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Study on genotypic variation for ethanol production from sweet sorghum juice☆

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ABSTRACT

Sugarcane molasses is the main source for ethanol production in India. Sweet sorghum with its juicy stem containing sugars equivalent to that of sugarcane is a very good alternative for bio-ethanol production to meet the energy needs of the country. Sweet sorghum is drought resistant, water logging resistant and saline–alkaline tolerant. Growing sweet sorghum for ethanol production is relatively easy and economical and ethanol produced from sweet sorghum is eco-friendly. In view of this, it is important to identify superior genotypes for ethanol production in terms of percent juice brix, juice extractability, total fermentable sugars, ethanol yield and fermentation efficiency. This paper presents the study on the variability observed for the production of ethanol by various sweet sorghum genotypes in a laboratory fermentor. Five Sweet Sorghum (*Sorghum bicolor* L. Moench) genotypes were evaluated for ethanol production from stalk juice (Keller, SSV 84, Wray, NSSH 104 and BJ 248). Sweet sorghum juice differs from cane juice mainly in its higher content of starch and aconitic acid. Data were collected for biomass yield; stalk sugar yield and ethanol production in five genotypes. Maximum ethanol production of 9.0%w/v ethanol was obtained with Keller variety (20% sugar concentration was used), and decreased for other genotypes. A distiller's strain of *Saccharomyces cerevisiae* (gifted by Seagram Distilleries Ltd.) was employed for fermentation. The fermentation efficiency (FE) was 94.7% for this strain. High biomass of yeast was obtained with BJ 248 variety. When the similar experiments were conducted with unsterile sweet sorghum juice (15% sugar concentration) 6.47%w/v ethanol was produced.

1. Introduction

Sweet sorghum [*Sorghum bicolor* L. Moench] is the only crop providing grain and stem that can be used as substrates for the production of sugar, alcohol, syrup, fodder, fuel, bedding, roofing, fencing and paper [1]. Sweet sorghum is an attractive feedstock for ethanol production. The juice extracted from the fresh stem is composed of sucrose, glucose, and fructose and can, therefore, be readily fermented to alcohol [2]. In the event of new Government's policy of blending ethanol at 5% in petrol, the demand for the production of ethanol from potential renewable sources has increased enormously; sweet sorghum can be grown for this purpose as a supplementary crop to sugarcane using the existing machinery of sugar mills. Sugarcane molasses are the traditional raw material for ethanol production in India. Sweet sorghum (*S. bicolor* L. Moench) has the potential of becoming a useful energy crop. It has been evaluated as an alcohol fuel crop with a promising future [3]. The primary advantages of sweet sorghum are (i) its high ethanol productivity 3.1–5.6 $m^3\,ha^{-1}\,y^{-1}$ [4], (ii) its

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Table 1 – Percent chemical composition of sweet sorghum juice of different varieties and hybrids.

Parameter	Keller	SSV 84	BJ 248	Wray	Madhura	NSSH 104
Sucrose	19.69 ± 0.02	18.57 ± 0.03	19.41 ± 0.05	18.42 ± 0.08	16.14 ± 0.05	17.09 ± 0.10
Total sugar	21.05 ± 0.05	21.00 ± 0.04	20.44 ± 0.03	19.74 ± 0.04	18.62 ± 0.05	19.10 ± 0.03
Protein	1.64 ± 0.01	1.50 ± 0.005	2.01 ± 0.01	1.04 ± 0.005	1.86 ± 0.03	2.16 ± 0.015
Ash	2.34 ± 0.01	2.18 ± 0.01	2.04 ± 0.01	2.52 ± 0.005	2.19 ± 0.015	2.14 ± 0.005
Crude fibre	6.12 ± 0.01	6.00 ± 0.02	6.32 ± 0.02	7.48 ± 0.01	5.95 ± 0.025	5.68 ± 0.02
Fat (ether extract)	0.89 ± 0.005	1.21 ± 0.005	0.92 ± 0.01	1.05 ± 0.005	0.90 ± 0.005	1.02 ± 0.002

Data are represented as mean ± standard deviation.

adaptability to diverse climatic and soil conditions [5], and (iii) its reduced need for nitrogen fertilizer [4] and water [5] when compared with corn and wheat.

