 families.
4. Availability of better seed material for farmers. The varieties of various crops developed at NARI have been spread to the local farmers via our extension network. It is therefore envisaged to make available to the local farmers seed material of sweet sorghum. About 700 ha of sweet sorghum are required for a 5000 lpd distillery.
5. Evaluation and deployment of inexpensive solar collectors for distillation plant. It is envisaged to use solar ponds as a means of providing heat for distillation. Research is also underway to use the effluent from the plant as the bottom layer for the solar pond.
6. Studies on the use of producer gas units, running on sweet sorghum bagasse, as a source of heat and electricity are also underway.
7. Besides the use of sweet sorghum for alcohol production, excellent jaggery (raw sugar) can also be made from it. There is an ongoing project on this at NARI. Jaggery is often used in place of sugar in rural areas, especially in certain special preparations.

VI. CONCLUSIONS AND RECOMMENDATIONS

The complete technology of producing alcohol from sweet sorghum has been developed at NARI. However, in order to spread this technology and to lessen the energy crisis in rural India, the following policy measures are recommended.

1. Liberalisation of existing excise laws so that alcohol is easily available for cooking and lighting.
2. A concerted R&D effort to develop an effective effluent treatment technology.
3. Incentives for setting up mini-distilleries in rural areas especially to those who carry out pollution control of distillery waste.
4. Good support prices to the farmers for growing sweet sorghum.
5. Policy changes in the national energy planning towards making alcohol as a substitute for kerosene in cooking and lighting. This change should be made by 2000 AD. and can result in savings of about Rs.2000 crores per year in foreign exchange for kerosene imports.

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i) **Breeding of Sweet Sorghum:** Indian Council of Agricultural Research (ICAR), New Delhi and United States Department of Agriculture (USDA), New Delhi.

ii) **Fermentation Studies:** Department of Non-Conventional Energy Sources (DNES), New Delhi.

iii) **Solar Distillation Studies:** DNES, New Delhi.

iv) **Alcohol Stoves and Lanterns:** NARI and Advisory Board on Energy (ABE), New Delhi.

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