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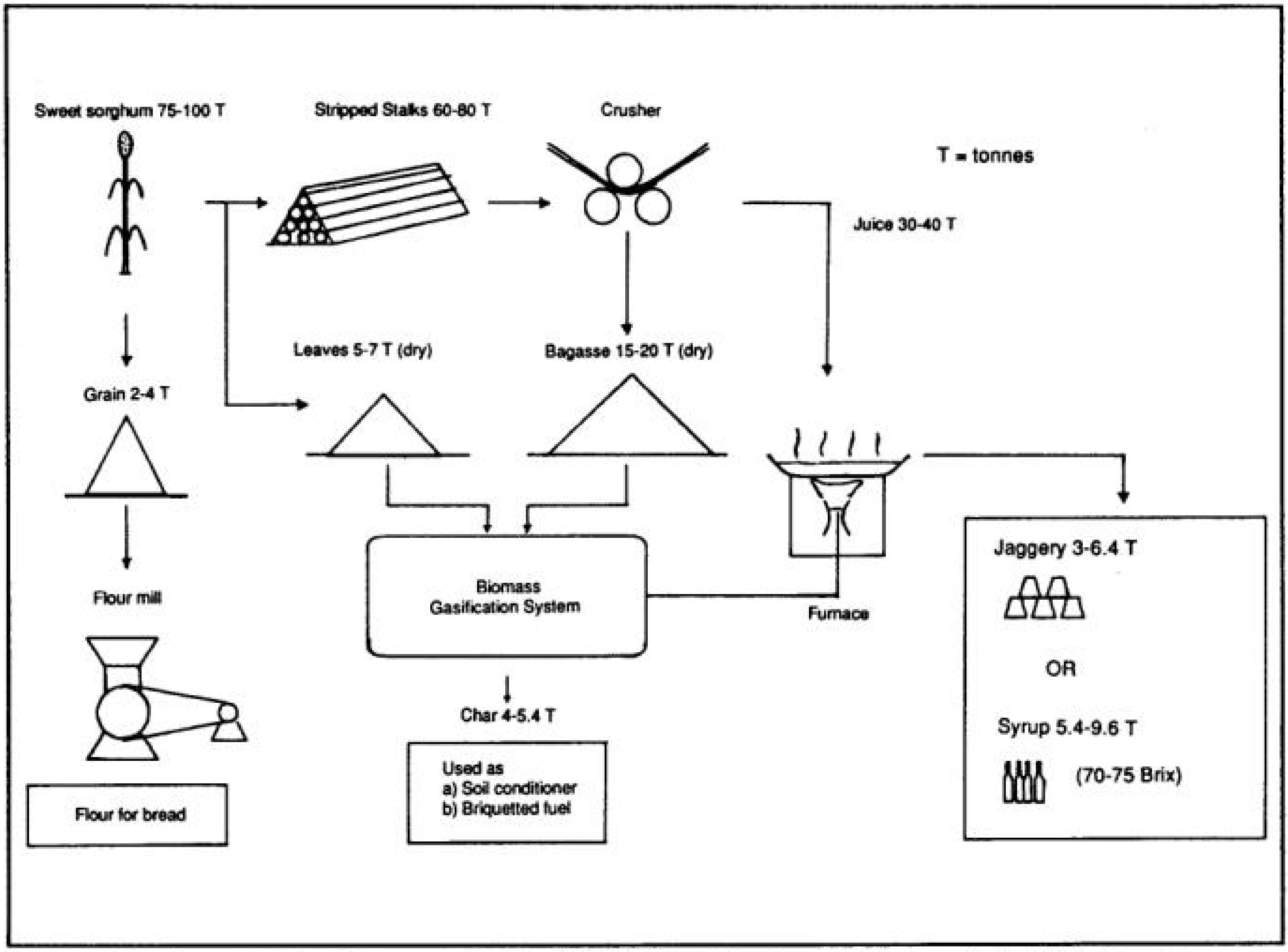

Yearly production of jaggery, syrup and grain from 1 ha of sweet sorghum hybrid "Madhura"

NARI

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ABSTRACT

This paper presents a pioneering developmental work on jaggery and syrup production from sweet sorghum. A hybrid sweet sorghum "Madhura" has been developed which produces excellent jaggery and syrup. The yearly production of jaggery from this hybrid is 3-6.4 tonnes per hectare. This paper details the agronomy and the juice characteristics of this hybrid. Protocols for making excellent jaggery and syrup from sweet sorghum are also outlined. Finally an economic analysis and future R & D for jaggery and syrup production are detailed.

