Syrup Production from Sweet Sorghum

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Abstract

This paper presents pioneering developmental work on syrup production from sweet sorghum. A hybrid sweet sorghum 'Madhura' has been developed which produces excellent syrup. This paper details the agronomy and the juice characteristics of this hybrid. Protocols for making excellent syrup from sweet sorghum are also outlined. Finally an economic analysis for syrup production is detailed.

Sweet sorghum-an attractive feedstock for syrup making

Sweet sorghum [*Sorghum bicolor* (L.) Moench] is the best multipurpose crop for simultaneous production of (i) grain from its earhead as food, (ii) sugary juice from its stalk for making syrup, jaggery or ethanol and (iii) bagasse and green foliage as an excellent fodder for animals, as biomass for gasification system, as organic fertilizer or for paper manufacturing. Moreover, sweet sorghum has a great tolerance to a wide range of climatic and soil conditions. It is a short duration crop of 110-130 days as compared to 12-18 months in sugarcane. In addition its water and fertilizer requirement is much less, resulting in lower cost of cultivation than sugarcane. Sweet sorghum is a plant with C_4 photosynthetic pathway, so its photosynthetic rate and dry matter production in g/m^2/day per unit of inputs are more than those of other sugar producing crops like sugarcane and sugarbeet. These characteristics make sweet sorghum an ideal crop for syrup and jaggery production. Existing sugar mills, small factories and '*gurhals*' (jaggery-making units) running on sugarcane can be used during off-season for processing sweet sorghum (as it can be grown round the year as a supplementary feedstock) to make these units more economical. Like sugarcane syrup ('kakvi' in Marathi), sweet sorghum syrup can be used as a liquid sweetener in various food products due to its excellent taste. It is a better source of calcium than honey.

NARI has pioneered development of syrup and jaggery production from sweet sorghum in India. Sweet sorghum was introduced in India in early 1970s by NARI. Besides syrup production NARI also pioneered the production of ethanol from sweet sorghum. Consequently complete technology has been developed. 'Madhura' - a sweet sorghum hybrid developed at NARI is recommended for round the year cultivation. It gives high quality grain and excellent fodder which can be fed to animals or used for producing natural, chemical-free, good quality, coloured syrup which at present is being marketed as 'Madhura syrup'. Its chemical composition compared to that of honey is given in Table 1.

Sweet Sorghum MADHURA crop

Table 1. Chemical composition of Madhura syrup compared to honey

	Madhura	Honey
Calorific value, Cal/g	2.60	3.26
Total soluble solids, % wt	77.00	81.00
Proteins (N X 6.25), % wt	1.65	-
Ash, % wt	3.69	0.59
mg/100 g		
Calcium	160.00	5.00
Phosphorous	11.00	4.10
Riboflavin (Vitamin B_2)	10.00	0.06
Vitamin C	11.50	5.00
Nicotinic acid	153.00	32.00
Iron	0.86	0.59
Sodium	86.00	4.70
Potassium	1810.00	90.00
Sulphur	Not detected	8.00
Benzoic acid	Not detected	
Added colouring matter	None	
Pesticide residues	Not detected	

Data for honey is from literature.
Analysis of samples of 'Madhura' syrup by CFTRI, Mysore and ITALB Pvt. Ltd., Mumbai.

About 240 kg syrup prepared from the juice of 'Madhura' has been test-marketed mainly in Phaltan and Pune during last six years. The response of consumers to the coloured syrup has been very encouraging, especially as the syrup is entirely chemical-free with only natural ingredients such as an aqueous extract of okra fruits or plants being used for facilitating scum removal during processing.

Madhura Syrup

Yield potential of Madhura per ha/season

- Green cane yield : 60-80 tonnes
- Stripped stalk yield : 40-50 tonnes
- Green leaf yield : 3.5-4 tonnes
- Grain yield : 1.5-2.0 tonnes
- Juice yield : 18,000-27,000 litres
- Syrup yield : 4,000-6,000 litres
- Jaggery yield : 2-4 tonnes
- Bagasse (wet) : 15-20 tonnes

The cultivation practices of sweet sorghum are similar to those of grain sorghum (Table 2).

