Chapter 7

SWEET SORGHUM: A SMART CROP TO MEET THE DEMANDS FOR FOOD, FODDER, FUEL AND FEED

G. Basavaraj,* P. Parthasarathy Rao,* C. Ravinder Reddy,* A. Ashok Kumar,* S. Datta Mazumdar,* Y. Ramana Reddy,† P. Srinivasa Rao,* S.M. Karuppan Chetty* and Belum V.S. Reddy*

**International Crops Research Institute for the Semi-Arid Tropics*
†International Livestock Research Institute, Patancheru 502 324, Andhra Pradesh, India

Sweet sorghum is a C4 plant with high photosynthetic efficiency producing high biomass with sugary stalks in a short time (4 months) under rain-fed conditions. The stalks can be crushed to make juice, which can be fermented to produce ethanol or boiled to produce syrup. The syrup can be converted to ethanol or to food grade quality syrup to be used as sweetener by the food industry. This chapter highlights income generating opportunities for smallholder farmers from sweet sorghum cultivation and processing through small scale agro-enterprise. This pilot project was conducted by ICRISAT by establishing a Decentralized Crushing Unit (DCU) at the village level to crush sweet sorghum stalks, extract juice and boil it to produce syrup to be used for various industrial uses (ethanol and food). The bagasse (fiber left over after crushing) was used as livestock feed or as fuel. The benefit–cost ratios (BCR) for the options explored indicate that a simple value addition in the form of chopping sweet sorghum stover provides the highest BCR of 2.56, though the sustenance of the agro-enterprise depends on the availability of multiple feedstocks like maize and sorghum stover

for optimum capacity utilization and profitability. This is followed by syrup production for the food industry. The establishment of small scale enterprises will pave the way for micro-entrepreneurship at village level and enhance income and employment opportunities, in the process reducing rural poverty.

Background

At present, energy demand for transport in India is primarily met through non-renewable energy sources like fossil fuels. Being short in domestic production, India depends mainly on crude oil imports for its energy needs. In the near future, oil imports are slated to rise further with no major breakthrough in domestic oil production. A compounding factor is the rise in the number of vehicles on the road, which has grown by 10% each year between 2001 and 2006,[1] and is expected to rise further. Against this backdrop, there is a renewed interest in energy augmentation through biofuel crops. One such promising biofuel crop is sweet sorghum, whose sugar-rich stocks can be crushed to produce juice, then fermented into bioethanol, and used to make a blended fuel replacing conventional gasoline (Reddy *et al.*, 2005).

Sweet sorghum is a C4 plant with high photosynthetic efficiency. It produces a high biomass (upto 40–50 tha^{-1}) in a short time (4 months) under rain-fed conditions (Reddy *et al.*, 2005). One advantage of sweet sorghum compared with other crops is that using sweet sorghum for fuel does not reduce its contribution as a food source because the grain can be harvested for food, and the bagasse — the fiber that remains after the juice used for biofuel has been extracted — may be used for fodder (Nalini Kumari *et al.*, 2011). Hence, sweet sorghum is a "smart" crop, which meets the triple requirements of food, fuel and fodder.

To assess the potential benefits of sweet sorghum as feedstock for bioethanol production, a new pilot program is being tested in the state of Andhra Pradesh, under the partnership of International Crops

[1] Authors' estimate based on MoRTH (2006).

Research Institute for
Council of Agricultural
Innovation Project (N
approach to augment f
sweet sorghum–ethano
ject is to provide greate
tunities for farmers and
supplying an environm
example of a successful
duction, this paper ex
development from swe

Sweet Sorghum Sy

Working with a ce

The project adopted t
(ICRISAT, 2008), wh
processing, value additi
After harvesting, sw
a short time to avoid lo
ing and crushing of sta
hand and the cultivatio
than 50 km from the d
ghum was initially proc
a private sector partne
Medak district of Andh
produce 40 kiloliters
ICRISAT's Agri-busine
The M/s distillery
were linked to the dist
governmental organiza
stalks to the distillery a
also liaised with resear
general and to provide
tation of the value ch
Figure 1.

Research Institute for the Semi-Arid Tropics (ICRISAT), Indian Council of Agricultural Research (ICAR), and National Agricultural Innovation Project (NAIP). The project promotes a value-chain approach to augment farmer incomes, while promoting a sustainable sweet sorghum–ethanol value chain. The overall objective of the project is to provide greater employment and income-generating opportunities for farmers and other stakeholders in the value chain, while supplying an environmentally friendly energy source. Through the example of a successful sweet sorghum value chain for ethanol production, this paper explores the opportunities for agro-enterprise development from sweet sorghum.

Sweet Sorghum Syrup for Bioethanol

Working with a centralized distillery

The project adopted the value chain model called "Seed to Tank" (ICRISAT, 2008), which encompasses sweet sorghum production, processing, value addition and marketing.