1 INTRODUCTION

1.1 Background

Jaggery (or gur) and khandsari production is a Rs. 3,000 crore industry in India and provides employment to about 2.5 million people in rural areas. About 40% of total sugarcane produced in India is diverted for jaggery and khandsari production. The reasons for this are as follows:

i) Farmers can get instant cash after selling jaggery in the open market. If they sell their cane to sugar factories instead, then they are paid in installments, sometimes even after 2-3 years!

ii) Due to the labour problem of cane cutters (especially in Maharashtra), quite a large number of small and medium-size farmers cannot get their cane cut on time and hence get a much reduced price because of reduction in cane weight. With their own "gurhals" (jaggery-making units), the farmers can make jaggery at the right time.

iii) Jaggery is still a preferred food item for cooking and other usages in quite a large number of households both in rural and urban areas of India. Besides it is more nutritious than white sugar.

However, there are quite a number of problems in the existing "gurhals". They are:

a) **Short season for jaggery-making**: Since sugarcane harvesting, and hence jaggery- making, is seasonal, the "gurhals" only operate for 3-5 months in a year which makes them uneconomical. Thus, to facilitate year-round operation, there is a need to have an alternative feedstock to complement the sugarcane season.

b) **Water shortage to produce sugarcane**: Sugarcane (presently the only crop used for jaggery-making) is an 18-month crop and requires about 30 irrigations per year. With perennial problem of water shortage, there is a need to find an alternative feedstock for jaggery-making. It should be a short duration crop with much less water requirement than sugarcane.

c) **Nonavailability of sugarcane for jaggery-making**: In Madhya Pradesh and in some parts of Maharashtra, jaggery-making is not allowed within 15-20 kms of a sugar factory. Probably this law came about to prevent any large scale diversion of cane from sugar factories. This problem then also points towards an alternative feedstock for jaggery-making which can be grown in this area and will not pose a threat to sugar factories.

d) **Poor efficiency of jaggery furnaces**: The furnaces used in "gurhals" are antiquated in design and work on the concept of free convection combustion. This results in poor thermal efficiency (10-15%), due to which, these "gurhals" have to use wood, tyres etc. to supplement bagasse as fuel. Besides, this poor efficiency also results in tremendous smoke and fly-ash in the flue gases, thereby increasing the local pollution.

This project was therefore undertaken to address the above problems of alternative feedstock and more efficient jaggery-making.

1.2 The solution

An attractive alternative feedstock for jaggery-making is sweet sorghum (*Sorghum bicolor* (L.) Moench). It provides grain from its earhead and sugar from its stalk. Besides, the bagasse is an excellent fodder for animals. Thus it is a multipurpose crop. Moreover, sweet sorghum has a great tolerance to a wide range of climatic and soil conditions. It is a short duration crop maturing in 120-140 days (as compared to 12 to 18 months for sugarcane) and requires much less water than sugarcane. These characteristics make it an ideal crop for jaggery and syrup production. Sugarcane syrup (or "Kakvi" in Marathi) is commonly used as a liquid sweetener in rural Maharashtra and in some parts of U.P. Recently, it is gaining popularity in urban areas as well. Hence sweet sorghum syrup can be an attractive marketable product.

Efficient systems for direct combustion of low density materials like sugarcane leaves, bagasse etc are not presently available. Besides, their rapid burning nature makes it difficult to control the combustion rates. Gasification of these residues seems to be a plausible solution. It provides a high quality flame without any smoke which results in a pollution-free furnace. Besides, these systems also provide higher efficiency than the free convection-type direct combustion furnaces presently in use.

This paper presents the results of a pioneering research effort at NARI aimed at developing a technology to produce jaggery and syrup from sweet sorghum using an efficient gasifier-powered furnace running on biomass residues.