Table 2. Cultivation practices for growing 'Madhura'

Sowing time	*Kharif* (Monsoon) – First fortnight of June *Rabi* (Winter) – Last week of September to first week of October Summer – January-February
Seed rate/ha	7.5 to 10 kg
Spacing	45 cm between rows and 15 cm between plants
Plant population/ha	125 to 150 thousand plants
Fertilizer dose/ha	N:P:K :: 100:50:50 kg (50% N with all P and K at the time of sowing and remaining 50% N one month after sowing) For organic cultivation at least 1500 kg vermicompost
Irrigations	4-9 (as per season and availability of water)
Crop duration	110-130 days

Syrup making from sweet sorghum:

It is instructive to see the details of syrup production from 1ha of sweet sorghum 'Madhura'. The schematic is shown in Fig. 1.

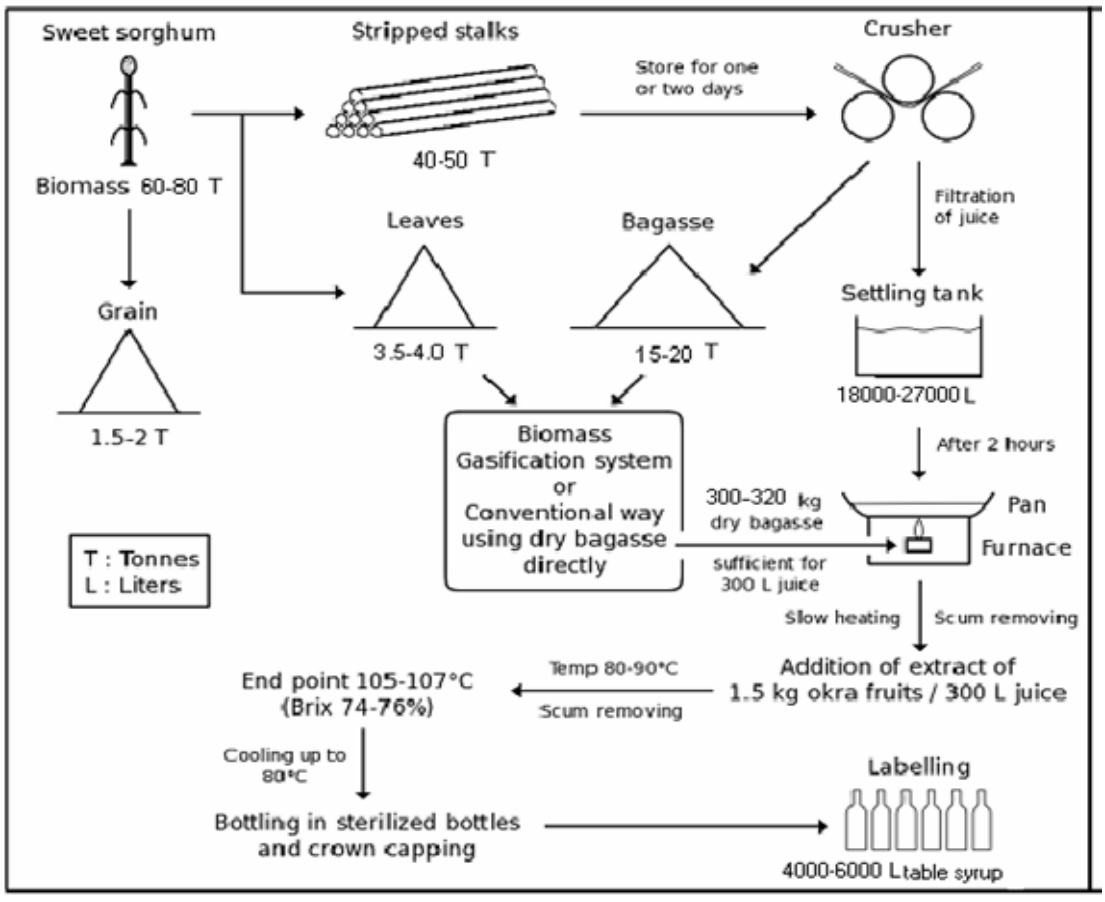

Fig. 1. Sweet sorghum syrup from hybrid 'Madhura' (ha/season)

Sweet sorghum syrup can be an attractive marketable product. It can give additional remuneration to the farmers growing it.