After harvesting, sweet sorghum stalks have to be crushed within a short time to avoid loss of juice due to drying. Hence, the harvesting and crushing of stalk to process into ethanol have to go hand-in-hand and the cultivation area of the crop ideally should be no more than 50 km from the distillery. In the case of this project, sweet sorghum was initially processed into ethanol in a distillery established by a private sector partner M/s Rusni Distilleries Pvt. Ltd., located in Medak district of Andhra Pradesh. The distiller had the capacity to produce 40 kiloliters of ethanol per day, and it was incubated in ICRISAT's Agri-business and Innovation Platform.

The M/s distillery was a 'centralized unit,' meaning that farmers were linked to the distillery through a partnership with a local non-governmental organization (NGO), whose role was to deliver the stalks to the distillery and to process payments to farmers. The NGO also liaised with research organizations to promote the program in general and to provide technological assistance. A schematic presentation of the value chain under a centralized unit is presented in Figure 1.

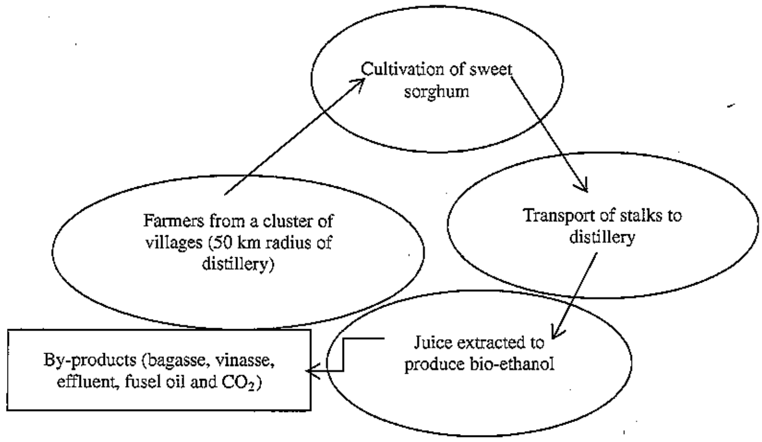


Figure 1. Schematic sweet sorghum value chain for ethanol production — centralized unit

Using the centralized distillery presented several challenges, namely:

- Using a centralized distillery, a typical ethanol yield of 40 kiloliters per day requires raw material from 8,000 ha of crop area per year spread over two seasons — 3,500 ha in the rainy season (rain-fed) and 4,500 ha in the post-rainy season (irrigated), which requires the mobilization of a large number of farmers (on average 1 farmer would cultivate 1 ha under sweet sorghum) preferably within a 50 km radius of the distillery. This presented significant limitations, namely: Finding 4,500 ha with irrigation facilities during the post-rainy season was a daunting task in the semi-arid tropics with limited access to irrigation.
- Organizing such a large number of farmers (3,000) to undertake sweet sorghum cultivation within the specified area (<50 km) also proved difficult.
- Farmers located more than 50 km from the distillery were burdened by high transportation costs owing to the bulkiness of stalks.
- A 24-hour delay in transportation of stalks to distilleries after harvest led to a reduction in stalk weight by up to 20%, depending on climatic conditions, causing economic loss to grower and processor.

Given these limitatio
decentralized crushing un
added benefit of being a

DCU: An innovative
sorghum syrup

A crushing unit at the vi
et al., 2009) in the close
lage, Medak district of
established in consultatio
farmers and was based on
existing natural resource
feasibility of cultivating
spread across seven villa
cultivate sweet sorghum
sweet sorghum stalks can
which the juice is boiled
syrup (between 70% and
juice — over 24 months

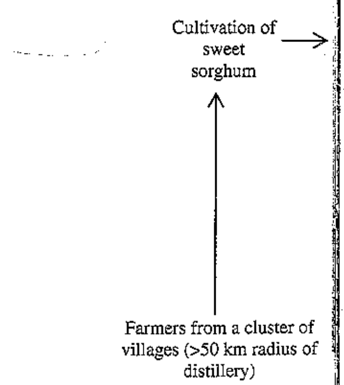


Figure 2. Schematic sweet
ethanol — DCU

Given these limitations, project coordinators decided to establish decentralized crushing units (DCU) at the village level, which had the added benefit of being a small-scale agro-enterprise.

DCU: An innovative approach to making sweet sorghum syrup

A crushing unit at the village level was established (Ravinder Reddy *et al.*, 2009) in the close vicinity of farmers' fields at Ibrahimbad village, Medak district of Andhra Pradesh. The site of the unit was established in consultation with the local NGO, village leaders, and farmers and was based on several socio-economic criteria, namely, the existing natural resource base, social harmony, agro-ecology and the feasibility of cultivating sweet sorghum. A total of 514 households spread across seven villages of Ibrahimbad cluster were selected to cultivate sweet sorghum. Having a DCU means that the harvested sweet sorghum stalks can be crushed and juiced on the same day, after which the juice is boiled into syrup (Figure 2). The brix content of syrup (between 70% and 80%) allows syrup to be stored longer than juice — over 24 months — without loss of fermentable sugars, and