1.3 Components of NARI program

The main components of the project are:

a) Breeding of high yielding sweet sorghum varieties for jaggery and syrup production.

b) Development of protocols for jaggery and syrup production from sweet sorghum.

c) Development of an efficient biomass residue gasification system for making jaggery.

d) Economic analysis of jaggery and syrup-making from sweet sorghum.

2 SWEET SORGHUM — ITS BREEDING AND AGRONOMY

2.1 Sweet sorghum breeding

Breeding work at NARI since the late 1970s has resulted in the development of about 38 varieties and 4 hybrids of sweet sorghum. The NARI hybrids contain maximum sucrose at grain maturity. Thus, both the grain and sugars are obtained simultaneously, thereby making sweet sorghum a multipurpose crop. The hybrid "Madhura" was found to be best suited for jaggery and syrup production. The brix and sucrose in the juice of this hybrid approaches nearly that of sugarcane. Table 1 compares the juice characteristics of sugarcane cultivar Co 740 (a variety normally used in jaggery-making) and "Madhura" sweet sorghum.

Table 1: Characteristics of sugarcane and sweet sorghum juice

Parameter	Sugarcane (Co 740)	Sweet sorghum (Madhura)
pH	5.8-6.4	4.7-5.5
Brix, degrees	16-22	12-21
Sucrose, %, w/v	13-18	10-15
Reducing sugar (RS), %, w/v	0.2-1.0	0.75-3.0
Starch, %, w/v	0.001-0.05	0.02-0.22
Aconitic acid, %, w/v	0.01-0.03	0.08-0.56
Minerals, %, w/v	0.4-0.7	0.4-0.5

Figure on cover page shows the yearly production of jaggery or syrup and grain from "Madhura". The jaggery and syrup recovery is strongly dependent on the crushing equipment. The 3-roller crusher used at NARI gives only 40-50% extraction. There is therefore a great need to develop efficient crushers for "gurhals" which would approach the extraction percentages found in sugar factories. This can enhance the jaggery recovery by 30-40%.