Excellent syrup can be made when brix of raw juice is greater than 15%. No chemicals are added in making the syrup. This is in marked contrast to the manufacture of sugarcane syrup/jaggery where normally various chemicals are added mainly to improve the colour of the product. Experiments were conducted to study in detail the effect of each juice and process parameter on syrup production (Nimbkar, 2005). About 124 batches (35 large scale and 89 medium scale) of syrup were produced in five years (January 2000 to December 2005 sowing time) during different seasons to study the effect of juice and process parameters. Syrup quality was ascertained by standard organoleptic tests for taste, smell, colour, clarity and flowability using a scale from 1 to 5 with 1 = best and 5 = worst. The parameters tested are given below:

Juice parameters:

Judging the right time for harvesting the crop is essential, since the sugar content of the juice usually continues to increase as maturity approaches and this also has an influence on juice composition. Though soft to hard dough stage of maturity is ideal for harvesting the crop, to get optimum sugar content (> 15% brix) for making syrup and also to obtain grain yield it is recommended to harvest the crop at physiological maturity. Brix of the standing crop can be judged with the help of a hand refractometer by squeezing the juice from the middle internodes of stalks taken from several places in the field. Alternatively, 5-10 stalks can be harvested from various places in the field, crushed and the juice assessed for quality.

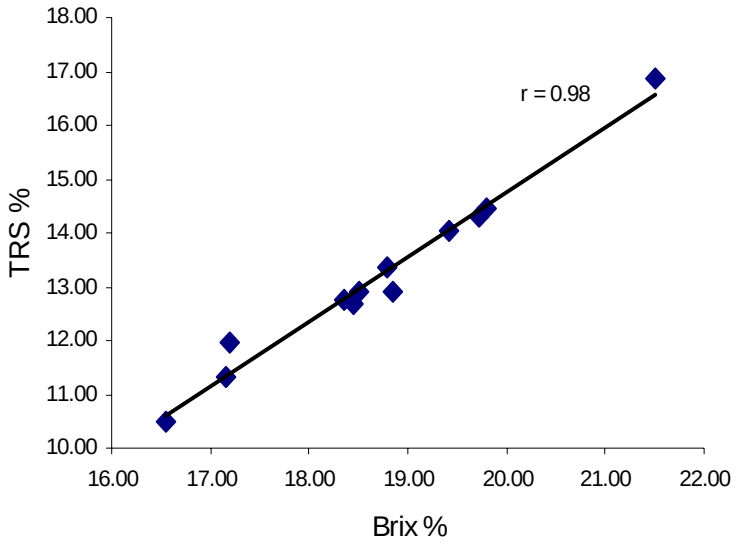

Fig. 2 shows the relationship between brix and total reducing sugar in juice. The brix of juice was highly correlated with the total reducing sugar in juice (r = 0.98). Whenever the brix is more than 15%, it is possible to make a good quality syrup.

Fig. 2. TRS % Vs Brix %.

Compared to other sowing times syrup taste was found to be very sour in October-sown crop probably due to high aconitic acid levels with comparatively low brix and low total reducing sugar percentage in juice. This is probably due to the heavy grain setting in October-sown crop.

