Chapter VIII: Sweet sorghum ethanol production – An economic assessment

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I. Background

Over the past two decades, India's economy has grown on average at the rate of 5-6% per annum. Energy consumption is one of the major indicators of the country's economic progress and is one of the major inputs whose use increases with economic growth and development. India ranks the sixth in terms of energy demand accounting for 3.6% of the global energy demand (Prasad et al. 2007) and this is expected to increase by 4.8% in the next few years (Gonsalves 2006). Currently, India's energy demand is primarily met through non-renewable energy sources like fossil fuels (coal, natural gas and oil). Being short in domestic production, India mainly depends on crude oil imports that have risen from 57.8 mt in 1999-2000 to 140.4 mt in 2009-10 which accounts for about 81% of the oil consumption in the country (GOI 2009).This in turn puts pressure on scarce foreign exchange resources (for instance, the import bill of $75.6 billion in 2009-10). In the near future the imports are slated to rise further with no major breakthrough in domestic oil production and rise in vehicular population that has grown at 10% per annum between 2001 to 2006 and expected to continue in the near future.

In lieu of the growing concerns of energy security and environmental pollution due to high dependence on fossil fuels, globally, the focus has shifted to resource augmentation through renewable alternative energy sources to meet the energy demand (GOI 2009). To accomplish this, mandatory blending requirements of automotive fuels with ethanol have been introduced across several countries[1] and this has promoted research efforts towards energy sources that are sustainable and economically viable.

Among several alternative renewable energy sources like wind, solar, hydro and plant biomass, energy derived from plant biomass is gaining importance

[1] The mandatory blending requirements across different countries are: 3% in the United States; 25% in Brazil; 5.75% in the European Union; 10% in China and Indonesia; 5% each in Canada, United Kingdom, Australia and India.

worldwide (Rao et al. 2007). Bioenergy derived from plant based biofuels has been the major thrust across countries as alternative energy source. Bioethanol and biodiesel[2] are the two most common biofuels that are commercially exploited. Palm, jatropha and switch grass are some of the feedstocks that are used for production of biodiesel while sugarcane, corn, sugar beet are commonly commercially exploited feedstocks for bioethanol. In India, molasses, a by-product from sugar production, is commonly used for alcohol and ethanol production. However, current estimates indicate that ethanol from molasses alone will not be able to meet the mandated requirement of blending. There is thus a need for alternative feedstock to augment ethanol production. One such feedstock that can be commercially exploited for ethanol production is sweet sorghum.

II. Sweet sorghum processing for ethanol production

In view of the potential benefits of sweet sorghum as a feedstock for bioethanol production a value chain approach model of sweet sorghum as a food-feed-fodder-fuel is being tested on a pilot basis in Andhra Pradesh to augment incomes of farmers while promoting a sustainable sweet sorghum–ethanol value chain. As part of the ICRISAT-ICAR (NAIP) sweet sorghum value chain project, ICRISAT through its Agri-Business Incubator has incubated the sweet sorghum ethanol production technology with Rusni Distilleries. Sweet sorghum being a season-bound crop can produce stalks for crushing only for a limited period (3-4 months) during the year. The stalks have to be crushed within a short span of time after harvest to avoid loss of juice due to drying-up of stalks. Hence harvesting and crushing of stalk to process into ethanol have to go hand in hand for an effective source-sink mechanism. If the processing unit or the distillery (referred to as the centralized unit (CU) throughout the chapter) is located further away from the source of cultivation, delays in transportation would lead to losses in juice content both at farm and distillery levels effecting ethanol recovery and profitability. Hence, the cultivation of sweet sorghum for the CU has to be in close proximity (< 50 kms) of the distillery. Additionally, the CU requires assured and continuous supply of raw material for at least 8-9 months of the year for economic sustainability.

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[2] For the details of future prospects of biodiesel production in India, see Biswas et al. (2010).

To overcome this problem and also allow farmers further away from the distillery to benefit from the sweet sorghum ethanol value chain, a crushing unit at the village level (referred to as decentralized crushing unit (DCU) throughout the chapter), is established in the close vicinity of the farmers' fields such that the harvested stalk is crushed on the same day for juice, boiled and converted to syrup. The syrup, which can be stored for a longer time period than the juice (over 9 months without loss in quality), can be transported to the distillery for processing into ethanol, as needed. It is in this context, that the chapter looks at the economics of processing sweet sorghum for ethanol production under the two different units, CU and DCU.

Specifically the economics looks at:

- Economics of ethanol production from sweet sorghum under CU.
- Supply and demand for ethanol in India and potential for sweet sorghum as an alternative feedstock.
- Future area requirement for sweet sorghum cultivation to meet a small proportion of mandated blending requirements if sweet sorghum is commercially exploited.
- Economics of syrup production for ethanol under DCU.
- Economic viability of DCU.

III. Economics of ethanol production under centralized unit (CU)

1. Cost and returns of sweet sorghum production and processing

The economics of processing sweet sorghum for ethanol production was analyzed based on the discussions with Rusni Distilleries (CU) on recovery of ethanol per ton of stalk and the costs incurred in processing. The economics of ethanol production without accounting for capital costs is presented in Table 1. Based on an average recovery rate of ethanol at 4.5% (45 l $t^{-1}$of stalk), feedstock priced at Rs 600 t^{-1} and ethanol priced at Rs 27 l^{-1}, the benefit cost ratio worked out to 1.22.