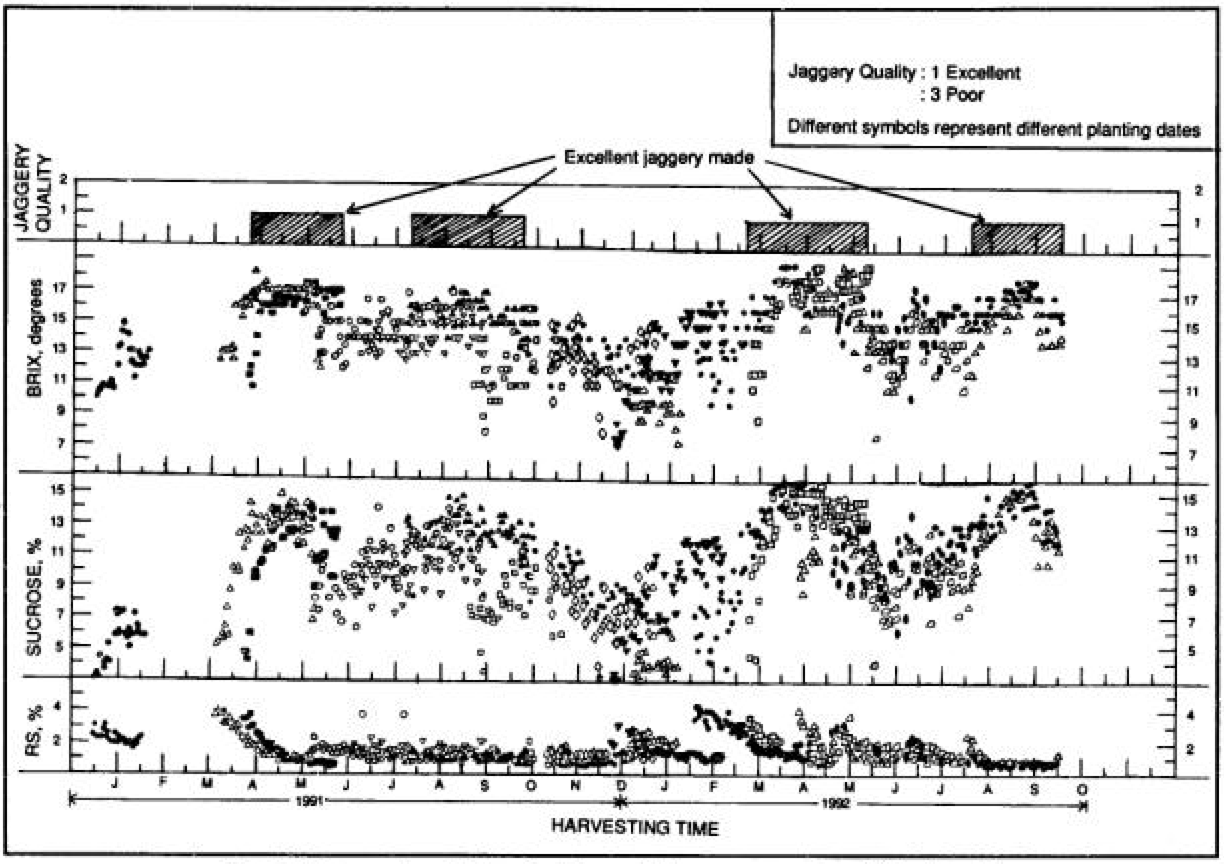


Fig. 1: Seasonal variations in different juice components of "Madhura"

2.2 Sweet sorghum agronomy

In general, the agronomic practices for sweet sorghum are similar to those of grain sorghum, and are outlined in Table 2 for irrigated conditions at the NARI farms in Phaltan.

Figure 1 shows the data for seasonal variations in different juice components of "Madhura" over a two year period. It is evident that excellent jaggery can only be made when this hybrid is planted in the months as given in Table 2.

Interestingly, the usual season for jaggery-making from sugarcane in Maharashtra is from October-end to March. Thus with sweet sorghum as a supplementary raw material, the "gurhal" can be run almost year-round, thereby significantly improving the economics as can be seen later.

"Madhura" is an excellent fodder crop and can also be planted in the winter season (1-15 October) for grain and fodder purposes. However, as the usual planting dates for sorghum during monsoon and sum-

Table 2: Agronomic practices for growing "Madhura" for jaggery and syrup production

1. Planting date	April-May	Mid November-Mid January
2. Duration of crop, days	110-120	120-130
3. Seed rate, kg/ha	7.5 to 10	7.5 to 10
4. Plant density	1.5 to 2 lakh plants/ha; spacing 45 cm between rows and 15-20 cm between plants	
5. Fertilizer dose, kg/ha	N:P:K (100:50:50) at planting and N (50) one month after planting	
6. Irrigation number	4-6	8-10
7. Irrigation interval, days	8-10	13-15

