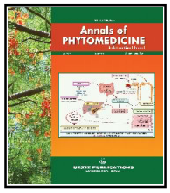
Annals of Phytomedicine 13(1): 449-460, 2024

DOI: http://dx.doi.org/10.54085/ap.2024.13.1.45

Annals of Phytomedicine: An International Journal
http://www.ukaazpublications.com/publications/index.php

Print ISSN : 2278-9839 Online ISSN : 2393-9885



Review Article : Open Access

Review of sugarcane juice: Phytochemicals, therapeutic properties, and spoilage with its preservative measures

Priyanka Chauhan◆, Manisha Kaushal, Devina Vaidya, Anil Gupta, Faruk Ansari, Sanjay Patidar and Shreya Kashyap

Department of Food and Technology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-173230, Solan, Himachal Pradesh, India

Article Info

Article history
Received 5 April 2024
Revised 22 May 2024
Accepted 23 May 2024
Published Online 30 June 2024

Keywords
Sugarcane
Polyphenol oxidase
Peroxidase
Microbial fermentation

Abstract

Sugarcane juice is a very popular drink and is extracted by crushing sugarcane between roller crushers. It is excellent for replenishing energy because it is rich in water (75-85%), reducing sugar (0.3-3.0%), and non-reducing sugar (10-21%), along with carbohydrates, minerals, enzymes, organic acids, and phenolic compounds. Being a nutritious product, sugarcane juice has many medicinal properties, but its processing and marketing are limited due to its rapid deterioration. Sugarcane juice is affected by several factors, such as physical (light, heat), chemical (oxygen), biochemical (enzymes), and biological (microorganisms). It is spoiled quickly after extraction due to the presence of simple sugars. The quality of sugarcane juice is also affected by chemical and enzymatic inversion, where polyphenol oxidase (PPO) and peroxidase (POD) are the major enzymes involved in the discoloration of juice. Furthermore, microbial fermentation of the juice turns it sour within a few hours of extraction, rendering it dangerous to consume. The polyphenol oxidase enzyme can be inhibited by heating. Traditionally, lime and ginger are used for short-term inhibition of enzymatic activity. Moreover, antibrowning chemicals such as citric acid and ascorbic acid are thus often utilized for short-term preservation in order to keep the juice's original taste. Therefore, the development of effective treatments and procedures to maintain the quality of sugarcane juice would allow a broader market and increase its quality and safety.

1. Introduction

Sugarcane (*Saccharum officinarum* L., Poaceae) is an important industrial crop, cultivated in tropical and subtropical regions of the world. It is a monocot plant and the principal raw material for the sugar industry, which accounts for 80.00% of the world's sugar. Nearly 50.00 million people work as farmers or in agriculture in some capacity; this makes it the second-largest agro based business. It is a long-duration crop and requires 10 to 15 or even 18 months to mature, depending on the geographical conditions. In north India, it is harvested from October to March, while in the southern part of the country, it is harvested from December to August. Sugarcane requires a hot and humid climate with an average temperature of 21-27^{o}C and 75-150 cm of rainfall, where too much rainfall results in low sugar content and a deficiency of rainfall results in fibrous crops. India is known as the original home of sugarcane and is the second-largest producer next to Brazil (Yadira *et al.,* 2005). Sugarcane has been utilized as a sweetening agent for thousands of years, and currently, refined sugar is extensively employed to augment the inherent sugar (fructose) present in fruits and vegetables. In India, sugarcane is primarily cultivated for the production of sweeteners including jaggery, khandasari, and sugar (Chauhan *et al.,* 2002). Apart from this, the most notable is sugarcane juice, which has a nutritional and energy quotient. Sugarcane juice is widely accessible in India, although its composition varies based on factors such as the variety, region, cultural practices, maturity at harvest, and mechanical treatment during harvesting and transit.

