IMPACT OF ADVERSE SUGARCANE PRODUCTION CONDITIONS ON MINERAL COMPOSITION AND MICROBIAL LOAD IN JAGGERY

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Abstract: Minerals are most important components of jaggery compared to centrifugal sugar which is nothing but sucrose. Jaggery rich in iron along with other minerals like calcium, phosphorus and zinc can be formidable source in the diet. However, the cane quality used for jaggery making makes it more tenable to embed the nutrients in it as a source of minerals. The poor-quality cane makes it deprived of the vital minerals in jaggery. An experiment conducted at Zonal Agricultural Research Station, V.C.Farm, Mandya has revealed that higher total salts of 3.16 g 100g-1 was recorded in cane of saline soil and cane of sodic soil (3.08 g 100g-1) conditions compared to cane from normal soils. Higher calcium content was recorded in cane of moisture stress condition (83.77 mg $100g^{-1}$) followed by cane of normal soil on research station (82.80 mg $100g^{-1}$). lowest magnesium content was recorded in lodged cane conditions (58.00 mg $100g^{-1}$). The higher iron content was recorded in cane of shaded area (11.46 mg $100g^{-1}$) followed by cane of normal soil on research station (11.26 mg $100g^{-1}$). The higher sodium content was recorded in cane of sodic soil (97.47 mg $100g^{-1}$). The higher ash content was recorded in cane of shaded area (3.63 %) which is a negative factor. However, the phenolic content of jaggery was not influenced by production conditions. The higher bacterial count (7.47 CFU 10^{-5} g^{-1}) and fungal count (7.36 CFU 10^{-4} g^{-1}) was recorded in lodged cane compared to normal soils. Jaggery from cane of normal soil on farmer's field (129 days) could be stored for longer period over lodged cane (34.67 days) and cane of saline soil (32.67 days) conditions.

Keywords: Minerals in jaggery, Microbial load in jaggery & Shelf life

INTRODUCTION

Sugarcane (Saccharum spp. complex hybrid) is one of the important commercial crops of the world. Modern sugarcane varieties are complex hybrids derived largely from the interspecific crosses involving Saccharum officinarum L. (2n = 80) and the wild species S. spontaneum L. (2n =40-128) (Srivastava and Gupta 2008). Sugarcane, a crop of great worldwide economic importance accounts for approximately 75 per cent of the global sugar production (Commodity Research Bureau 2015). Being a C4 plant with a long-life cycle, it utilizes high amount of water, nutrients, CO2 and solar energy to produce

Sugarcane is one of the most important agro- industrial crops in our country. Sugarcane is the raw material for producing three products viz. Sugar, Jaggery and Khandsari. Sugarcane is a renewable natural agricultural resource. The byproducts of sugar industry are bagasse and molasses and bagasse is largely used as fuel. Bagasse is also utilized for production of compressed paper, plastics and fiber board. Molasses is used in distilleries for the production of ethyl alcohol, butyl alcohol, citric acid etc.

Sugarcane is cultivated in an area of about 4.0 lakh hectares in Karnataka with 42 million tonnes of cane production. It is an important commercial crop in southern Karnataka cultivated mainly in Cauvery and Bhadra Command areas, which covers an area of about 1.5 lakh hectares. Apart from obtaining sugar from sugarcane, it is also used for preparation of jaggery. In Cauvery Command area alone 4.3 m t of canes is produced and more than 35-40 per cent of this goes for jaggery production (Anon, 2002a). Jaggery making is entirely a domestic cottage industry in rural areas fetching better income to sugarcane growers and helps in upliftment of their standards of living wherever sugar industry is in crisis.

By virtue of it having all the ingredients of sugarcane juice intact, jaggery is a better sweetener than sugar which contains only sucrose. Hence, nutritionally and from the part of view of its use in ayurvedic preparation, jaggery is a sweetener as sugar is seldom used in ayurvedic preparations.

Jaggery is an important sweetening agent apart from sugar. The quality of sugarcane juice determines the quality of jaggery. Jaggery is a traditional unrefined non–centrifugal sugar consumed in Asia, Africa, Latin America and Caribbean.