Fig. 2: Brix vs Jaggery quality

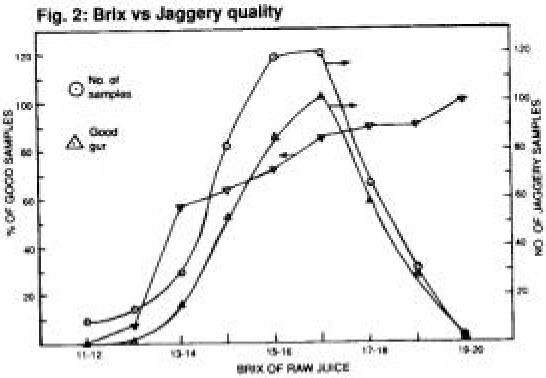


Fig. 3: Su/RS vs Su

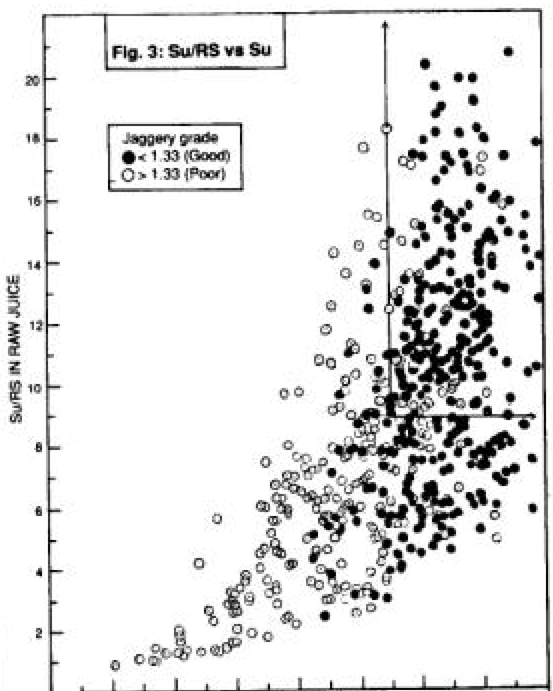
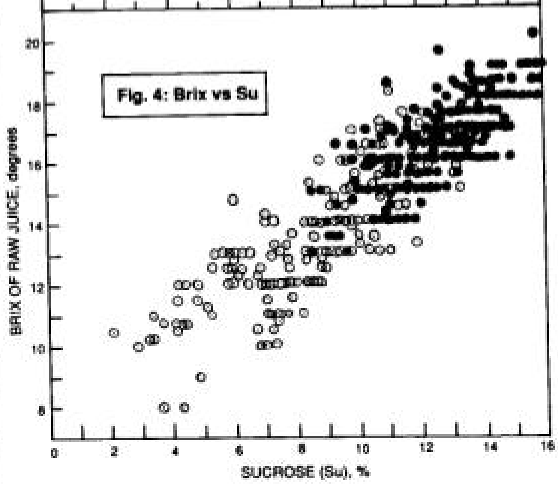


Fig. 4: Brix vs Su



mer are 15 June-15 July and 1-28 February respectively, planting for jaggery production will have to be undertaken on a large-scale so as to minimize grain damage by birds during these slightly off-season plantings.

3 PROTOCOL FOR JAGGERY AND SYRUP-MAKING

It is evident from Table 1 that the sweet sorghum juice characteristics are different from those of sugarcane juice. The regular sugarcane jaggery protocol resulted in sweet sorghum jaggery of unacceptable colour and texture. Hence there was a need to develop a protocol for making jaggery and syrup from sweet sorghum. Consequently, experiments were conducted to study in detail the effect of each juice and process parameter on jaggery production. About 560 jaggery samples were produced during different seasons to study their effect. Jaggery quality was ascertained by standard organoleptic tests for colour, texture and taste. Briefly, the parameters tested are given below.

3.1 Juice parameters

Experiments showed that excellent jaggery could be made when the brix of juice was greater than 15 degrees (Figure 2) and when the ratio of sucrose to reducing sugars (Su/RS) was greater than 9 (Figure 3). Figure 4 shows the relationship between brix and sucrose of juice. Starch and aconitic acid normally present in sweet sorghum juice did not affect the jaggery quality.

Excellent syrup could be made when brix of raw juice was greater than 14 degrees. No chemicals were added either for jaggery or syrup-making. This is in marked contrast to the manufacture of sugarcane jaggery where normally various chemicals are added mainly to improve the colour of jaggery.

3.2 Process parameters

Experiments conducted on various parameters like boiling rate, scum removal, striking point etc. resulted in the following recommendations for jaggery production:

i) Maximum scum removal (13-15% (w/w) of juice) took place when the boiling was achieved within 10-15 minutes (Figure 5). No external flocculent or clarificant was required. It should be emphasised that proper scum removal is the most important parameter in jaggery production from sweet sorghum.

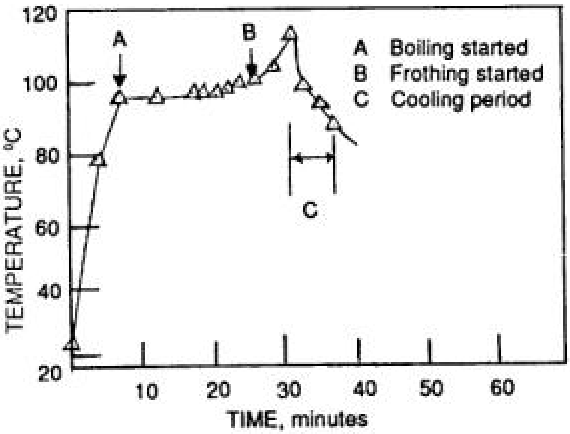


Fig. 5: Typical temperature-time history for jaggery-making from "Madhura"

ii) Best jaggery was made when the striking point was between 114-116°C.

iii) Excellent jaggery crystallization took place when the cooling time of the heated mass was between 7-10 minutes (Figure 5). Because of lower Su/RS in sweet sorghum as compared to that in sugarcane, more vigorous working of the concentrated mass is required during cooling period for better colour and quality of jaggery.

iv) Jaggery produced in aluminium utensil ("kadhai") had a better colour than that of jaggery made in M.S. one.

v) Following the above protocol, excellent syrup with good colour and flowability was made when the final brix reached 70-75 degrees (corresponding to syrup temperature of ~105°C).