However, since the results presented in Table 1 did not account for capital cost of establishment of the distillery, economic viability assessment was carried out taking into consideration the various economic and financial cost in establishment of the distillery. The economic viability assessment of ethanol production from sweet sorghum was carried out through discounting techniques to examine whether ethanol production is profitable along the different segments of the supply chain of sweet sorghum under CU.

The data on various parameters used for economic viability assessment of ethanol production from sweet sorghum were collected from the distillery and presented in Table 2. For certain of the parameters where the data was not available assumptions were made based on expert opinion and secondary literature review for financial analysis.

The capacity of the plant is 40 kilo liters per day (KLPD) operating for 180 days. The reference year chosen is 2010 and the economic life of the project is 20 years. All economic costs and benefits (including by-products) are valued at current prices. The prevailing administered price of Rs 27 l^{-1} of

Table 1. Costs and returns of sweet sorghum production, Medak, Andhra Pradesh, 2007, Centralized Unit.

Sweet Sorghum (production)	
Average stalk yield (t ha^{-1})	14.7
Variable costs of production excluding family labor (Rs ha^{-1})	7,716
Gross returns (Rs ha^{-1})	10,718
Net returns excluding family labor (Rs ha^{-1})	2,999
Sweet Sorghum (ethanol production)	
Cost of the raw material (Rs t^{-1})	600
Cost of processing (Rs t^{-1})	384
Recovery of ethanol (l t^{-1})	45
Cost of ethanol (Rs l^{-1})	22
Price of ethanol received (Rs l^{-1})	27*
Benefit cost ratio	1.22

*The price of ethanol was Rs 21.5 when centralized unit was established and increased to Rs 27 l^{-1} during 2010.

ethanol announced by Government of India and recovery rate of 4.5% per ton of sweet sorghum[3] was considered for financial and economic viability assessment. The landed cost of feedstock during 2010 was Rs 1200 t^{-1} of stalk.

[3] A range was provided by the distillery on the recovery of ethanol which varies between 4 to 4.8 %. For economic feasibility assessment an average recovery of 4.5% is considered for analysis.

Table 2. Details of the indicators used in financial feasibility assessment[*].	
Labour cost (Rs $KLPD^{-1}$)	400
Cost of power (Rs KL^{-1})	2500
Chemical cost (Rs KL^{-1})	1000
Operation and maintenance cost (Rs/annum)	30000
General costs Rs (for entire life of project)	3000000
Marketing and other expenses (Rs KL^{-1})	1000
General inflation (%)	3
Output (main product and by-products)	
Recovery of ethanol per ton of stalk (l)	45
Output of ethanol (KLPD)	40
Selling price of ethanol (Rs l^{-1})	27
Escalation in price of ethanol (%)	1.5[**]
Recovery of CO_2 (t/40 KLPD)	20
Selling price of CO_2 (Rs t^{-1})	10000
Additional recovery of bagasse (t/40 KLPD)	150

* The interest on working capital is taken as 13% and debt to equity ratio as 60:40. The term loan interest assumed is 6% as loans provided for biofuels are classified as priority sector lending. A depreciation rate of 5% is assumed on the capital expenditure and repayment of 10 years.

** Though the demand for alcohol from potable and alcohol are growing at 4% per annum, the escalation in prices of alcohol is assumed on a conservative basis.

2. Methodology and data on indicators for economic feasibility assessment

The evaluation of investments on long term projects from economic assessment perspective is through discounted cash flow technique. The net present value (NPV) and internal rate of return (IRR) are commonly used measures to evaluate the projects' economic performance and investment risks. Accordingly, these two measures are used in our analysis.

3. Net present value (NPV)

NPV is an important financial index which plays a key role in decision making of long-term investment projects. A positive, higher NPV indicates that the net profits are higher so the investment may have favorable economic performance or investment is considered as economically feasible.

NPV is calculated as:

$$NPV = \sum_{n=0}^{N}(B_n - C_n)/(1+d)^n$$

Where $B_n = P_n x\ Q_n$

B_n is Benefits or the returns from the distillery by selling ethanol and by-products P_n is the ethanol selling price during year n,

Q_n is the annual production volume of ethanol in year n, d is the discount rate (the required rate of return), n is the economic life of the investment.

4. Internal rate of return (IRR)

The IRR is the rate of return refers to the average earned capacity of an investment/project during its economic life. It equals the discount rate when NPV is set to zero. In general, the IRR should be greater than the discount rate for a project for economic feasibility.

IRR is calculated as

$$IRR \Rightarrow \sum_{n=0}^{N}(B_n - C_n)/(1+d)^n = 0$$

B^n is Benefits or the returns from the distillery by selling ethanol

P^n is the ethanol selling price during year n,

Q^n is the annual production volume of ethanol in year,

d is the discount rate (the required rate of return), and n is the economic life of the investment.

5. Results and discussion

The indicators of economic viability (Table 3) showed negative NPV of the project at a discount rate of 10% (bank rate) and benefit cost ratio of 0.89 with feedstock price at Rs 1200 t^{-1} and ethanol price of Rs 27 l^{-1}. Clearly, the cost of ethanol is highly sensitive to ethanol price, feedstock price and recovery rate. It would thus be difficult for the industry to take off under the current scenario of ethanol price, feedstock price and recovery rate.