Nutritional value of jaggery

The acceptable taste and nutritive value of jaggery has attracted man since ancient times. Jaggery is also called "Non centrifugal sugar" or Artisan sugar. It forms an important item of Indian diet for its high nutritive value and as a sweetening agent. White sugar contains only sucrose (99.70%), whereas jaggery has sucrose (65-85 %), protein (0.25%), glucose (21.20%) and minerals (3.40%) in addition to traces of fats (0.02 to 0.03%), calcium (0.39%), vitamin A, vitamin B, Phosphate (0.025%) and provides 383 K cal/100g jaggery (Shrilakshmi, 2003).

Dietary sucrose (sugar) is a mixed blessings which makes food more attractive and appetizing but excessive consumption often leads to several kinds of pathological conditions like coronary thrombosis, heart disease, diabetes, acidity, depression and obesity etc., Numerous studies have also revealed that high sugar consumption leads to higher cancer risk. Jaggery which is an alternative sweetener from sugarcane is considered health friendly. In Ayurveda, jaggery is considered to be the best of all the sugarcane preparations (Shrilakshmi, 2003).

As sugarcane is a versatile crop in the command area, since inception of irrigation projects, many adverse conditions have been thrown against it to be able to survive. The area under saline and alkaline conditions have been on the rise due to faulty irrigation methods adopted. This has led to a greater challenging task of rising the crop under these conditions. In addition, recent drought and moisture stress conditions have made the problem even more tough for the crop. However, under adverse conditions also, sugarcane is being cultivated. Hence, the present investigation was taken up for characterization of sugarcane yield parametres and juice qualities with a focus on mineral contents, salts, microbial load and shelf life of jaggery prepared from cane from adverse production conditions.

Methodology

Sugarcane samples were drawn from the five adverse sugarcane growing conditions in addition to sugarcane from normal soil in farmer's field and research station condition. This was done after assessing the soil conditions to classify the soils as adverse production conditions accordingly. Following are the villages from which these conditions were identified and samples drawn for the study. The villages were viz., Basavanapura, Bandur and Dadadapura villages of Malavalli taluk of Mandya district which had the adverse sugarcane production conditions like saline soil, sodic soil, lodged cane, shaded area and moisture stress conditions.

Assessment of adverse conditions

Adverse cane production conditions viz., saline soils, sodic soils, lodged cane, shaded area, moisture stress in comparison with normal soil were assessed based on the sampling of soils from the fields with purposive sampling method. These adverse conditions of soil were characterized by analyzing pH, EC, ESP of soil as per the standard procedure for assessing the adverse production conditions of normal, saline and sodic soils. The conditions like lodged cane and shaded area were assessed by making field observations. Moisture stress condition was assessed by rainfall during the crop season, irrigation given to the crop and also by assessing crop stand with field observations.

Table 1: Initial soil properties of sugarcane fields of adverse conditions.

Sl. No	Soil conditions	pH $_{1:2.5}$	EC $_{1:2.5}$(dS m^{-1})	ESP (%)
1.	Normal soil from farmer's field	7.1	0.96	7.40

2.	Normal soil from research station	7.3	1.04	9.70
3.	Saline soil	8.2	1.5	10.80
4.	Sodic soil	8.7	0.85	32.0
5.	Lodged cane	7.7	0.87	7.23
6.	Shaded area	7.9	0.78	7.40
7.	Moisture stress	8.1	0.32	11.20

Collection of samples

From the assessment of conditions and fixing the field for sampling each sampling, field was divided into three clusters of equal population but uneven in area. From these clusters twenty fully matured (12 months old) sugarcanes were sampled at random. From each cluster observations were recorded and used for characterization of quality parameters.

Number of clusters: 3
Number of conditions: 7
Population size: 20 canes from each replication

Results and Discussion

Mineral composition

The data on mineral compositions of jaggery analyzed are presented in Table-2 & figure 1.