3.3 Shelf-life of jaggery and syrup

Sweet sorghum jaggery was stored using the protocol for sugarcane jaggery storage. It was found that the shelf-life of sweet sorghum jaggery was similar to that of sugarcane.

However, in storage of syrup, there is a possibility of partial crystallization and mold formation due to fungal attack. In order to prolong the shelf-life of sweet sorghum syrup, various procedures like storage of stalks for conversion of sucrose to reducing sugars etc. were studied. Eventually a protocol was developed which prolonged the shelf-life of syrup to more than 3 months. Efforts are underway to study other factors so that the shelf-life can be prolonged further.

Table 3 shows the major constituents of jaggery from sugarcane (variety Co 740) and sweet sorghum

Table 3: Major constituents of jaggery from sugarcane and sweet sorghum (wet basis)

Crop	Moisture content (%)	Sucrose % (w/w)	Reducing sugar, % (w/w)
Sugarcane (Co 740)	9-11	70-78	7-10
Sweet sorghum (Madhura)	7-13	53-69	8-23

(Madhura). Organoleptic tests showed that the sweet sorghum jaggery was at par with that from sugarcane.

This report therefore presents for the first time in India or anywhere else the protocol for sweet sorghum jaggery production.

It is also tempting to suggest that besides jaggery production, sweet sorghum can also be used as a feedstock for sugar production. Thus the sugar factories can run year-round with NARI variety "Madhura" as a supplementary feedstock. This can make it possible to further improve the economy of sugar factories. Another technology pioneered by NARI is the production of ethanol from sweet sorghum. The details of this technology are given elsewhere [Ref. 5]. Thus sweet sorghum being a multi-product crop is very attractive from the farmers' point of view.

4 BIOMASS RESIDUE GASIFIER FOR JAGGERY FURNACE

One of the major improvements in jaggery-making can be effected by improving the furnace efficiency. Existing furnaces are normally very inefficient (10-15% overall efficiency). A major program of development of a furnace coupled to a low density biomass gasifier was therefore initiated at NARI. This is a multifuel gasifier which can run on sweet sorghum bagasse, sugarcane leaves, wheat husk, grasses etc. The details of this gasifier are given elsewhere [Ref. 6]. Figure 6 shows the gasification system used for jaggery-making. This pilot gasification plant is of 100 kW (thermal) capacity and produces about 15-20 kg of jaggery per batch. The advantages of this gasifier over a conventional furnace are:

i) It is a fully automated system and hence removes the drudgery of continuous manual feeding of bagasse.