Sugarcane juice is very popular delicious drinks that enjoys wide popularity in view of its pleasing taste, refreshing tingle, and availability during the greater part of the year throughout the country. Sugarcane juice is great for recharging energy because it is rich in carbohydrates and minerals, especially iron (Karthikeyan and Samipillai, 2010). Sugarcane juice is not produced commercially, and it is only extracted and sold by roadside vendors, so the data on production and consumption is not available. The flavonoids, phenolic acids, and other phenolic components found in sugarcane contribute to the antioxidant properties of its syrup and juices. It contains natural sugars, numerous vitamins, minerals, organic acids, amino acids, starch, polysaccharides, and phosphatides rendering it exceptionally nutritious. In addition to its cooling effects (Parvathy, 1983), the juice is believed to have medicinal benefits in treating ailments such as bleeding, dysuria, anuria, jaundice, cancer, cardiovascular illnesses, and urinary infections (Karthikeyan and Samipillai, 2010). Sugarcane is utilized in ancient Indian Ayurveda both as an individual remedy and in combination with other botanical and herbaceous substances. However, the marketing of sugarcane juice is hindered by a rapid deterioration in quality soon after it is extracted. Fresh sugarcane juice cannot be stored for more than 6 h, and commercially, it has a short shelf-life. Due to its high sugar content, fresh sugarcane juice ferments quickly after extraction, and it also turns brown due to polyphenol oxidase activity. *Enterobacter,*

Corresponding author: Ms. Priyanka Chauhan
Department of Food and Technology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-173230, Solan, Himachal Pradesh, India
E-mail: priyankafpt38@gmail.com
Tel.: +91-8580716986

Leuconostoc, Micrococcus, Lactobacillus, Flavobacterium, and *Actinomyces* are the microbes that cause sugarcane juice to spoil. Yeasts and molds such *Aspergillus flavus*, *Cladosporium cladosporioides*, *Monilla fructicola*, *Penicillium expansum*, *Saccharomyces paradoxus*, *Candida albicans*, *Pichia pastoris*, and *Torulopsis delbrueckii* are mostly to blame for the deterioration (Frazier and Westhoff, 2007). All these adverse alterations restrict the processing and commercialization of sugarcane juice. Conventional heat processing adversely affects the taste of fresh sugarcane juice and imparts the taste of jaggery (Abhilasha and Pal, 2018). Therefore, the drink is mostly sold fresh by roadside vendors and small eateries (Yasmin *et al.,* 2010). Thus, most of the attempts to preserve the sugarcane juice have focused on the use of refrigeration, heat treatment, and preservatives. Effective treatments or procedures to maintain the fresh quality of sugarcane juice are low-temperature storage, irradiation, spray drying, ohmic heating, antimicrobial and antioxidant agents, hurdle technology, freeze concentration, and heat treatment. Among these, the hurdle technology (combined processing) is widely employed in the food processing industry. Hurdles active in stabilizing sugarcane juice include acidification (pH> 4.6), thermal treatment followed by the aseptic filling of juice, and refrigerated storage of the end product (Silva *et al.,* 2016). Keeping the above facts in mind, the review was undertaken to study the processing and storage of sugarcane stalks and juice.

2. Chemical and characteristics of sugarcane juice

The composition of sugarcane juice varies according to variety, geographical location, cultural practices, maturity at harvest, and mechanical treatment during harvesting and transportation. The chemical characteristics of fresh sugarcane juice are given in Table 1.