Table 3. Indicators of economic viability assessment for ethanol production from sweet sorghum.

Indicators	Feed stock price (Rs t^{-1})	Recovery rate (%)	Ethanol price (Rs l^{-1})
	1200	4.5	27
NPV (million rupees)		(344)	
Benefit cost ratio		0.89	

6. Sensitivity analysis

Sensitivity analysis was performed to derive the values of the key parameters where the project NPV becomes zero. The key parameters identified include, recovery rate, feedstock price and ethanol price.

Two scenarios were developed, one based on increase in feedstock prices and the other on anticipated increase in price of ethanol as gasoline prices are also increasing. In the first scenario, at an optimistic recovery rate of 4.9% and feedstock price fixed at Rs 1200 t^{-1} of stalk, the price of ethanol should be Rs 29 l^{-1} of ethanol where the project NPV becomes positive (Table 4). With the rise in cost of cultivation of sweet sorghum, if the stalk price increased to Rs 1500 t^{-1} with the recovery rates at 4.9% the price of ethanol has to be increased to Rs 36 l^{-1}.

In the second scenario, since it is mandated to blend petrol with ethanol, it is anticipated that ethanol prices are expected to increase, with the increase

Table 4. Scenario 1: Sensitivity analysis with change in feedstock prices.

Conversion rate (%)	Feedstock price (Rs/ton)	IRR	Expected ethanol pricing (Rs/liter)
4.9	1200	10.53	29
	1500	13.19	36

in prices of petrol. If the ethanol price was increased to Rs 37 l^{-1}, even with a lower recovery of 3.7% the centralized unit can break even. If the feedstock price was increased to Rs 1500 t^{-1} of stock with the ethanol prices remaining unchanged, the expected ethanol recovery should be 4.6% to generate zero NPV (Table 5). Sensitivity analysis carried out had shown that even with a marginal improvement in recovery the NPV becomes positive.

Table 5. Scenario 2: Sensitivity analysis with change in ethanol and feedstock prices.

Feedstock price (Rs t^{-1})	Ethanol pricing (Rs l^{-1})					
	27		32		37	
	IRR	Expected Ethanol recovery (%)	IRR	Expected ethanol recovery (%)	IRR	Expected ethanol recovery (%)
1200	8.10	5.3	13.7	4.3	9.60	3.7
1500	12.83	6.7	13.7	5.5	8.91	4.6

7. Some lessons learnt from pilot model for crushing sweet sorghum for ethanol production

The CU did not realize potential benefits from sweet sorghum value chain due to few shortcomings. One of the major shortcomings is extensive co-ordination and planning requirements in the supply chain management. Delay in crushing stalks beyond 24 hours of harvest causes low recovery of ethanol per ton of stalk. Additionally, the distillery faced some teething issues in terms of functioning of crushers, boilers and other equipment. A 40 KLPD ethanol distillery requires feedstock from 8000 ha of crop area per year spread over two seasons – 3500 ha in the rainy season (rainfed) and 4500 ha in the postrainy season (irrigated). Hence mobilizing farmers to cultivate sweet sorghum and sourcing the raw material becomes difficult. However, the observations have shown that under the centralized system, considerable scope exists to increase the efficiency of the value chain both at crop production and processing stages.

One of the major limitations of the financial viability assessment studies is that they look at benefits only from financial returns. The same limitation holds good here also. The environmental benefits in cultivation of sweet sorghum for ethanol production incorporated in viability assessment should be more attractive and hence make a case for justifying policy support and enabling environment which does not exist in the current scenario.

8. Sustainability of ethanol production from molasses and competitiveness of sweet sorghum as an alternate source

The Government of India has set an indicative target of 20% blending of ethanol with petrol and also for diesel with biodiesel across the country by

2017. Given the mandatory blending and projected demand for petrol in India, ethanol demand for blending are estimated at 5, 10 and 20% blending mandates (Fig. 1). Based on the projections, it is estimated that bioethanol requirement would be 3.46 billion L in 2020 at the rate of 10% blending.

Currently the entire bioethanol requirement has to come from molasses, a by-product of sugarcane. The availability of molasses to meet blending mandates depends on cane and sugar production that are cyclical in nature. Lower molasses availability will put pressure on molasses prices and availability of molasses for ethanol production. For instance, molasses prices in the last decade have fluctuated between Rs 1000 and Rs 5000 t^{-1} (Shinoj et al. 2011). Additionally, ethanol produced has many other alternative uses such as in the potable alcohol, chemical and pharmaceutical industry. During a normal year, cane converted into sugar generates enough molasses to produce alcohol that can meet the needs of both potable and chemical sectors (30-40% each). Another 20-30% surplus alcohol is available for conversion into ethanol for blending. During 2009, though the total supply of ethanol (2.4 million tons) was sufficient to meet total amount demanded (1.80 million tons), the utilization was more towards potable and industrial uses due to inability of the oil marketing companies (OMCs) to procure the required amount of fuel ethanol at prevailing market prices (Shinoj et al. 2011). Import of ethanol for fuel usage is currently restricted through policy and even if made free, would cost the exchequer very dearly, as the international markets for ethanol are already very tight due to demand from other biofuel-consuming countries.