Sweet sorghum may differ from grain sorghums by only a few genes, that control plant height, the presence of juice in stem, and the presence of sugar in the juice. It is also widely used for the production of forage and silage for animal feed. Efforts have been made to produce crystalline sugar from sweet sorghum juice in early 1970s in Iran. The possibilities of growing sugar beet, potato, sweet sorghum and vines for the production of ethanol for use as a fuel in Italy are reviewed [6]. The recent oil crises and Gulf war renewed the commercial production of sweet sorghum for use as fuel and fuel additives. There are several advantages to use sweet sorghum instead of sugarcane, as the biomass source for alcohol production [7].

1. Sweet sorghum can be harvested in 4 months (whereas the first cut of sugarcane is 18 months after planting).
2. Sweet sorghum cane production can be completely mechanized.
3. Sweet sorghum crop is established from seed.
4. Sweet sorghum grain may be used either as food or feed.
5. The bagasse from sweet sorghum has a higher biological value than the bagasse from sugarcane when used as forage for animals.

Despite these advantages there are relatively few studies on ethanol production from sweet – stem sorghum [8–10]. Earlier studies also included the potential of whole sweet sorghum plant juice and its residue for ethanol production [2]. Sugarcane, sweet sorghum and sugar beets are discussed as feed stalks for fuel alcohol fermentation; land availability and processing costs are reviewed [11]. Several research groups have developed new cultivars with high grain and sugar yields [12–14]. In the present study, the genotypes were comparatively evaluated for ethanol production under sterilized and unsterilized conditions.

2. Materials and methods

2.1. *Sweet sorghum harvesting and storage*

Five genotypes of sweet sorghum viz. Keller, SSV 84, Wray, NSS 104, Madhura and BJ 248 were grown during kharif, 2005 (rainy season: June–October) in medium to light soils in the experimental farms of Directorate of Sorghum Research (formerly National Research Centre for Sorghum), located in Rajendranagar, Hyderabad (17°19′7″N, 78°24′4″E). Among the genotypes Keller, SSV 84, Wray and BJ 248 are varieties and NSSH 104 (now released as CSH 22SS through All India Coordinated Sorghum Improvement Project, DSR, Hyderabad) and Madhura are hybrids. The planting was done on ridges with 60 cm spacing and crop was grown up to 115 days after planting. The total rain fall received during the season May–October was 830 mm. In addition to rains, 3 essential irrigations were supplemented in furrows to the crop to maintain juiciness of the stalk; however, the amount of irrigation was not estimated. The crop was harvested at the panicle (ear head) maturity stage. The stalks were harvested leaving the basal internodes from ground level by side arm mower. Leaves were removed and stalks were tied into loose bundles and shifted to laboratory immediately. The stems are crushed to extract the juice in a three-roller juice crusher. The juice collected was stored at 4 °C till it is further used for fermentation experiments.

2.2. *Microorganisms*

The yeast strains *Saccharomyces cerevisiae* CFTR 01 and SG, obtained from CFTRI, Mysore and Seagram Distilleries Ltd.,

Table 2 – Agronomic traits, total sugar and ethanol production yields from sweet sorghum varieties and hybrids.

Variety/hybrid	Juice extraction (%)	Juice ($m^3\ ha^{-1}$)	Total sugar ($t\ ha^{-1}$)	Ethanol ($m^3\ ha^{-1}$)
Keller	39.7 ± 0.38	21.12 ± 0.08	4.66 ± 0.23	2.95 ± 0.04
SSV 84	45.9 ± 0.10	34.36 ± 0.53	7.35 ± 0.39	4.50 ± 0.02
BJ 248	47.6 ± 0.63	23.04 ± 0.63	4.14 ± 0.20	2.55 ± 0.03
Wray	44.3 ± 0.17	20.73 ± 0.95	4.81 ± 0.48	1.57 ± 0.04
Madhura	45.1 ± 0.15	20.56 ± 0.82	4.01 ± 0.19	2.00 ± 0.03
NSSH 104	47.1 ± 0.14	30.14 ± 0.22	6.14 ± 0.53	3.04 ± 0.01

Data are represented as mean ± standard deviation.