Table 1: Chemical characteristics of fresh sugarcane juice

Parameters	Values [a1] [f2]	References
Moisture content: Moisture content is the quantity of water contained in a material.	75.00-85.00% 80.00-81.70% 68.00-74.34% 82.91% 57.00-71.00% 81.05%	Swaminathan (1995) Sharma *et al*. (1979), Bhupinder *et al.* (1991) Sornpoon *et al.* (2014) Saxena *et al.* (2016) Rawat and Pokhriyal (2014), Dias *et al.* (2010) and Franco *et al*. (2013). Chew *et al.* (2018)
Titratable acidity: The most important function of acids in food is their contribution to sour taste. Besides, they also identify and modify the taste perception of other flavouring agents (Thomas and Corden, 1970). The titratable acidity of extracted sugarcane juice increased with storage and the increase was higher in juice samples stored at room temperature as reported by Krishnakumar *et al.* (2013) and Abhilasha and Pal (2018). Of all the organic acids, citric acid is the most prominent acid in sugarcane juice (Teng *et al.,* 2009).	0.46% 0.13% 0.13-0.18% 0.24-0.39% 0.05-0.15% 0.09% 0.16-0.21% 0.63-0.70%	Chauhan *et al*. (2002) Khare *et al.* (2012) Singh *et al.* (2012) Sangeeta and Khatkar *et al.* (2013) Krishnakumar *et al*. (2013), Kunitake *et al.* (2014) Huang *et al.* (2015) Saxena *et al.* (2016) Abhilasha and Pal (2018), Yasmin *et al*. (2010), Rajendran and Bharathidasan (2018)
pH: The pH value of a food is a direct function of free hydrogen ions present in the food. Acids present in food release these hydrogen ions, which give the food its distinct sour flavour. The increase in acidity caused a concomitant decrease in pH value (Krishnakumar *et al*., 2013).	5.16-5.27 5.00-6.85 5.28-5.54 4.40 5.10-5.40 5.32-5.36 4.67-5.76 5.20-5.60	Chen and Chou (1993) Prasad and Nath (2002), Huang *et al.* (2015), Chauhan *et al.* (2002) Krishnakumar *et al*. (2013) Singh *et al.* (2012) Brochier *et al.* (2016) Mathew *et al.* (2016), Saxena *et al.* (2016) Ramachandran *et al.* (2017), Teng *et al.* (2009) and Garud *et al.* (2017)
Total soluble solids (TSS): In general, green type tropical sugarcane is the sweetest and the juiciest variety (Yasmin *et al.,* 2010). Increase in total soluble solids may be attributed to the increase in soluble sugars, soluble pectin and soluble organic acids (Bhagwan and Awadhesh, 2014). During storage, the total soluble solids of sugarcane juice decreased considerably at both room and refrigeration temperature; however, the reduction was less pronounced at refrigeration temperature. The decline is caused by the conversion of carbohydrates to acids during storage as a	18.00-19.50°B 16.00-18.50°B 18.40°B 17.50°B 20.40-24.26°B	Sharma *et al.* (1979) Krishnakumar *et al*. (2013) Andrade *et al.* (2014) Chew *et al.* (2018), Huang *et al.* (2015) Yasmin *et al*. (2010), William *et al.* (2015), Silva *et al*. (2016), Kunitake *et al*. (2014), Kunitake *et al*. (2014), Teng *et al*. (2009).