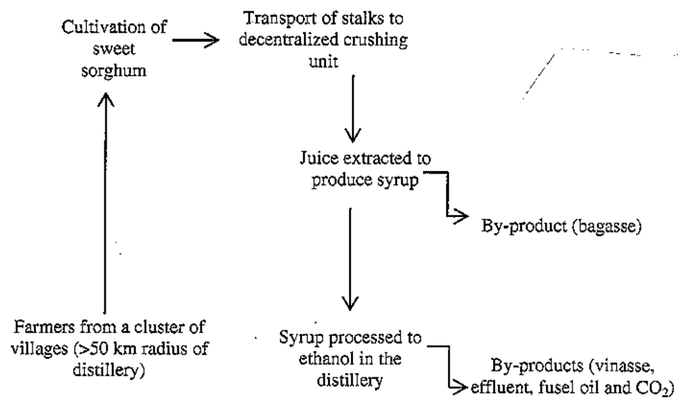
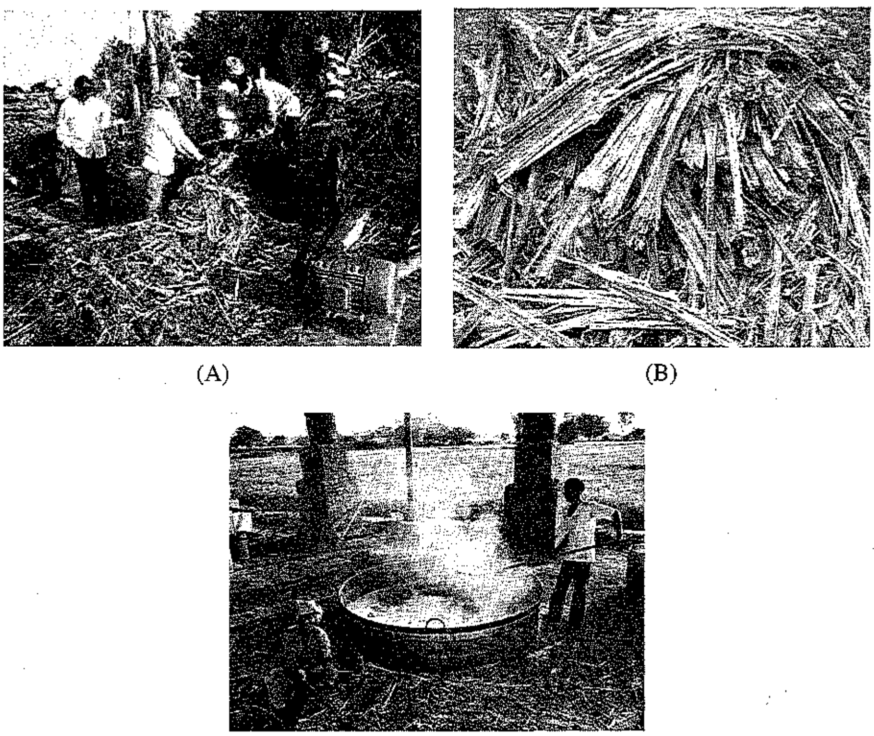


Figure 2. Schematic sweet sorghum value chain for syrup production to ethanol — DCU

can be processed to produce ethanol at the distillery. The decentralized approach makes the supply chain more efficient by reducing the volume of feedstock to be supplied to the centralized crushing units and by increasing the period of feedstock availability (supply of syrup) to industry (Figure 3). Further, the establishment of DCUs benefits the farmers farther away from the distillery as long as they have a crushing unit relatively close to them.

The crushing of sweet sorghum into syrup continued for 4 years under this project, and was carried out using a modified sugarcane crusher. (A crusher customized for sweet sorghum had not been designed.) The crushing capacity was 2 tons per hour and



(A) (B) (C)

Figure 3. Decentralized sweet sorghum crushing unit: (A) crushing; (B) bagasse; (C) boiling the juice to produce syrup

the crushing efficiency
crushing season, time l
temperature. During th
grown only in rainy seas
crushing unit could cru
The initial cost of the un
ICAR and NAIP (Ravin

To meet the raw mat
backward linkages had
established between Far
unit facilitated the mobi
and the dispensation of
harvesting schedules to
Inputs such as fertilizer
farmers, payment for w
made to farmers. Othe
advice on crushing the
with contract agreeme

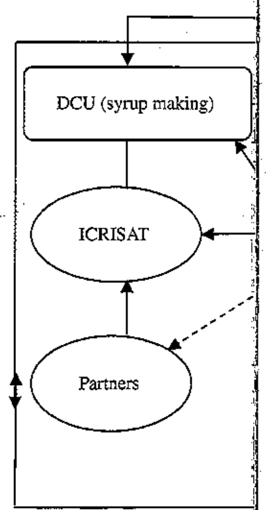
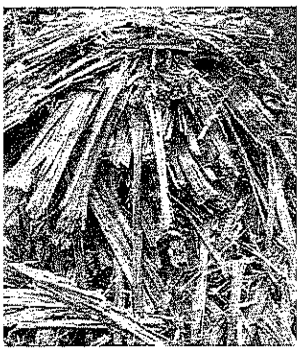


Figure 4. Flow ch

[2]Solid lines in the figure repr

listillery. The decentral-
fficient by reducing the
ntralized crushing units
ability (supply of syrup)
ment of DCUs benefits
as long as they have a

p continued for 4 years
ʒ a modified sugarcane
orghum had not been
tons per hour and



(B)

:: (A) crushing; (B) bagasse;

the crushing efficiency depended on the sweet sorghum genotype, crushing season, time lapse between harvesting and crushing, and temperature. During the rainy season (sweet sorghum is presently grown only in rainy season), in 30 days, working 8 hours a day, the crushing unit could crush sweet sorghum cultivated on 25–30 ha. The initial cost of the unit for the pilot phase was jointly financed by ICAR and NAIP (Ravinder Reddy *et al.*, 2009).