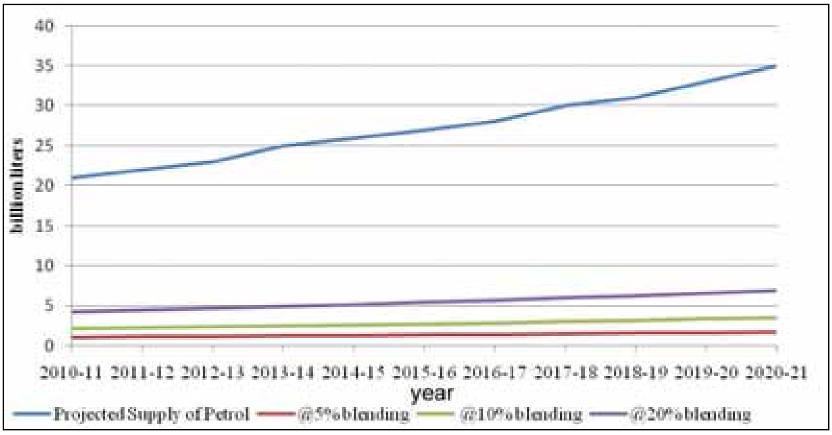

Fig. 1. Projected demand for petrol and ethanol for blending in India.

Given the scenario of 10% blending requirement, the growing demand for alcohol from potable and chemical sector (growing at 3-4% per annum) and the highest available alcohol from molasses pegged at 2.3 billion L, there will be shortage of alcohol for blending (Table 6). If molasses alone has to meet the entire requirement, an approximate area covering 10.5 million ha with 736.5 million ton of sugarcane has to be produced to meet the 10% blending requirement (around 20–23% in excess of what is required for meeting the corresponding sugar demand) which translates into doubling of both area and production. Presently, the country lacks both technology and infrastructure required to implement this. Further, it is not possible to increase the area under sugarcane beyond some limit given the fact that sugarcane is highly water intensive with a water requirement of 20000–30000 m^3 per ha per crop. Bringing additional area under sugarcane will be at the cost of diverting land from other staple food crops (Shinoj et al. 2011). Hence, ethanol production has to be augmented from alternative feedstocks like sweet sorghum.

Table 6. Availability and utilization of ethanol in India.

Year	Highest quantity of alcohol from molasses (bl)	Ethanol utilization (bl)			Ethanol for blending (bl)	
		Potable	Industry	Balance	@ 10%	Deficit/ surplus
2010-11	2.3	0.86	0.82	0.62	1.53	-0.96
2011-12	2.3	0.89	0.84	0.57	1.64	-1.14
2012-13	2.3	0.91	0.87	0.52	1.70	-1.32
2013-14	2.3	0.94	0.90	0.46	2.02	-1.53
2014-15	2.3	0.97	0.94	0.39	2.13	-1.76
2015-16	2.3	1.00	0.97	0.33	2.23	-1.99
2016-17	2.3	1.03	1.00	0.27	2.34	-2.24
2017-18	2.3	1.06	1.04	0.2	2.46	-2.51
2018-19	2.3	1.09	1.07	0.14	2.58	-2.78
2019-20	2.3	1.12	1.11	0.07	2.71	-3.09
2020-21	2.3	1.16	1.15	-0.01	2.85	-3.42

Source: Planning Commission (2003) estimates on highest available alcohol from molasses

9. Economic competitiveness

The result of relative economics of ethanol production from different feedstocks in India favors ethanol conversion from molasses (Table 7).

Table 7. Relative economics of ethanol production from different feedstocks in India.

Parameter	Sweet sorghum	Sugarcane molasses	Sugarcane juice	Grains (pearl millet & broken rice)
Cost of raw material (Rs t^{-1})	700*	3000-5000**	1200+	8000+
Cost of processing (Rs t^{-1})	384	1890	490	2800
Total cost of ethanol production (Rs t^{-1})	1084	4890-6890	1690	10800
Output of ethanol (l)	45	270	70	400
Value of ethanol (Rs t^{-1})	1215	7290	1890	10800
Net Returns (Rs t^{-1})	131	2400-400	200	0
Cost of feedstock (Rs l^{-1})	15.56	11.11-18.51	17.14	20.0
Cost of ethanol (Rs l^{-1})	24.08	18.11-25.51	24.14	27
Profit from ethanol (Rs l^{-1})	2.91	8.88-1.48	2.85	0

Note: The information on the parameters is collected from Rusni Distilleries for sweet sorghum, Nizam Deccan Sugars Pvt. Ltd. for molasses and AGRO Bio-tech, Ajitgarh, Rajasthan for grains.

*The value of by-products is not considered in the analysis. Even when the feedstock is priced at Rs 800, it becomes profitable to produce ethanol from sweet sorghum without accounting for capital costs. However, the cost of feedstock has varied between Rs 700 and 1200 t^{-1}.

**Molasses prices have ranged between Rs 3000 and 5000 t^{-1} during the last few years and hence the profitability of molasses ethanol production is highly sensitive to fluctuating molasses prices.

+The data on all the other feedstocks cost is for the year 2009. The prices of feedstock (sugarcane and grains) have increased in the recent years.