Process parameters:

The yield and quality of sweet sorghum syrup are influenced by the equipment and process used in manufacturing and by the syrup maker's knowledge and skill. Some of the major reasons for poor quality syrup are presence of settled as well as floating mass in syrup or general cloudy appearance due to inadequate removal of scum, gelling of syrup due to high quantity of starch in juice, crystallization due to high concentration of sucrose in juice and very low or high viscosity of syrup produced due to faulty recording of brix and/or temperature of syrup.

Experiments conducted on various parameters such as stripping, filtering, rate of boiling, scum removal, finishing temperature, bottling etc. resulted in following recommendations for syrup production.

I) Equipment:

For making syrup on large scale the following equipments are required:

a) A 3-roller crusher which can give an extraction of at least 45–55%. More efficient crushers will give higher extraction percentage and thus enhance syrup recovery.
b) Settling tank.
c) Motor for pumping juice.
d) Flat- bottomed aluminium or stainless steel vessel (*kadhai*) having a capacity to boil 350-400 litres juice.
e) A conventional furnace with at least 10-15% overall efficiency or a gasifier-powered furnace. NARI has developed a multifuel gasifier which can be run on sweet sorghum bagasse, sugarcane leaves, wheat husk, grasses etc (Fig. 3). A pilot gasification plant of 300-500 kW (thermal) capacity was set up giving 20-27% overall efficiency (biomass to useful heat) (Rajvanshi, 1992). It was environmentally very clean as there was no smoke production. [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 cow dung) to produce excellent smokeless fuel briquettes for *chulhas* (stoves). Besides, preliminary results indicated that this char can also act as a soil conditioner when applied to fields].

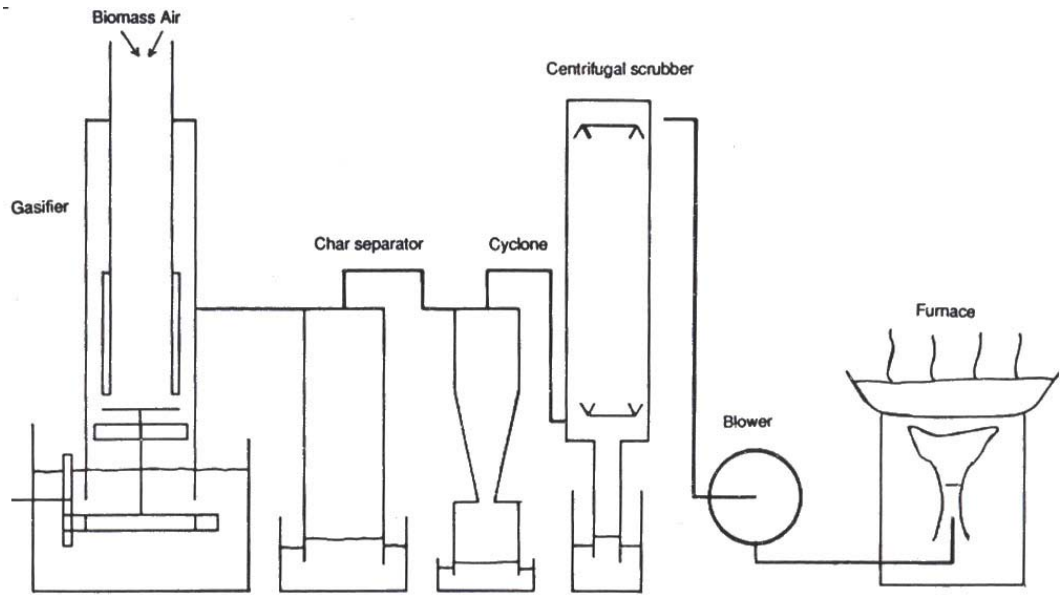

Fig.3. Schematic of gasifier-powered syrup making furnace

It is seen that the bagasse and leaves generated from the stalk are sufficient to make syrup for that batch. About 4-5 kg dry biomass is sufficient for making 1kg syrup.

f) Weighing balance.
g) Bottling machine.
h) Crown capping machine.
i) Other accessories such as 200-mesh stainless steel wire gauze sieves, skimmers, buckets, hand refractometer, thermometer, sterilized bottles, crown caps, etc.