To meet the raw material requirements of the DCU, forward and backward linkages had to be established (Figure 4). The linkage established between Farmers' Association, local NGO, and crushing unit facilitated the mobilization of farmers, the distribution of seed, and the dispensation of technical advice related to production and harvesting schedules to supply sweet sorghum stalks to the unit. Inputs such as fertilizer and herbicides were supplied on credit to farmers, payment for which was later deducted from the payment made to farmers. Other forward linkages included the technical advice on crushing the stalk to produce juice and syrup, assistance with contract agreements between farmers and distillery, and

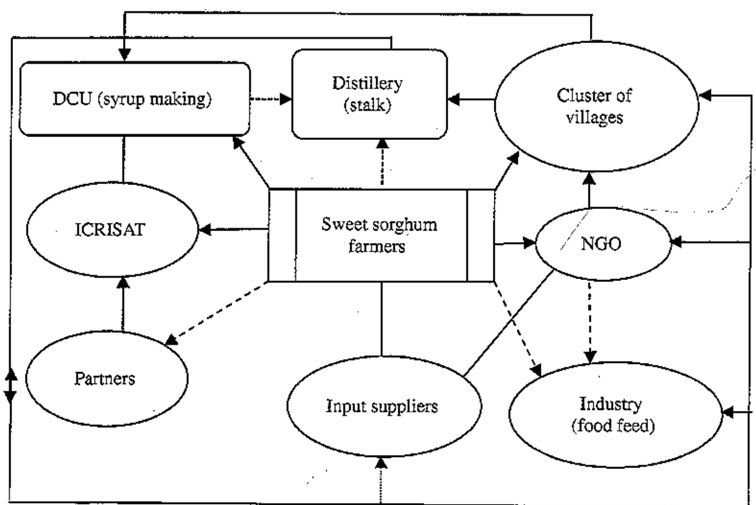


Figure 4. Flow chart of linkages in sweet sorghum value chain[2]

[2] Solid lines in the figure represent strong linkages, dotted lines weak linkages.

information on value addition of the bagasse being provided by consortium partners.

Economics of syrup production

Under the pilot project, the crushing unit produced sweet sorghum syrup between 2008 and 2012. Below, we provide an overview of the economics of syrup production for the years 2008–2010. Our discussion is in two parts: the cost of sweet sorghum cultivation and the cost of processing sweet sorghum to syrup.

Economics of sweet sorghum cultivation

Data on the cost of cultivation was collected from farmers who were part of the project and analyzed for various costs, gross and net returns, and input–output ratios of the crop. The cost of cultivation included both paid out costs and imputed costs. In 2008, total cost of cultivating sweet sorghum was Rs 15,804 (US$316)/ha with an average stalk yield of 15 t/ha during 2008.[3]

Economics of syrup production

Data for syrup production was analyzed for the stalks supplied to the crushing unit by 102 households in 2008–2009 and 94 households during 2009–2010. A total of 600 tons of sweet sorghum was crushed in 2009 with an average crushing capacity of 22 tons per day (Table 1). The average labor requirement was 54 person days, with an average production of 5,897 liters of juice per day. The total quantity of juice extracted from crushing 600 tons of sweet sorghum was 161,565 liters with a total quantity of 28.8 tons of syrup.

The total cost of production of 28.8 tons of sweet sorghum syrup was Rs 739,528 (US$14,790) and on average, the cost incurred in processing 1 kg of syrup was Rs 25.65 (US$0.50) during 2009.

[3] Rs is the abbreviation for India currency rupees. At 2012 exchange rate, US$1 = Rs 50.

Table 1: Swee
DCU, Ibrahim

Indicator
Number of farr
Stalks crushed
Stalk yield (t/h
Average stalk c
Crushing days
Juice extracted
Syrup/t of stal

Table 2: Cost of syrup
Andhra Pradesh

Cost Item
Cost of raw material
Stalk yield (tons)
Cost of stalk (Rs)
Processing costs
Labor costs
Chemical costs
Firewood
Operating expenses
Fuel costs
Repair and maintenance
Miscellaneous
Total costs

The cost of syrup progr
kilogram during 2011.
stalks) accounted for 57
by labor costs (29%) and
age the crushing unit; th
cost of syrup production

Table 1: Sweet sorghum crushing indicators under DCU, Ibrahimbad, Andhra Pradesh

Indicator	2008	2009
Number of farmers	102	94
Stalks crushed (tons)	557	600
Stalk yield (t/ha)	15	20
Average stalk crushed (t/day)	13	22
Crushing days	43	27
Juice extracted/t of stalk	261	269
Syrup/t of stalk	40	48