Sweet sorghum is the second best alternative for ethanol production. Though economics favors production of ethanol from molasses, there is the problem of sustainability due to the reasons already discussed. The direct conversion of sugarcane juice to ethanol is also not economical and additionally there exists concerns of food security due to diversion of land for cultivation. Similar concerns (food security, increase in prices and economic viability) exist for conversion of grains for ethanol production. Given the scenario, sweet sorghum serves as an excellent alternative source to augment ethanol production to meet the blending mandates as sweet sorghum has a few advantages:

- It does not compromise on food and feed security.
- It has a short growing period and low water requirement.
- It is a familiar crop that has a low cost of cultivation.
- Pollution levels from ethanol production are low.

The economic viability assessment does not favor well for ethanol production from sweet sorghum in the current scenario of feedstock and ethanol prices. Hence policy and enabling environment support plays a crucial role in promotion of ethanol production from alternate feedstocks like sweet sorghum.

If an enabling environment is in place it would be interesting to know what would be the future area required to cultivate sweet sorghum. A land requirement exercise was carried out to understand this.

10. Land requirement assessment for sweet sorghum ethanol production

To understand how the ethanol blending demand would translate into future requirement of sweet sorghum area and production, an analysis was performed to assess the land requirement for sweet sorghum cultivation by 2020, if it is commercially exploited for alternate source of ethanol production. It is expected that a crop like sweet sorghum would only bridge the gap in ethanol requirement supply from the existing feedstock ie, molasses. The land requirement assessment for cultivation of sweet sorghum and production is undertaken with certain assumptions with sweet sorghum meeting the entire deficit or partially in varying proportions.

Land requirement for sweet sorghum cultivation is dependent on farm productivity and recovery rate of ethanol. On farms trials have shown that farmers can harvest upto 40 t h^{-1} of sweet sorghum and there is significant scope to improve productivity on farmers' fields. Taking into consideration the research efforts to improve the productivity of sweet sorghum with higher recovery rates, the assessment is developed based on the existing scenario of 20 t h^{-1} with 4.5% recovery and a case where productivity improves to 30 t h^{-1} with 4.5% ethanol recovery. Since in the short run it would not be possible to bring larger area under sweet sorghum cultivation, the following scenarios are developed to meet the deficit of ethanol for blending at 10% mandatory blending:

a) to meet 30% of the ethanol deficit for blending;

b) 50% of the ethanol deficit for blending; and

c) 80% of the ethanol deficit for blending.

The estimates showed that to meet deficit at 10% blending by 2020 (3.47 billion liters), at 20 t ha^{-1} productivity and 4.5% recovery, the area required will be about 1.16 million hectare with the assumption that 30% of the deficit is met from sweet sorghum (Table 8). However, with the improvement in productivity at 30 t ha^{-1}, the requirement of land would be only 0.77 mh. Assuming that 80% of the deficit ethanol requirement for blending is met through sweet sorghum still a modest area of about 2.06 mh will be required to cultivate sweet sorghum. This would amount to about 50% of the current kharif (rainy season) sorghum area which is under cultivation. Given that grain sorghum area under rainy

Table 8. Land assessment for sweet sorghum cultivation in ethanol production.

Year	Deficit @ 10% blending requirement (billion liters)	Area requirement (million hectare)					
		Meeting 30% of the deficit		Meeting 50% of the deficit		Meeting 80% of the deficit	
		20 tons yield & 4.5% recovery	30 tons yield & 4.5% recovery	20 tons yield & 4.5% recovery	30 tons yield & 4.5% recovery	20 tons yield & 4.5% recovery	30 Tons yield & 4.5% recovery
2011-12	-1.66	0.55	0.37	0.92	0.62	1.48	0.99
2012-13	-1.83	0.61	0.41	1.02	0.68	1.63	1.09
2013-14	-2.01	0.67	0.45	1.11	0.74	1.78	1.19
2014-15	-2.19	0.73	0.49	1.22	0.81	1.95	1.30
2015-16	-2.38	0.79	0.53	1.32	0.88	2.12	1.41
2016-17	-2.58	0.86	0.57	1.43	0.96	2.29	1.53
2017-18	-2.79	0.93	0.62	1.55	1.03	2.48	1.65
2018-19	-3.01	1.00	0.67	1.67	1.11	2.67	1.78
2019-20	-3.23	1.08	0.72	1.80	1.20	2.87	1.92
2020-21	-3.47	1.16	0.77	1.93	1.29	3.08	2.06

season sorghum in Maharashtra is declining at an alarming rate, cultivation of sweet sorghum in these rainfed areas will provide income for farmers provided there is enabling environment in place to support sweet sorghum production for ethanol production.

IV. Economics of processing sweet sorghum for syrup production under decentralized unit

The purpose of setting up decentralized crushing units (DCU) at the village level was to crush sweet sorghum stalks and extract the juice, which then is boiled to produce syrup. It aids supply chain management particularly by reducing the volume of feedstock that would otherwise have to be supplied to centralized crushing unit and by increasing the period of feedstock availability (supply of syrup) to industry to make sweet sorghum ethanol a commercial reality. The DCU also serves as a model for farmer-centric, farmer-driven rural industry towards improving the livelihoods of small-scale sorghum farmers.

The process of DCU site selection, selection of villages and farmers, supply chain management, process of crushing and syrup production has been described in other chapter of this book. This section provides an overview of the economics of the DCU and options to increase its economic viability.

1. Operations of decentralized unit

During 2009 kharif (rainy) season under the project, 53.6 ha was under sweet sorghum cultivation involving 94 households. Sweet sorghum stalk was harvested from only 29.8 ha and crushed for syrup production since the germination was poor in the remaining area and hence was abandoned by the farmers.