Total salts (g 100g^{-1})

There was a significant difference in total salts in jaggery among various production conditions. The higher total salts of 3.16 g 100g^{-1} were recorded in cane of saline soil and cane of sodic soil (3.08 g 100g^{-1}) conditions which were significantly superior over with cane of moisture stress condition (2.88 g 100g^{-1}) followed by cane of shaded area (2.82 g 100g^{-1}) and lodged cane (2.73 g 100g^{-1}) conditions. The lowest salt content was recorded in normal soil condition of research station and farmer's field (1.73 and 1.87 g 100g^{-1} respectively).

Calcium (mg 100g^{-1})

Calcium content in jaggery significantly differed among production conditions. The higher calcium content was recorded in cane of moisture stress condition (83.77 mg 100g^{-1}) followed by cane of normal soil on research station (82.80 mg 100g^{-1}) and normal soil on farmer's field (82.74 mg 100g^{-1}) conditions which were on par and were significantly superior over with lodged cane condition (73.27 mg 100g^{-1}) and cane of sodic soil (70.70 mg 100g^{-1}) conditions. The lowest calcium content was recorded in cane of saline soil (69.10 mg 100g^{-1}) condition.

Magnesium (mg 100g^{-1})

The significant difference in magnesium content was recored among the sugaracne production conditions. The higher magnesium content was recorded in cane of saline soil (81.63 mg 100g^{-1}) followed by cane of sodic soil (81.33 mg 100g^{-1}) conditions which were on par and significantly superior over with cane of moisture stress condition (63.30 mg 100g^{-1}), cane of normal soil on research station (61.67 mg 100g^{-1}), cane of normal soil on farmer's field (61.63 mg 100g^{-1}) and cane of shaded area (61.09 mg 100g^{-1}) conditions. The lowest magnesium content was recorded in lodged cane conditions (58.00 mg 100g^{-1}).

Iron (mg 100g^{-1})

There was a significant difference in iron content among various production conditions. The higher iron content was recorded in cane of shaded area (11.46 mg 100g^{-1}) followed by cane of normal soil on research station (11.26 mg 100g^{-1}), cane of normal soil on farmer's field (11.23 mg 100g^{-1}) and cane of moisture stress (10.88 mg 100g^{-1}) conditions which were on par and significantly superior over lodged cane (10.65 mg 100g^{-1}) and cane of saline soil (8.78 mg 100g^{-1}) conditions. The lowest iron content was recorded in cane of sodic soil conditions (8.18 mg 100g^{-1}).

Sodium (mg 100g^{-1})

Significant difference in sodium content among various sugarcane production conditions. The higher sodium content was recorded in cane of sodic soil (97.47 mg 100g^{-1}) condition which was significantly higher over cane of saline soil (67.81 mg 100g^{-1}) followed by cane of moisture stress conditions (54.54 mg 100g^{-1}). The lowest sodium content was recorded in cane of normal soil on research station and farmer's field conditions (29.39 and 28.62 mg 100g^{-1} respectively). Total salts were higher in saline and sodic soil conditions. These results are in conformity with findings of Lingle and Wiegand (1997) and Vasantha *et al* (2009) where electrical conductivity of the juice at harvest increased due to increased accumulation of Na and K ions causing a reduction in sucrose per cent juice and Juice sodium content influence the jaggery quality to a greater extent.

Calcium and magnesium content in jaggery showed no significant differences due to the various irrigation. Calcium and magnesium content in jaggery showed no significant differences in normal soil and moisture stress condition but more in saline and sodic soil conditions. However, salt had more influence on Ca^{2+}content and partitioning in different parts than others essential nutrients as reported by Dang *et al.* (1998). The reduction in Ca^{2+} content under salinity conditions might be associated with precipitation of calcium ions with phosphorous forming calcium phosphates and displacement of Ca^{2+} from its extra cellular binding sites by other cations (Na^{+}).

Table 2: Characterization of mineral composition of jaggery under adverse sugarcane production conditions.