Table 2: Cost of syrup production under DCU (2009), Ibrahimbad, Andhra Pradesh

Cost Item	Total Costs (Rs)	Percent of Total Costs
Cost of raw material		
Stalk yield (tons)	600	
Cost of stalk (Rs)	419,930	57
Processing costs		
Labor costs	210,830	29
Chemical costs	20,850	3
Firewood	10,825	1
Operating expenses		
Fuel costs	47,359	6
Repair and maintenance	15,869	2
Miscellaneous	13,265	2
Total costs	**739,528**	**100**

The cost of syrup progressively decreased to Rs 22 (US$0.44) per kilogram during 2011. Table 2 shows that raw material (sorghum stalks) accounted for 57% of the total costs of production, followed by labor costs (29%) and fuel (6%) (Figure 5). Currently farmers manage the crushing unit; there is still significant scope for reducing the cost of syrup production with the proper protocols in place.

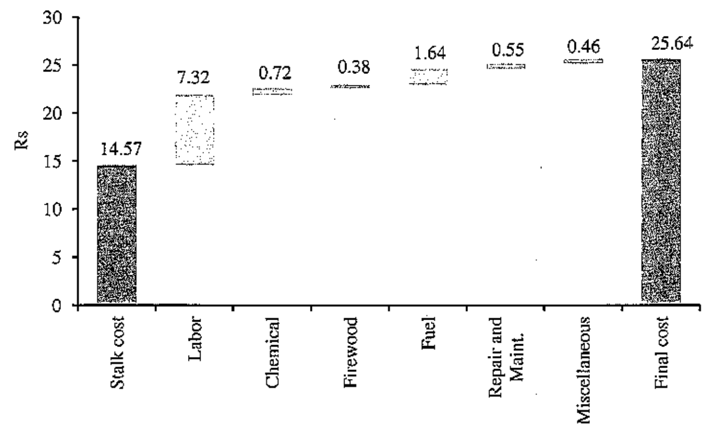


Figure 5. Item-wise break-up of costs of processing sweet sorghum to syrup production

Table 3: Costs and returns to syrup production for ethanol

Indicator	Per Ton of Stalk (Rs)	Per Hectare (Rs)
Cost of syrup production	1,232	24,783
Gross returns (@ Rs 10/kg)	480	9,670
Net returns	(752)	(15,113)
Benefit cost ratio	0.38	

Note: Syrup was sold to the distillery at Rs 10/kg.

The gross returns realized per hectare and per ton of sweet sorghum stalk produced for syrup were Rs 9,670 (US$193) and Rs 480 (US$10), respectively (Table 3). Currently, the purchase price of syrup by the distillery for ethanol conversion is Rs 10 (US$0.02)/kg. The pricing is based on ethanol recovery from syrup, processing costs of syrup to ethanol, and the selling price of ethanol (based on discussions held with the distillery). The distillery requires about 3 kg of syrup to convert to 1 liter of ethanol. The government of India regulates prices for ethanol to be blended with gasoline and the 2012 administered price of ethanol was Rs 27 (US$0.5)/l. It is not feasible for the distillery to pay more for the syrup unless and until the government revises the ethanol price.

Several other alterna
ing cost of syrup produ

- Reducing labor cost
- Further mechanizat
ciency and extractio
- Increasing the brix
genotypes.

The above-mentione
syrup extracted by 50%

Benefits of the DC

The long-range goal
agro-enterprise is to re
this was envisioned thro
duce and creating new
enhance the livelihoods
DCU in Ibrahimbad vil
The tangible benefits in
especially during the p
period for agricultural a
ject generated about 4
household. The moneta
ated was about Rs 6,40
rate prevailing during 2
intangible benefits were
a small-scale village-leve
due to increased income

Besides developing
more alternatives for agr
to make the DCU via
smallholders from sweet

- Sweet sorghum syru
- Value addition for b

Several other alternatives were also explored to reduce the operating cost of syrup production, namely:

- Reducing labor costs (labor efficiency);
- Further mechanization of production (improving crushing efficiency and extraction efficiency);
- Increasing the brix (sugar content) of stalks through improved genotypes.

The above-mentioned efforts resulted in increasing the amount of syrup extracted by 50% and reducing labor costs by 28%.

Benefits of the DCU as an agro-enterprise

The long-range goal of establishing a village-level small-scale agro-enterprise is to reduce poverty and unemployment. Achieving this was envisioned through producing value-added agricultural produce and creating new employment opportunities in the villages to enhance the livelihoods of the rural population. Establishment of a DCU in Ibrahimbad village had both tangible and intangible benefits. The tangible benefits included increased employment opportunities, especially during the post-rainy season, which tends to be a lean period for agricultural activities in the drylands. On average, the project generated about 40 additional person days of employment per household. The monetary value of the additional employment generated was about Rs 6,400 (US$128) per household/annually (the wage rate prevailing during 2012 was Rs 160 (US$3) per day). Some of the intangible benefits were an improvement in farmers' ability to manage a small-scale village-level agro-enterprise and enhanced food security due to increased incomes.