From the sweet sorghum harvested area a total of 599.9 t of sweet sorghum stalk was produced in kharif 2009 with an average yield of 20 t ha^{-1}. There was however considerable variation in the yield levels, varying between 3 t to 31 t ha^{-1}. Relative to the kharif 2008 season, average stalk yield per hectare was higher by 34% increasing from 15 to 20 t ha^{-1}. The entire stalk of 599.9 t was crushed in 27 days with an average crushing capacity of 22 t day^{-1}. The average labor requirement was 54 man days with an average sweet sorghum juice production of 5,897 l day^{-1}.

The total quantity of juice extracted from crushing 599.9 t of sweet sorghum was 161,565 l and fresh bagasse weighed 419 t. In comparison to 2008, juice yield extracted from the stalk improved by about 3% in 2009. The total quantity of syrup produced from boiling 161,565 l was 28.8 t. The average syrup production per ton of stalk is 48 kg, which was 20% higher compared to syrup production of 40 kg in 2008 (Table 9).

Table 9. Comparison of sweet sorghum cultivation and crushing indicators under DCU, Ibrahimbad, Andhra Pradesh.

Indicator	2008	2009	% change
Number of farmers	102	94	-
Number of villages	7	11	-
Area sown (ha)	42	53.6	28
Area harvested (ha)	37	29.8	(19)
Stalk yield (t ha^{-1})	15	20	33
Average stalk crushed (t/day)	13	22	69
Crushing days	43	27	(37)
Average labor/day	NA	54	
Juice extracted/t of stalk	261	269	3
Syrup yield/100 L of juice	15	18	20
Average syrup/t of stalk	40	48	20

Note: % figures in parenthesis show a decline from the previous recording.

2. Cost of processing stalk to syrup

The total cost of production of 28.8 tons of sweet sorghum syrup from crushing 600 t of stalk was Rs 739,528 and the net return realized in rupees was Rs 384,248. The breakup of cost indicated that the procurement of sweet sorghum stalk as the raw material for extracting juice accounts for 57% of the total costs followed by labor cost of 29% and fuel cost of 6% besides other miscellaneous costs accounting for the remaining amount. On an average, the cost incurred in processing 1 kg of syrup was Rs 25.65 (Table 10, Fig. 2). The cost per kg of syrup production declined from Rs 31.4 kg^{-1} in 2008 to Rs 25.6 kg^{-1} in 2009. The decline in cost of production was Rs 6 kg, which is an 18% decline relative to 2008.

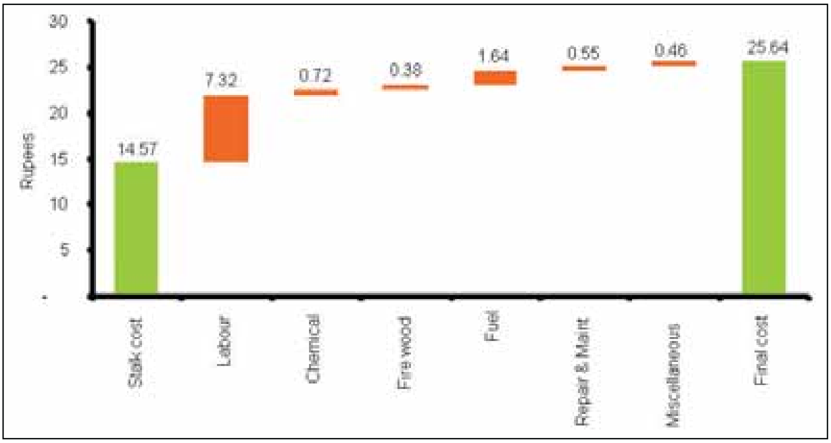

Fig. 2. Item-wise break-up of costs of processing sweet sorghum to syrup production.

Table 10. Cost of syrup production in decentralized unit, kharif 2009, Ibrahimbad, Medak, Andhra Pradesh.

Cost of item	Total costs (Rs)	Cost/kg syrup	Percent to total costs
Cost of raw material			
Cost of stalk (Rs)	419,930	14.57	57
Processing costs			
Labor costs	210,830	7.32	29
Chemical costs	20,850	0.72	3
Firewood	10,825	0.38	1
Operating expenses			
Fuel costs	47,359	0.08	6
Repair & maintenance	15,869	0.03	2
Miscellaneous	13,265	0.46	2
Total costs	739,528	25.65	100

A further break-up of labor costs revealed that the cost incurred for drying the bagasse after crushing the stalk accounted for 39% of the total labor costs t^{-1} of stalk. A total of 694 man days of labor is used for drying bagasse and is the highest labor requirement, followed by 33% for crushing and 17% for boiling juice to syrup. On an average, about 52 man days of labor are required to convert one ton of stalk to syrup, which at current wage rates amounted to Rs 8,800.

3. Returns from processing sweet sorghum

The cost incurred and returns realized per hectare and per ton of stalk for production of syrup from sweet sorghum stalk are presented below (Table 11). The gross returns and total costs per hectare realized from sweet sorghum for syrup production worked out to Rs 9,670 and Rs 24,783, respectively, with a net deficit of Rs 15,113.

Table 11. Costs and returns from sweet sorghum from syrup production (in Rs).