Conditions	Total salts (g 100g^{-1})	Ca (mg 100g^{-1})	Mg (mg 100g^{-1})	Fe (mg 100g^{-1})	Na (mg 100g^{-1})
C_1: Normal soil from farmer's field	1.73	82.74	61.63	11.23	28.62
C_2: Normal soil from research station	1.87	82.80	61.67	11.26	29.39
C_3: Saline soil	3.16	69.10	81.63	8.78	67.81
C_4: Sodic soil	3.08	70.70	81.33	8.18	97.47
C_5: Lodged sugarcane	2.73	73.27	58.00	10.65	31.80
C_6: Shaded area	2.82	82.09	61.09	11.46	39.00
C_7: Moisture stress	2.88	83.77	63.30	10.88	54.54
S.Em±	0.06	1.54	1.67	0.23	1.86
CD @ 5%	0.19	4.75	5.14	0.70	5.72

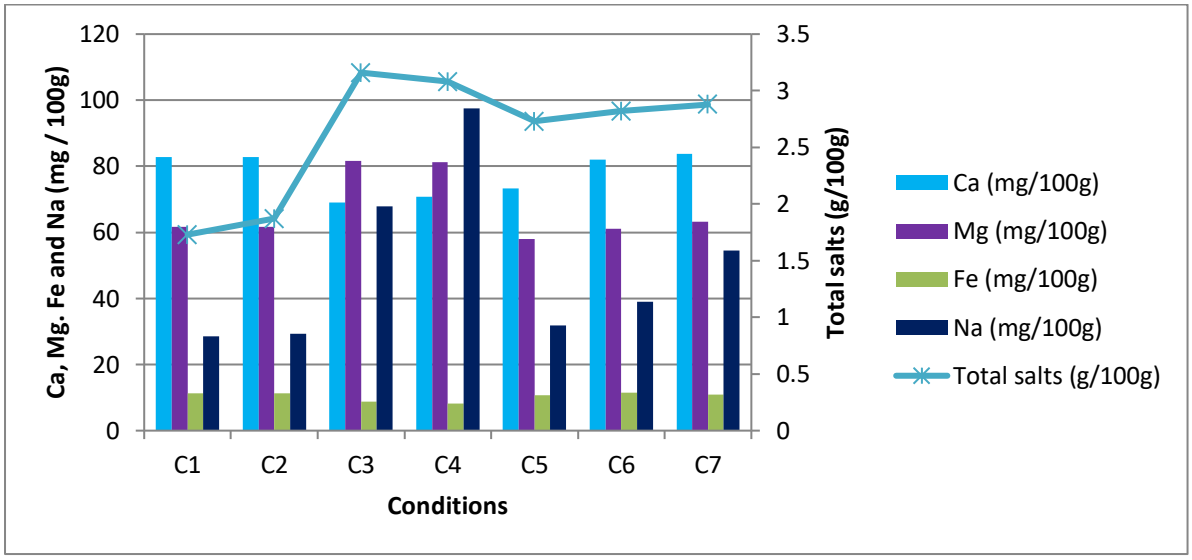

Fig 1: Characterization of Ca, Mg, Fe, Na and total salts content in jaggery under adverse sugarcane production conditions.

Dirt and insoluble (%)

Data on dirt and insoluble, ash content and total phenols of jaggery in adverse production conditions are provided in Table-3& figure 2.

Dirt and insoluble content were significantly different among various sugarcane production conditions. The higher dirt and insoluble content were recorded in lodged cane (2.58 %) followed by cane of saline soil (2.11 %) conditions which was significantly higher over with cane of moisture stress condition (1.86 %) followed by cane of sodic soil (1.84 %) and cane of shaded area (1.78 %) conditions. The lowest dirt and insoluble content were recorded in cane from normal soil from farmers field and research station (1.34 and 1.20 % respectively).

Ash (%)

There was a significant difference in ash content of jaggery from sugarcane production conditions. The higher ash content was recorded in cane of shaded area (3.63 %) condition which was significantly higher over with lodged cane (3.32 %) followed by cane of sodic soil (3.17 %) and saline soil (2.71 %) conditions. the lowest ash content was recorded in cane from normal soil from farmers field and research station (1.13 and 1.15 % respectively) as well as cane of moisture stress (1.37 %) condition. **4.4.16 Total phenols (µg g^{-1})**

Total phenol content in jaggery was not influenced by sugarcane production conditions.