Besides developing sweet sorghum syrup as a fuel source, two more alternatives for agro-enterprise development have been explored to make the DCU viable and provide alternative opportunities to smallholders from sweet sorghum:

- Sweet sorghum syrup for use in food industry and,
- Value addition for bagasse.

Alternative Options for Agro-Enterprise Development from Sweet Sorghum

Syrup for use in the food industry

An alternative use for sweet sorghum syrup is in the food industry, provided the product is food grade. Food grade syrup can be used as a sugar replacement in certain value-added food products. In addition, the syrup, which is rich in iron, calcium and potassium, also has potential pharmaceutical applications.

If sweet sorghum syrup were to compete with sugar cane, it could claim a share of the country's sugar industry, which in 2011 produced 24 million ton of sugar (Indian Sugar Mills Association, 2012) valued at US$144 million (at current prices of Rs 27 (US$0.5) per kilogram of sugar). If just 1% of sugar market value were tapped, the market potential for sweet sorghum would be US$1.44 million.

The processing of sweet sorghum juice for food grade syrup involves the removal of leaves and leaf sheath from the stalks before crushing. The juice is then pre-heated and clarified. The clarified juice is then further concentrated to syrup by heating and slow evaporation ensuring the taste profile is not compromised. Some of the products developed by the NutriPlus Knowledge Program of the Agri-business and Innovation Platform, ICRISAT, using food grade sweet sorghum syrup include ready-to-serve beverage, tamarind–sweet sorghum sauce, sweetened tomato sauce, and energy bars (Figure 6).

When it comes to making value-added food products from sweet sorghum, opportunities exist for the entrepreneur to establish an agro-enterprise that integrates production and processing at the village level. Strict regulations and stringent quality requirements of the food industry need to be observed, however, which is likely to increase the costs of production.

The economics of syrup for food industry

The entrepreneur has the option to either cultivate sweet sorghum and produce syrup or purchase stalks from the farmer and convert it to syrup. The economics of syrup production presented below in

Figure 6. (A) Ready-to-serv
sorghum sauce; (C) Sweet sor

Table 4 is for a stand-alo
only the returns realized
included in the econom

Value addition to b

The by-product of bagas
is produced for ethanol
livestock feed and value
or producing feed block
tunities for farmers. The
into facilities that produ
The additional returns g
product can enhance the
entrepreneurs.

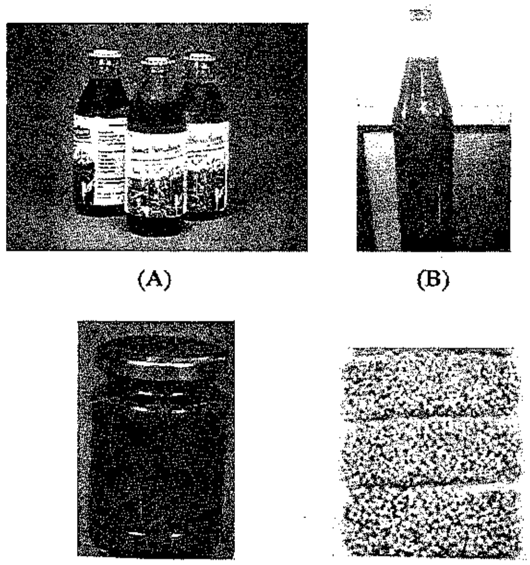
se Development

s in the food industry,
ıe syrup can be used as
ɔod products. In addi-
ınd potassium, also has

ʼith sugar cane, it could
ʼhich in 2011 produced
sociation, 2012) valued
(US$0.5) per kilogram
ere tapped, the market
14 million.
for food grade syrup
from the stalks before
ified. The clarified juice
g and slow evaporation
. Some of the products
ım of the Agri-business
d grade sweet sorghum
ıarind–sweet sorghum
ırs (Figure 6).
ɔd products from sweet
reneur to establish an
d processing at the vil-
ity requirements of the
ʼer, which is likely to

stry

ıltivate sweet sorghum
e farmer and convert it
ɔn presented below in



(C) (D)

Figure 6. (A) Ready-to-serve sweet sorghum-based beverage; (B) Tamarind–sweet sorghum sauce; (C) Sweet sorghum-based tomato sauce; (D) Sweet sorghum crispies

Table 4 is for a stand-alone agro-enterprise producing only syrup and only the returns realized from by-product (bagasse) value addition are included in the economic analysis.

Value addition to bagasse

The by-product of bagasse is obtained regardless of whether the syrup is produced for ethanol or for the food industry. Bagasse is a good livestock feed and value addition to bagasse in the form of chopping or producing feed blocks or pellets provides additional income opportunities for farmers. The processing of bagasse can also be integrated into facilities that produce syrup for ethanol or for the food industry. The additional returns generated from the value addition of this by-product can enhance the attractiveness of the business proposition for entrepreneurs.