Indicator	Per ton of stalk	Per ha
Syrup yield (kg)	48	967
Total cost	1,232	24,783
Gross returns (Rs @ 10/kg)	480	9,670
Net returns	(752)	(15,113)

4. Break-even scenario and sensitivity analysis

The decentralized unit can be made viable either by increasing revenues through better technical outputs (juice, syrup yield) or increasing the price of syrup and other by-products sold to the end user. The second alternative is to reduce costs of processing. A combination of the two would be the best option for economic viability. Break-even scenarios of syrup production per ton of stalk and per hectare of sweet sorghum are presented (Table 12). The figures in bold indicate the break-even scenario pertaining to syrup production.

Sensitivity analysis for the break-even scenario of syrup production from sweet sorghum reveals that syrup production from the existing level of 48 kg of syrup per ton of stalk has to be increased to 124 kg of syrup, or alternatively, the price of syrup has to be increased to Rs 26 kg^{-1} to make the unit viable.

Table 12. Break-even scenarios for syrup production from sweet sorghum (per ton and per hectare of stalk).

Indicator	Break-even scenario/ton of stalk			
	Current scenario	Juice & syrup yield increase	Price increase	Cost decrease
Syrup yield (kg)	48	124	26	48
Total cost (Rs)	1,232	1,232	1,232	480
Gross returns (@ Rs10/kg)	480	1,240	1,248	480
Net returns (Rs)	-752	8	16	0
Break-even scenario/ha				
Syrup yield (kg)	967	2,480	967	967
Total cost (Rs)	24,783	24,783	24,783	9,670
Gross returns (@ Rs 10/kg)	9,670	24,800	24,794	9,670
Net returns (Rs)	-15,113	17	11	0

5. Options for increasing returns

Currently, the pricing of syrup for ethanol is at Rs 10 kg^{-1}. Since a monopsonic (only buyer) market exists in the industry, there is no better bargaining power to increase the prices. In the long run, with the establishment of additional industries for processing syrup to ethanol, higher prices realized will help in making the unit more viable. Other options include sale of syrup to the food industry. Under the project, a small quantity of sweet sorghum syrup was sold to the food industry on a trial basis (as the use of sweet sorghum syrup is still being evaluated by the industry). As the opportunity of marketing syrup for the food industry (confectionary, pharmaceutical, bakery, etc) opens up, efforts should be made to link these markets to the decentralized unit. Since we can expect a higher price for syrup from the food industry and associated industries, this would help in making the decentralized unit viable for syrup production, supplying syrup both for bioethanol and allied sectors.

To optimize returns from syrup production, sensitivity analysis was carried out with various scenarios developed for cost decline, efficiencies in juice and syrup yield, utilization of bagasse and selling syrup in alternative markets such as food and pharmaceutical industry individually and in combination. Accordingly, an Excel-based Visual Basic (VB) tool was developed to report the economic viability of syrup production under various scenarios.

6. Viability of DCU

Currently, the DCU is managed by farmers themselves. Since the cultivation of sweet sorghum and the processing of sweet sorghum to syrup is new to the farmers, there are limitations for efficiency gains. The current production cost of sweet sorghum syrup at Rs 26 kg^{-1} needs to be reduced by increasing the juice recovery and % Brix content. Reducing unit cost of processing by improving labor efficiency will also significantly help in reducing the unit cost of syrup.

A) Importance of syrup recovery and quality

The present recovery of juice per ton of stalk is 26.9% (269 l of juice t^{-1} of stalk). If the juice recovery increases to 32% (320 l $t^{-1}$of stalk) with cost of processing remaining the same at Rs 25.65, the total yield of syrup will be 57 kg t^{-1} of stalk, instead of the present 48 kg. Hence, the cost per ton of syrup will be reduced by Rs 4.00, which is a 15% decline, or the increase in gross returns will be to the extent of Rs 4 kg of syrup.

Present recovery of syrup per ton of stalk is 48 kg at 70-80% Brix. With the increase in Brix content by 1%, the increase in recovery of syrup will be by 6%, ie, from 48 kg of syrup to 50.88 kg. With the increase in Brix content, the reduction in unit cost of syrup will be by Rs 1.44 from the current level (Rs 25.65 to 24.20), a decline of 6%. Alternatively, both increases in juice and syrup recovery will have a multiplicative effect on productivity gains (Fig. 3).

Fig. 3. Reduction in unit cost of syrup due to improvement in juice yield.

B) Importance of selling bagasse as fodder

Presently, the price received for bagasse sold to the fodder industry is Re 1 kg^{-1}. Since there is scope for value addition from bagasse sold for fodder, efforts should be made in this direction to market a better product to realize higher prices.

The current rate of conversion of a ton of stalk to juice is 26.9% (269 l) with 700 kg available as wet bagasse. Only about 30% (210 kg) of the wet bagasse (700 kg) can be used as fuel and fodder for livestock after drying. About 45% of the dry bagasse (94.5 kg) is utilized as fuel for converting juice to syrup and the remaining 55% (115 kg) of the bagasse left over can be sold as fodder for livestock.