These results are in line with the findings of Roy (1951); The higher dirt and insoluble was recorded in cane from saline soil and lodged condition which might be due to the more fibre content and ash content in cane juice from these conditions. However, these results are in line with Pathak *et al.*, 1999 who have reported that more fibre and ash content in juice results more of dirt particles in resultant jaggery sample.

Light coloured jaggery has lesser impurities than dark coloured one. Similarly, ash content of the jaggery is also an important indicator of the jaggery quality. Higher the ash content, lesser will be the quality of the jaggery. Ash per cent showed a range of 1-4 per cent which are in concordance with the findings of Jambulingam *et al.* (2001) where non-significant variation in per cent ash in jaggery due to different moisture regimes, where in the recorded range was 1-3 per cent.

Table 3: Characterization of dirt and insoluble, ash and total phenols of jaggery under adverse sugarcane production conditions.

onditions	Dirt and insolubles (%)	Ash (%)	Total phenols (µg g^{-1})
C_1: Normal soil from farmer's field	1.34	1.13	3029.00
C_2: Normal soil from research station	1.20	1.15	3040.33
C_3: Saline soil	2.11	2.71	3072.67
C_4: Sodic soil	1.84	3.17	3057.67
C_5: Lodged sugarcane	2.58	3.32	3075.67
C_6: Shaded area	1.78	3.63	3022.67
C_7: Moisture stress	1.86	1.37	3067.00
S.Em±	0.03	0.09	16.21
CD @ 5%	0.10	0.28	49.95

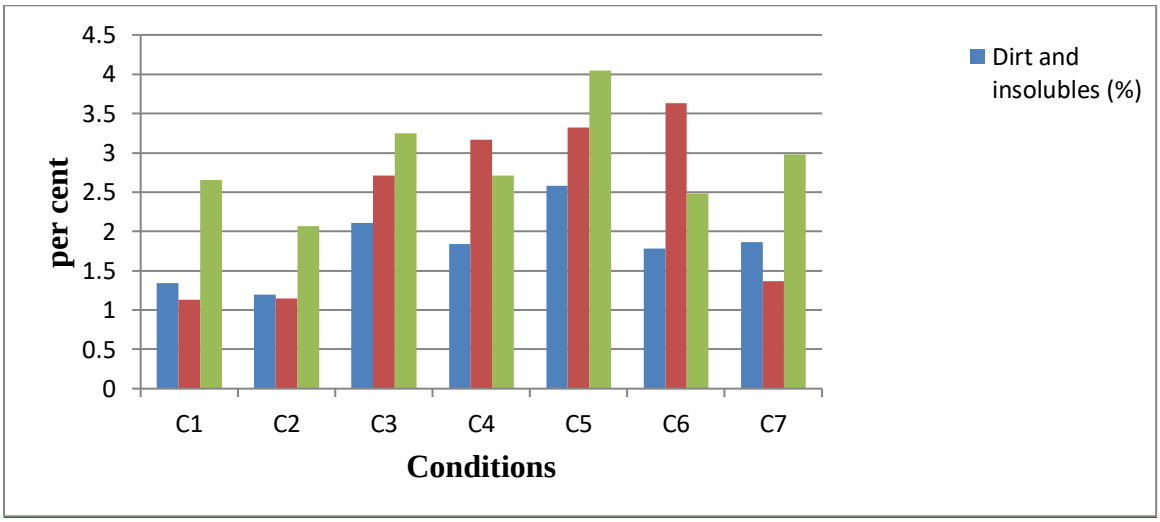

Fig 2: Characterization of dirt and insoluble, ash and moisture content of jaggery under adverse sugarcane production conditions.

Microbial load

Data on microbial load including bacterial count and fungal count are provided in Table-4 & figure 3.

Bacterial count in jaggery was significantly influenced by the sugarcane production conditions. The higher bacterial count was observed in lodged cane (7.47 CFU 10^{-5} g^{-1}) condition which was significantly higher over the rest of the conditions. The lowest bacterial count was observed in cane of normal soil on farmer's field and research station (3.86 and 3.97 CFU 10^{-5} g^{-1} respectively).