Table 4: Economics of syrup production for food industry

Indicator	Value (Rs)
Cost of sweet sorghum per ton of stalk	800
Processing cost of sweet sorghum to syrup per ton of stalk[a]	531
Total cost of syrup per ton of stalk	1,331
Returns from syrup per ton of stalk[b]	1,755
Returns from bagasse per ton of stalk[c]	115
Gross returns per ton of stalk	1870
Net returns per ton of stalk	539
Benefit cost ratio	1.40

[a]The cost escalation in producing food grade syrup is not accounted for in the analysis.
[b]The sale price of syrup is assumed to be Rs 27/kg which is equivalent to price of sugar at 2012 prices.
[c]Returns from sale of bagasse is at the rate of Rs 1.2/kg (the value realized may go upto Rs 4/kg in distant locations) for surplus bagasse of 115 kg/t of sweet sorghum crushed.
Source: Authors' estimates.

The economics of bagasse processing

The current rate of conversion of a ton of stalk to juice is 27% to 30% (269–3501), leaving 650–700 kg of wet bagasse. The wet bagasse is dried and used as a source of fuel during the process of syrup production. Even after using the bagasse for fuel, about 55% of it remains as surplus, however, which can serve as a good livestock feed. Consortium partner International Livestock Research Institute (ILRI) conducted research on the quality and composition of bagasse fodder, as described in Blümmel *et al.* (2009).

During 2009, the surplus bagasse was sold directly to fodder traders by an arrangement facilitated by ILRI and partners in the project. During 2010, the fodder traders chopped the bagasse and transported it by truck to their customers in Hyderabad, 70 km away. This type of value addition resulted in selling the bagasse at higher prices of Rs 0.70 (US$0.014) per kilogram during the start

Table 5: Economics o

Cost or Returns Parame
Feedstock cost (Rs/t)
Cost of other raw material
Processing cost (Rs/t)
Transport cost (Rs/t/100
Total cost
Gross returns[b]/t
Net returns/t

[a]Cost of other raw material
preparation of feedblock.
[b]The selling price of a feedbl
Source: Rows 3 and 4 are
estimates.

of season and a higher
season, which was rema
sweet sorghum stalks w
kilogram. The scope fo
ucts (feedblock, pellets
ILRI under the proje
sented only for two e
(Table 5).

The small-scale ent
stover and bagasse pro
ing labor and infrastru
based DCU. In case
agro-enterprise the re
range of Rs 2,440–9,
products. The bagasse
either syrup productio
grade syrup.

Table 5: Economics of bagasse value addition to different end products

	Bagasse Based Value Added Products	
Cost or Returns Parameters	**Feedblock**	**Chopped Bagasse**
Feedstock cost (Rs/t)	800	800
Cost of other raw material[a] (Rs/t)	8,840	—
Processing cost (Rs/t)	260	85
Transport cost (Rs/t/100 km)	260	675
Total cost	10,160	1,560
Gross returns[b]/t	20,000	4,000
Net returns/t	9,840	2,440

[a] Cost of other raw material includes molasses, bran, husk and cotton seed cake for preparation of feedblock.
[b] The selling price of a feedblock is Rs 150 and chopped bagasse is Rs 4/kg.
Source: Rows 3 and 4 are from Anandan *et al.* (2010) and the rest are authors' estimates.

of season and a higher Rs 1.2 (US$0.24) per kilogram at the end of season, which was remarkable given that the whole (*i.e.*, unextracted) sweet sorghum stalks were valued only slightly higher at Rs 0.80 per kilogram. The scope for further value addition to different end products (feedblock, pellets, mashed and chopped) was demonstrated by ILRI under the project. The economics of value addition is presented only for two end products: feedblocks and chopped fodder (Table 5).

The small-scale entrepreneur may set up a stand-alone small-scale stover and bagasse processing agro-enterprise, which will suit prevailing labor and infrastructural conditions or integrate with the syrup-based DCU. In case of a stand-alone stover and bagasse based agro-enterprise the returns realized per ton of stalk will be in the range of Rs 2,440–9,840 (US$49–197) depending on the end-products. The bagasse based agro-enterprise has to be integrated with either syrup production for ethanol or through production of food grade syrup.

Conclusions: Viable Sweet Sorghum Agro-Enterprise Options

This chapter has discussed three different options for agro-enterprises from sweet sorghum. The benefit–cost ratios (BCR) for each of the options are presented in Table 6. Through simple value addition in the form of chopping, the sweet sorghum stover provides the highest BCR of 2.56, though the sustenance of the agro-enterprise depends on the availability of multiple feedstocks like maize and sorghum stover for optimum capacity utilization and profitability. Syrup production from sweet sorghum for the food industry as an agro-enterprise integrated with chopping of surplus bagasse with a small-scale processing unit provides a BCR of 1.40. The bagasse can be stored and processed to chopped form after the syrup has been produced. This practice aids in increasing the operating window and optimum capacity utilization of the agro-enterprise. However, since setting up of an agro-enterprise for processing sweet sorghum to food grade syrup would require strict regulations, the cost of syrup would increase to meet the quality standards and cost of establishment. The benefit cost ratio of producing and processing syrup for ethanol was the least at 0.38 relative to other options explored.