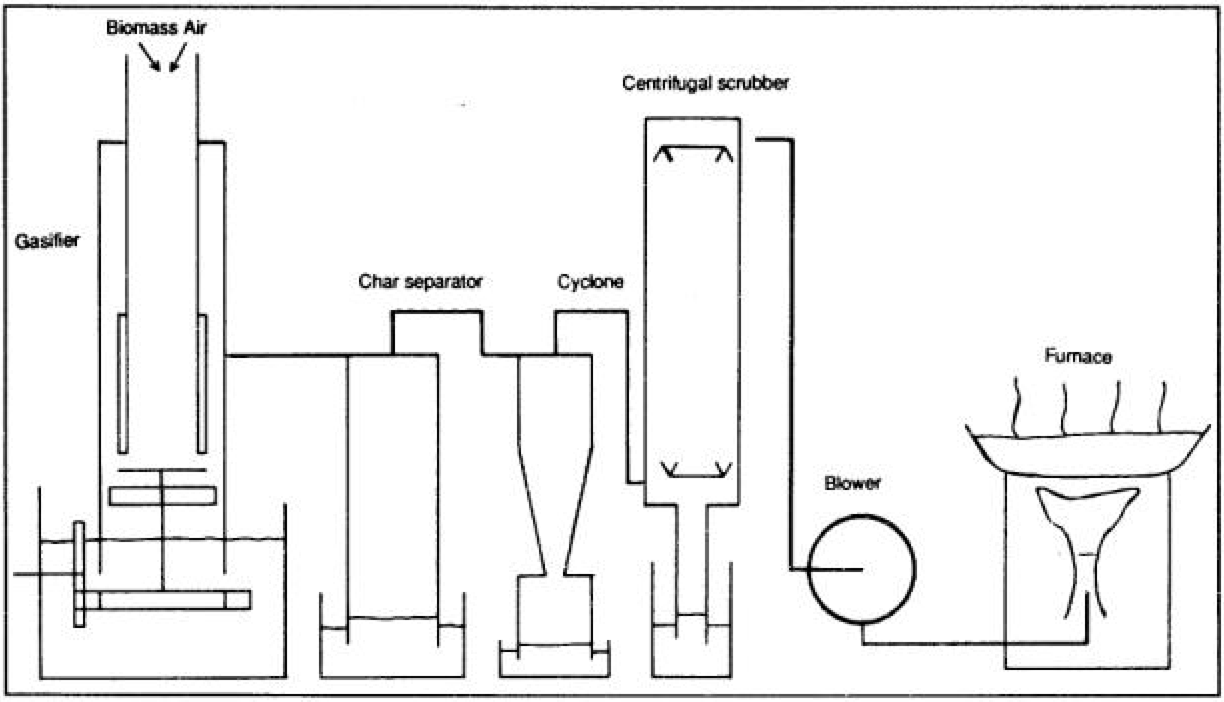


Fig. 6: Schematic of gasifier-powered jaggery or syrup-making furnace

ii) It produces a bluish white flame with flame temperatures in excess of 1250°C. Hence the system is environmentally very clean. There is no smoke from the chimney as in commercial systems.

iii) The overall efficiency (biomass to useful heat) of the system is 20-27%. This is much higher than that of the existing furnaces. Thus for sweet sorghum, the gasification system uses 4-4.5 kg fuel per kg of jaggery, while for sugarcane the fuel consumption is 2-3 kg fuel/kg jaggery.

iv) The gasification system produces char as a by-product (20-25% (w/w) of fuel). This char can be mixed with a suitable binder (15% (w/w) cowdung) to produce excellent smokeless fuel briquettes for chulhas. Besides, preliminary results indicate that this char also acts as a soil conditioner when applied to fields.

The gasification system can also be used to run a diesel engine or genset and thus the gasifier-powered jaggery unit has the potential to be energy self-sufficient where the crusher and jaggery unit can be powered by the same gasifier.

5 ECONOMIC ANALYSIS

A simple economic analysis for jaggery and syrup from sweet sorghum was carried out. Since both syrup and jaggery-making are batch processes, the costing was done for processing of 1 tonne of stripped sweet sorghum stalks per batch. The major assumptions made are given in Table 4, and the results are shown in Figure 7.

It is seen that all the bagasse and leaves generated from the stalks are sufficient to make jaggery or syrup from the same stalks. Thus, the gurhal is self-sufficient in fuel.

The results seen in Figure 7 show that jaggery or syrup recovery and the number of batches made per year greatly affect the cost of production. Higher recovery can be ensured by using efficient crushers. Besides, 1800 batches/year are possible by using sweet sorghum and sugarcane as complementary raw materials as was outlined earlier. In this case, the cost of jaggery (assuming 8% recovery) comes to Rs. 6.80/kg at a sweet sorghum cost of Rs. 200/tonne. The corresponding syrup cost comes to Rs. 4.56/kg assuming a recovery of 12% on stalk basis.

6 ONGOING RESEARCH AND DEVELOPMENT

For this technology to spread in rural areas, the following R & D is being proposed or is underway.

1. Production of better varieties and hybrids of sweet sorghum so that they can have higher jaggery

Table 4: Assumptions made for economic analysis for jaggery and syrup from sweet sorghum

Basis: 1 tonne of sweet sorghum stalks/batch.