There was a significant difference in Fungal count in jaggery samples assessed from various production conditions. The higher fungal count was recorded in lodged cane (7.36 CFU 10^{-4} g^{-1}) condition which was significantly higher over cane of saline soil (5.89 CFU 10^{-4} g^{-1}) followed by cane of sodic soil (4.65 CFU 10^{-4} g^{-1}), cane of moisture stress condition (4.63 CFU 10^{-4} g^{-1}) and cane of shaded area (4.28 CFU 10^{-4} g^{-1}) conditions. The lowest fungal count was observed in cane from normal soil on farmers field and research station conditions (4.03 and3.95 CFU 10^{-4} g^{-1}

respectively). Singh *et al.* (2009) reported a microbial load value of 1.3 x10^6 and 4.8 x10^6 cfu/g in commercially available jaggery after fifteen and thirty days of storage under open atmospheric conditions. In this study, jaggery from saline soil condition recorded higher bacterial and fungal attack due to higher moisture and reducing sugar content. Similar results were reported by Singh *et al.* (2012) and Shahi (1999) where higher reducing sugar is attributed to hydrolysis of sucrose that inturn triggered the increase in moisture content and microbial attack.

Table 4: Microbial count of jaggery under adverse sugarcane production conditions.

Conditions	Bacterial count (CFU 10^{-5} g^{-1})	Fungal count (CFU 10^{-4} g^{-1})
C_1: Normal soil from farmer's field	3.86	4.03
C_2: Normal soil from research station	3.97	3.95
C_3: Saline soil	6.10	5.89
C_4: Sodic soil	5.19	4.65
C_5: Lodged sugarcane	7.47	7.36
C_6: Shaded area	4.12	4.28
C_7: Moisture stress	4.37	4.63
S.Em±	0.20	0.10
CD @ 5%	0.61	0.32

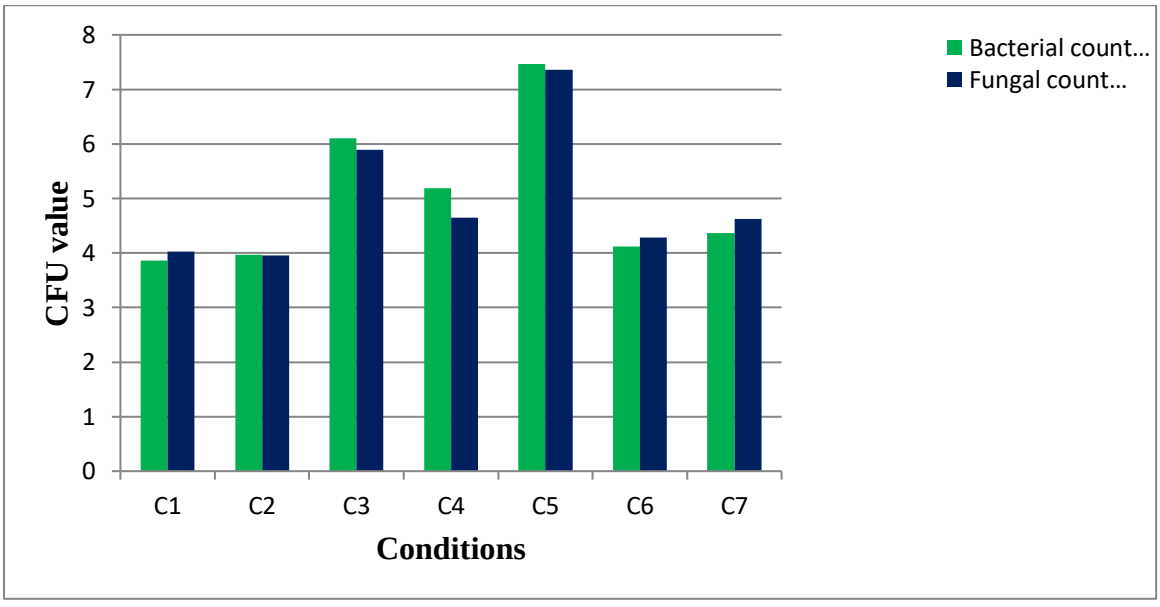

Figure 3: Characterization of microbial load of jaggery under adverse sugarcane production conditions.