II) Processing of the sweet sorghum stalk*:*

a) **<u>Stripping of stalks</u>:** Harvested stalks are stripped by removing the leaf lamina along with the sheath and panicles with peduncle as these contain very little sugar. The stalks are stored in shade for one or two days before milling for juice extraction. This conditioning allows the inversion of sucrose to reducing sugars and thus improves the quality of juice. Conditioning of stalks before milling also removes excess moisture from the stalks and increases the brix of juice which ultimately helps to reduce the time and fuel required for syrup concentration.

Stripping of Madhura stalks

b) **<u>Extraction of juice</u>:** A horizontal 3-roller power mill (crusher) strong enough to apply 50-100 tonnes of pressure on the stalk is used to crush the millable stalk for extraction of the juice. Passing the same stalk 2-3 times through the crusher gives maximum extraction. Bagasse obtained after juice extraction makes an excellent roughage for livestock with proper supplementation or it can be used as a fuel for juice evaporation process after drying.

(c) **Filtration and settling of the juice:** Sweet sorghum juice has low purity. Apart from sugars it contains soluble solids like anthocyanins and chlorophyll and insoluble solids such as starch granules. The extracted juice should be strained through a wire screen to remove big pieces of crushed material and then strained through a fine mesh screen to the settling tank. This is to be done so as to get clean juice. The strained juice should be kept undisturbed for 1-2 hours for settlement of starch granules and then the supernatant juice (keep at least 3-4 cm juice from the bottom of the tank undisturbed) is pumped into the evaporation pan (*kadhai*) installed on the furnace.

Extracted juice being strained into settling tank

III) **Juice evaporation**:

a) ***Evaporation process***: This is the most critical aspect of making high quality syrup. To improve the overall quality of sweet sorghum syrup, paying close attention to the cooking process is most important. Good quality syrup can be made after carrying out evaporation with continuous skimming of coagulated materials, which have risen to the surface. To make chemical-free syrup only okra (*Hibiscus esculentus*) aqueous extract should be used to facilitate scum removal. Filtered extract of 1.5 kg okra fruits crushed in a mixer is sufficient for effective scum removal from 300 liters of juice. Evaporation should be done with uniform heating. Initially coagulation starts when juice temperature increases. This scum should be removed during slow heating. Then okra solution should be added in three to four equal instalments in boiling juice for effective scum removal. Evaporation should not be done fast as scum gathered on the top of the juice may get dissolved during rapid boiling and then floating or settled mass problems may be seen in the syrup made. If scum is completely removed then syrup clarity is observed to be good. In case of non availability of fresh okra fruits, about 500 g powder of dried okra plants can also be used instead of fresh okra fruits for effective scum removal from 300 liters of juice.

Juice evaporation

b) ***Judging the end point of the syrup:***

As the syrup density increases, the boiling temperature rises gradually. Slow heating is required when frothing starts, as otherwise the syrup will get burned. When the temperature reaches to 105-107^{0}C with a brix of 74 to 76% as measured with hand refractometer, heating should be completely stopped. Fig. 4 shows how the temperature varies during the process of syrup making.