A. Gasifier system	
1. Gasifier cost (Net output: 309 kW), Rs.	: 5,00,000
2. Gurhal cost (including crusher, pan and furnace), Rs.	: 70,000
3. Operating life, years	: 10
4. Discount rate, % p.a.	: 20
5. Operation and maintenance cost (including replacement cost of materials, labour for operating the gasifier etc), Rs./batch	: 115
6. Char production, w/w of input fuel	: 0.20
7. Net profit from char briquettes, Rs./kg	: 0.50
8. Fuel required, kg/batch : Bagasse 250 : Leaves 50	: 300
B. Sweet sorghum	
1. Recovery, % (w/w) of stalks	
: Jaggery	: 5-8
: Syrup	: 9-12
2. Bagasse availability w/w of stripped stalks, (dry)	: 0.25
3. Leaves availability w/w of stripped stalks, (dry)	: 0.05
4. Total (bagasse + leaves) availability, kg/batch	: 300
5. Sweet sorghum cost, Rs./tonne of stripped stalks	: 100-600
C. "Gurhal"	
1. Wage bill (including 1 supervisor and 7 labourers), Rs./batch	: 120
2. Diesel and other utilities cost, Rs./batch	: 40
3. Number of batches/year, N	: 900-1800

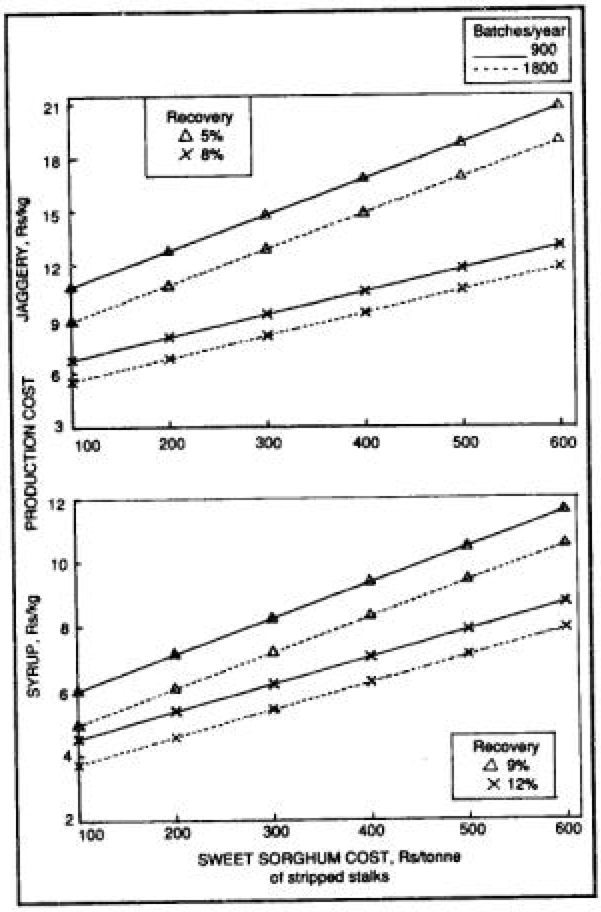


Fig. 7: Economics of jaggery and syrup production from sweet sorghum

yields year-round. This will make the jaggery and syrup production from sweet sorghum a year-round activity. Efforts are also underway to increase the sucrose content of some of these varieties.

2. Development of a table syrup. Development is also underway to explore the possibility of sweet sorghum syrup as a "sherbet" concentrate. Consequently, several flavours and shelf-life enhancers are being explored. Efforts are also underway to explore the possibility of using jaggery or syrup as a raw material for "chikki" making. Thus the marketability of these products is being actively explored.
3. Efforts are underway to set up a prototype of a full scale "gurhal" (500 kW thermal capacity) run by a gasifier using low density biomass.
4. The use of char (a by-product) from gasifier as soil conditioner for crops is being thoroughly explored.

7 STATUS OF TECHNOLOGY

The technology of producing jaggery and syrup from sweet sorghum is available for commercialization. Consequently seed of "Madhura" is available from NARI. For further information on this technology, please contact the Director, Dr. Anil K. Rajvanshi at the Institute's address.

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