With the assumption that value realized from a kilogram of bagasse is Re 1, the total value for 115.5 kg of bagasse that is left over after use as fuel for the pans will be Rs 115.5. With better utilization of bagasse, the cost of processing a ton of stalk (Rs 1,231 for both raw material and processing) will reduce by Rs 115.5 (1,231-115.5=1,115.5), and hence the unit cost of syrup production will reduce from Rs 25.65 to Rs 23.23, a decline of Rs 2.40 kg-1 or 9% decline in cost. In other words the gross returns will increase by Rs 2.40 kg^{-1} of syrup due to additional returns from selling bagasse. Fig. 4 below presents a graphical representation of reduction in unit cost of syrup/ increased returns because of additional returns from bagasse.

C) Importance of labor efficiency

At present, the labor cost of producing syrup from sweet sorghum stalk is high, and comprises 29% of the total processing cost. There is scope for improving labor efficiency and crushing efficiency through mechanization to reduce the cost of processing by 40 to 50%. Of the total cost of processing ie, Rs 11.07 for one kg of syrup (excluding cost of raw material), the labor cost is Rs 7.32. If the labor efficiency improves by 30%, the reduction in cost of labor will be Rs 2.19. The labor cost will thus be reduced from Rs 7.32 to Rs 5.12 and the reduction in cost of syrup because of labor efficiency alone would be by 8%, ie, from Rs 25.65 to Rs 23.45. If the labor efficiency improves by 40%, the reduction in cost of syrup will be by Rs 2.92, ie, to Rs 22.72 from Rs 25.65, and 50% improvement in labor efficiency will reduce the cost by Rs 3.66.

To optimize returns from syrup production and reduce the cost of syrup production, sensitivity analysis was carried out with various scenarios. Thus there is scope to improve overall efficiency gains in labor, juice and syrup recovery and by-product utilization to reduce per unit cost of syrup production. One of the scenarios developed below shows that a modest increase in syrup and juice efficiency by 40%, decline in cost of labor by 40% and additional returns from utilization of bagasse for livestock feed by 15% will reduce cost of syrup production to Rs 17 kg^{-1} from Rs 25.65.

V. Summary and conclusions

The economic and financial viability analysis under the CU has shown that viability of ethanol production from sweet sorghum depends on the ethanol and feedstock pricing, besides the recovery rate of ethanol. A marginal improvement in recovery to 4.9 % from the current level of 4.5%, with feedstock price fixed at Rs1200 t^{-1} of stalk ethanol production becomes attractive at Rs 29 l^{-1}. The current administered price of ethanol in India is Rs 27 l^{-1}. With the rise in cost of cultivation of sweet sorghum, if the stalk price increases to Rs1500 t^{-1} with the recovery rate remaining the same at 4.5%, the price of ethanol has to be increased to Rs 36 l^{-1}. This analysis does not take into account the expected environmental benefits of producing ethanol from sweet sorghum due to unavailability of data. The economic viability assessment would become more attractive with the environmental benefits incorporated and can make a better case for justifying policy support. With further improvements in crop and processing technology for ethanol production, the overall profitability of sweet sorghum cultivation and processing can be increased.

The estimates on the demand side of ethanol blending show deficits from the current level of supply. The estimates show that the demand is going to outstrip supply. With the highest available alcohol from molasses at 2.3 billion l and further with the inability to increase area under sugarcane (due to adverse impacts on food production), the future supply of bioethanol has to be augmented through alternative feedstock. Hence, it calls for the attention of policymakers to provide policy support to the industries in the form of 'infant industry sops' in the initial years so that they can sustain the losses incurred in the beginning.

The potential food versus fuel conflict from the diversion of crop land for cultivation of sweet sorghum does not arise as it meets the multiple requirements of food, fuel and fodder for the smallholder farmers. Land requirement assessment for sweet sorghum cultivation has shown the area required for cultivation to be a modest 1.16mh with the assumption that 30% of the mandated 10% blending deficit is met from sweet sorghum at 20 t^{-1} ha productivity with 4.5 % recovery.

Given that grain sorghum area under rainy season in Maharashtra (the biggest state cultivating sorghum in India) has decelerated in the last decade, cultivation of sweet sorghum in these rainfed areas will provide income for farmers provided there is enabling environment in place to support ethanol production from sweet sorghum under CU. The relative economics augur well in the agro-ecological regions of Maharashtra and Andhra Pradesh where predominantly sorghum is cultivated. Since ethanol production is from the stalks the harvested grain from sweet sorghum it adds to the food basket and the diverted land for ethanol production will not compromise on food production.

The results of the economic assessment of crushing sweet sorghum and value addition under the DCU has shown that production of syrup can be made viable by improving yield of sweet sorghum stalks, system efficiencies such as crushing and labor use, and mechanization of the whole process. The decentralized system was managed by the growers of sweet sorghum (farmers' association). This was a new task area for them, and there are limitations of efficiency gains leading to high processing costs. The initial technology used for crushing the stalks was not tailor-made for a crop like sweet sorghum. The value realized by supplying syrup to the distillery was also low because of further processing costs incurred by the processor to convert it to bioethanol. Consequently, the decentralized unit was incurring losses. A major challenge, therefore, is to bring down the cost of processing syrup in the decentralized unit. In view of the potential benefits of syrup for bioethanol production and food industry, efforts should be made to improve the technology for processing of sweet sorghum syrup, reduce cost of bioethanol production, add value to bagasse utilization, and provide capital assistance for small-scale entrepreneurs. In the long run this will be a boon for smallholder farmers of rainfed regions as this will aid in development of agro-enterprise development at the village level and contribute in enhancing their income through generation of additional employment.

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