Net Rendement Value (NR value)

Data on net rendement value and shelf life of jaggery was provided in Table-5 & figure 4.

Net Rendement Values are the computed values specific to jaggery and based on proportion of sucrose, reducing sugars (RS) and ash content. Net Rendement Values were computed according to Indian Trade Convention using formula.

The NR values differed significantly under various production conditions. The higher NR value was observed in cane of normal soil on farmer's field (61.98) and cane of normal soil on research station (60.52) conditions due to higher sucrose per cent and lower ash and reducing sugar which was significantly higher over cane of sodic soil (51.47) followed by cane of moisture stress condition (51.33), cane of saline soil (48.00) and cane of shaded area (46.60) conditions. The lowest NR value was observed in lodged cane (36.96) conditions which was due to higher ash and reducing sugar.

According to the above parameters, sugarcane from normal soil conditions gave grade A1 jaggery with good quality and sugarcane from moisture stress, cane from shaded area and cane from saline and sodic soil gave grade B with medium quality. Grade C with poor quality was obtained cane from lodged condition.

Shelf life (days)

Shelf life was influence significantly with various sugarcane production conditions. Jaggery from cane of normal soil on farmer's field (129 days) could be stored for longer period followed by cane of normal soil on research station (124 days) conditions which was significantly superior over cane of shaded area (89.33 days) followed by cane of sodic soil (66 days) and cane of moisture stress (63.67 days) conditions. The lowest storage period was observed in lodged cane (34.67 days) and cane of saline soil (32.67 days) conditions

These results are in line with the findings of Asokan and Chiranjivi Rao (1988), Vermeshwar (1989) and Patil *et al.* (1994) stated that jaggery having higher per cent of sucrose (75 % and above) keeps better in storage. While jaggery having low sucrose content (75 % and below) is poor in storage. However, Chand *et al.* (2011) reported that moisture content of jaggery was higher in open storage, results in reduction of sucrose per cent and increase the reducing sugar and microbial attack. In this study, longer shelf life has been recorded with jaggery from sugarcane of normal production conditions with lowest moisture content.

Table 5: Net Rendement values and shelf life of jaggery under adverse sugarcane production conditions.

Conditions	Net Rendement values	Shelf life (days)
C_1: Normal soil from farmer's field	61.98	129.00
C_2: Normal soil from research station	60.52	124.00
C_3: Saline soil	48.00	32.67
C_4: Sodic soil	51.47	66.00
C_5: Lodged sugarcane	36.96	34.67
C_6: Shaded area	46.60	89.33
C_7: Moisture stress	51.33	63.67
S.Em±	1.27	1.57
CD @ 5%	3.91	4.84

Sr. No.	Net Rendement values	Grade	Quality
1.	>65	A_1	Excellent
2.	60-65	A_2	Good
3.	45-60	B	Medium
4.	<45	C	Poor