The DCU was established to overcome some of the shortfalls of the centralized unit. The establishment of the crushing unit on a pilot

Table 6: BCR of different agro-enterprises from sweet sorghum

Sweet Sorghum Agro-Enterprise[a]	BCR of Agro-Enterprise	Ranking Based on BCR
Syrup for ethanol only	0.38	5
Syrup for ethanol with by-product bagasse valuation	0.98	4
Syrup for food industry only	1.31	3
Syrup for food industry with by-product bagasse valuation	1.40	2
Stover/bagasse value addition only	2.56	1

Source: Authors' estimate.

[a] Investment cost of establishing the agro-enterprise is not considered in the calculations.

basis to aid in supply chain management for the centralized unit led to alternative options for syrup utilization and establishment of alternate agro-enterprises. The direct benefits of DCU establishment as an agro-enterprise for supply of syrup to the ethanol industry provided 40 person days of employment with monetary benefits of Rs 6,400 during the lean season of agriculture.

The results of crushing sweet sorghum over a four-year period show a gradual decline in costs of syrup production by 31%. The existing costs of syrup production still are on the higher side for converting it to ethanol and there is significant scope for reducing the cost through mechanization of the DCU. Policy options and enabling environment also play a significant role in promoting the DCU as a village level agro-enterprise complementing ethanol production from the centralized unit. Capital assistance for establishment of the DCU and increase in procurement price of ethanol will help in sustainability and economic viability of the DCU.

Alternative options explored for establishing an agro-enterprise producing food grade syrup integrated with bagasse value addition has also shown to be a promising avenue. Setting up an agro-enterprise producing food grade syrup requires strict regulations to meet the quality requirements of the industry, however. Hence, these parameters and their cost implications need to be taken into consideration before establishment of the unit.

Given the scarcity of fodder and the growth of the livestock economy at the rate of 4% *per annum* in India, alternate options of sweet sorghum stover-based and bagasse-based agro-enterprise are promising. Hence, establishing a small-scale agro-enterprise for sweet sorghum stover value addition might be an economically viable proposition taking into consideration the availability of multiple feedstocks for processing (enabling utilization of capacity for more than 6 months in a year), prevailing labor supply and infrastructural conditions.

The DCUs will pave the way for micro-entrepreneurship development at village level and bring income and employment opportunities, in the process reducing rural poverty. At the same time, they may prevent (or at least slow down) rural-to-urban migration, thereby mitigating the growth of urban slums.

Acknowledgments

This research work was carried out the under National Agricultural Innovation Project (NAIP) — Indian Council of Agricultural Project, Government of India project and Common Fund for Commodities (CFC). The funding support from both NAIP and CFC is greatly acknowledged.

References

Anandan S, Khan AA, Ravi D and Blümmel M (2010) A comparison of two complete feed blocks based on sorghum stover of two different cultivars on weight gain in sheep and economy of feeding. *Animal Nutrition and Feed Technology* 10S: 101–104.

Blümmel M, Rao SS, Palaniswami S, Shah L and Reddy BVS (2009) Evaluation of sweet sorghum [*Sorghum bicolor* (L.) Moench] used for bio-ethanol production in the context of optimizing whole plant utilization. *Animal Nutrition and Feed Technology* 9: 1–10.

Indian Sugar Mills Association (2012) *Statistics.* Available at www.indiansugar.com/Statics.aspx [accessed on 24 April 2012].

ICRISAT (2008) *ICRISAT-NAIP Sub-Project on Value Chain Model for Bioethanol Production from Sweet Sorghum.* Patancheru, Andhra Pradesh, India: International Crops Research Institute for Semi-Arid Tropics.

Ministry of Road Transport and Highways (MoRTH) (2006) *Road Transport Year Book 2006–07.* Available at http://indiagovernance.gov.in/files/road-transprt-annual-report.pdf [accessed on 20 March 2012].

Nalini Kumari R, Reddy Y, Blümmel M, Nagalaxmi M, Pavani, Sudhakar Reddy, Ravinder Reddy C and Reddy BVS (2011) Effect of feeding different processed sweet sorghum bagasse based complete diet on growth and carcass traits in growing ram lambs. Paper presented at the 8th international symposium on nutrition of herbivores at Wales, UK, 6–9, September 2011.

Ravinder Reddy C, Ashok Kumar A, Reddy BVS, Karuppan Chetty SM, Sharma KK, Gowda CLL, Parthasarthy Rao P, Wani SP, Rao SS, Umakanth AV, Srinivas I, Kamal Ahmed, Blummel M, Ramana, Reddy Y and Palaniswami AR (2009) Establishment and maintenance of

decentralized sweet
Information bulletin
International Crops R
Reddy BVS, Ramesh S,
Rajashekar Kachapur
raw material for bioe
Millets Newsletter 46:

decentralized sweet sorghum crushing-cum syrup making unit. Information bulletin No. 79, Patancheru, Andhra Pradesh, India: International Crops Research Institute for Semi-Arid Tropics.

Reddy BVS, Ramesh S, Sanjana Reddy P, Ramaiah B, Salimath PM and Rajashekar Kachapur (2005) Sweet sorghum — A potential alternative raw material for bioethanol and bio-energy. *International Sorghum and Millets Newsletter* 46: 79–86.