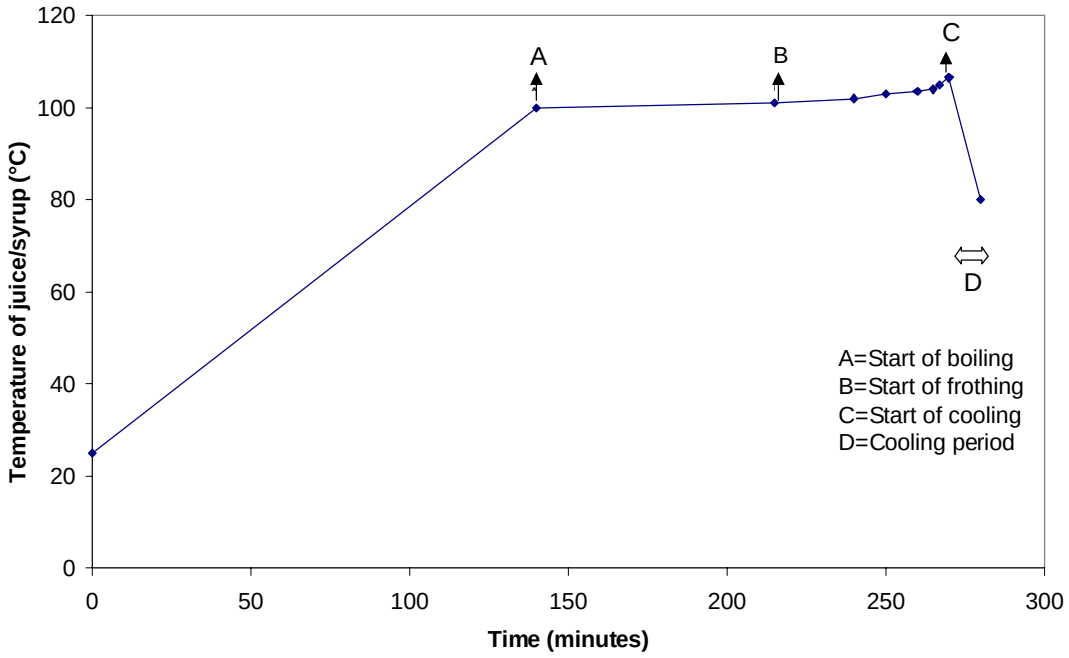

Fig.4 Typical temperature-time history for syrup making from "Madhura"

c) Cooling of finished syrup:

This is an important step followed after making the syrup because if quick cooling is not carried out, the product will have a burnt taste and the colour of the syrup will become dark brown. Therefore the syrup should be cooled to 80^0C within 10-15 minutes of preparation before filling it into sterilized bottles.

IV) **Storage of syrup**:

a) ***Bottling****:* A vacuum-based bottle filling machine has been used successfully to package the syrup so that its shelf-life is increased. The syrup should be filled in sterilized bottles to avoid fungus problems. The hot syrup should be filled in these bottles leaving 1.5 cm headspace.
b) ***Capping****:* The bottles filled with the help of the bottling machine should be capped with a crown capping machine to make them air tight.
c) ***Labelling****:* Capped bottles should be labelled properly. The label should give precise information about the syrup ingredients, date of preparation and producer's details. The bottles should be stored in a cool place.

Comparison with sugarcane:

Sweet sorghum has less water and fertilizer requirements and hence lower cost of cultivation than sugarcane(Table 3). Sweet sorghum can be an additional or an alternative raw material to sugarcane. In most situations, it will be a supplement rather than a substitute for sugarcane.

Table 3: Comparison with sugarcane

Crop	**Sugarcane**	**Sweet sorghum**
Duration (days)	Seasonal - 360 Pre-seasonal - 420 Adsali - 480	110-150
Fertilizer requirement N: P: K (Kg/ha)	Seasonal - 250:115:115 Preseasonal - 340:170:170 Adsali - 360:170:170	100:50:50
Amount of water required (mm)	Seasonal - 2000-2200 Preseasonal - 2500 Adsali - 3000-3500	400-450
Commercial cane sugar produced (T/ha-season)	9.4	2.4
Cost of cultivation of stalks (Rs./ha - season)	46,355	23,245

Conclusions:

- Sweet sorghum hybrid ‘Madhura’ can be cultivated as a multipurpose crop round the year.
- Chemical-free Madhura syrup can be a better source of calcium than honey.
- Sweet sorghum can be used as a substitute for sugarcane for syrup making.
- Sensitivity analysis showed that higher the stripped stalk yield and syrup recovery, lower would be the syrup cost.
- Comparison of sugarcane with sweet sorghum revealed that sweet sorghum is more economical to grow than sugarcane.

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