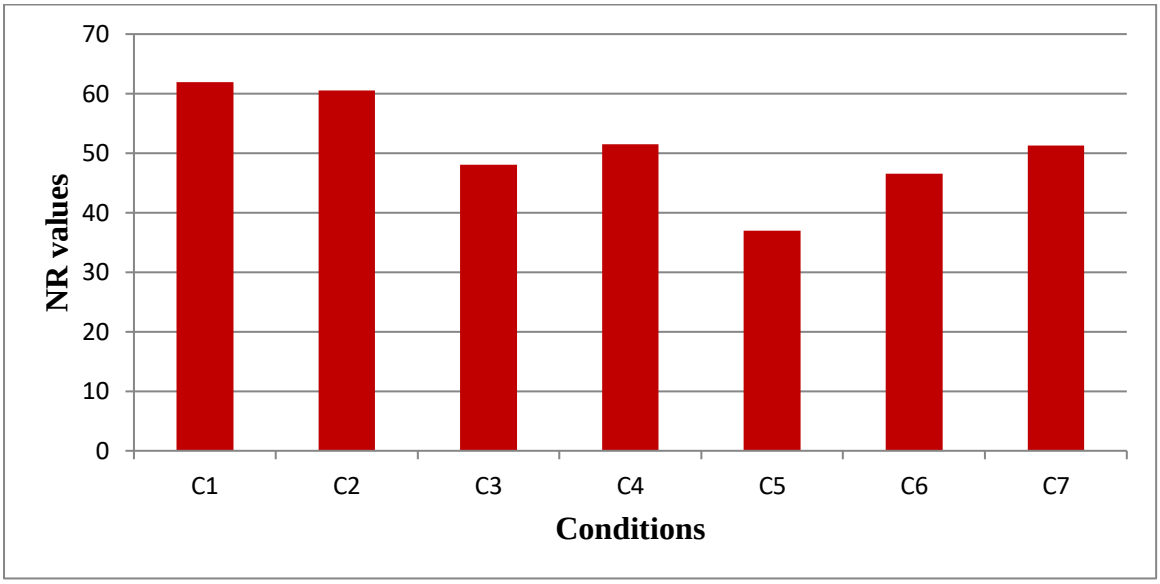

Figure 4: Characterization of NR values of jaggery under adverse sugarcane production conditions.

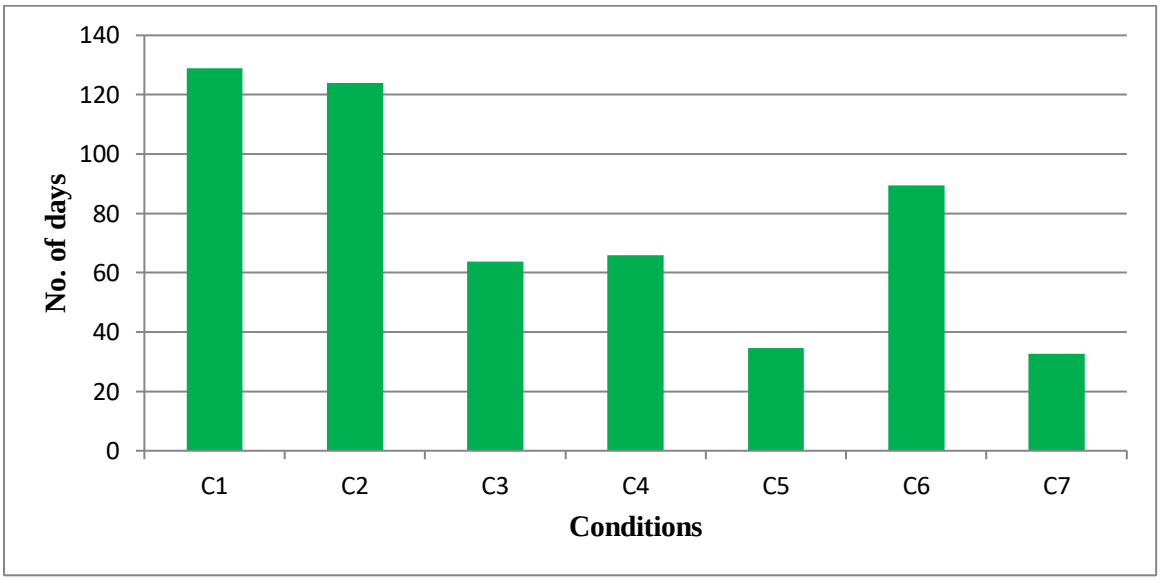

Figure 5: Characterization of shelf life of jaggery under adverse sugarcane production conditions.

Conclusion

Compared to centrifugal sugar jaggery is a better sweetener known for its nutrition from the point of view of its mineral constituents derived from sugarcane juice. However, it is governed by the sugarcane quality. The better quality of cane better will be its mineral contents in jaggery prepared from such cane. The sugarcane drawn from adverse production conditions pose many issues like higher accumulation of salts, sodium contents which makes such jaggery to value for low quality in addition to poor shelf life. The microbial load of such jaggery will be very high which makes it untenable for longer storage.

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