result of the action of microorganisms present in the juice Chauhan *et al.*, 2002 and Krishnakumar *et al.*, 2013).			
Sugars: Carbohydrates are a class of energy yielding substances such as starch, glucose, cane sugars, *etc*., which provide most of the energy in almost all human diets. Carbohydrates provide 4.00 kcal/g of energy and promote the utilization of fats and reduce the wastage of proteins (Solomos and Latles, 1973). The storage of canes resulted in a reduction in the overall sugar concentration of the extracted juice, with a more noticeable effect at room temperature compared to low temperatures. The decrease in total sugar content may be caused by the breakdown of total sugar into reducing sugar and other sugars (Krishnakumar *et al.,* 2013; Shukla *et al*., 2018).	**Reducing sugar** 0.30-0.50% 0.20-0.64% 4.36-5.43%	**Total sugar** 16.32% 17.60-19.10% -	 Rawat and Pokhriyal (2014) Bhupinder *et al.,* 1991) Sangeeta and Khatkar *et al.* (2013) Chauhan *et al*. (2002), Sharma *et al*. (1979), Bhupinder *et al*. (1991), Patil *et al.* (1994), Abhilasha and Pal (2018), Swaminathan (1995), Singh *et al.* (2012)
Ascorbic acid: Vitamin C, also known as ascorbic acid varies with the type of fruit, exposure to the sun and other growing conditions (Franke *et al*., 2014; Reddy *et al.,* 2022). It is likely to be higher in early fruits than in late fruit (Combes, 2001). The stability of ascorbic acid decrease with rise in temperature and pH as reported by Nagymate and Fodor (2008).	1.25-1.98 mg /100 ml 2.98 mg/100 ml 3.35-3.39 mg /100 ml 3.18-4.44 mg/100 ml 6.05-6.16 mg/100 ml		Chauhan *et al.* (2002), Khare *et al.* (2012) Ramachandran *et al*. (2017) Rawat and Pokhriyal (2014), Mthembu (2018), Sangeeta and Khatkar *et al.* (2013) Saxena *et al.* (2016) Singh *et al*. (2012).
Total phenols: Phenolic compounds are secondary metabolites which are important components of many fruits and vegetables (Kumar and Choudhary, 2023). They not only have a significant impact on the sensory aspects of the fruit, but also for their antioxidant, anticarcinogenic, antibacterial, antiallergic, antimutagenic, and anti-inflammatory characteristics (Eberhardt *et al*., 2000; Joshipura *et al*., 2001; Juranic *et al*., 2005; Duthie, 2007 and Alesiani *et al*., 2010). The main phenolic compounds present in sugarcane juice are apigenin, luteolin, tricin, caffeic acid, hydroxycinnamic acids and sinapic acid (Almeida *et al*., 2006).	62.50-87.00 mg GAE/100 ml 532.96 mg GAE/100 ml 271.00 mg GAE/100 ml 460.00 mg GAE/100 ml 27.10 mg GAE/100 ml 31.80 mg GAE/100 ml		Sharma and Kanwar (1985) Duarte-almeida *et al*. (2006) Sreeramulu and Raghunath (2011) Brochier *et al.* (2016) Rupinder (2018) Sreedevi *et al.* (2018)
Antioxidant activity: Natural antioxidants are of plant origin which include vitamins, flavonoids and phenolic compounds (Hudson, 1990; Goel *et al.,* 2022). Antioxidants act as oxygen scavengers and prevents oxidative damage by interfering with the oxidation process thereby reacting with free radicals, chelating and catalytic metals (Shahid and Wanasundara, 1992; Thakur *et al.,* 2021 and Buyukokuroglu *et al*., 2001).	16.35-23.64% 22.00% 62.84% 56.73-70.06%		Kadam *et al.* (2008) Sreeramulu and Raghunath (2011) Kong *et al.* (2015) Noor *et al.* (2018)
Non-enzymatic browning (NEB): NEB is highly significant chemical reactions responsible for quality and colour changes during heating or prolonged storage of products (Buera *et al.* 1987 and Rodriguez *et al.* 1991). It is referred as a Maillard reaction which it is triggered by the condensation of the carbonyl group of reducing sugars with free amino groups of amino acids and/or proteins which results in the formation of brown colour in food where melanins and other chemical compounds are responsible for the same. It is generally understood that the degradation products of L- ascorbic acid and/ or sugars, *e.g.* furfural, 5-hydroxymethyl furfural (HMF), and other carbonyl compounds contribute to juice browning by polymerizing or reacting with amino acids to produce browning material (Kacem *et al.* 1987,; Kennedy *et al.* 1990,; Robertson and Samaniego, 1986 and Clegg, 1964). The accumulation of 5-HMF indicates severity of heating applied to fruit juices during processing (Lee and Nagy, 1988).	0.12 0.18		Lo *et al.* (2007) Azhari *et al.* (2018)

3. Nutritional value of sugarcane juice

India and other nations that produce sugarcane often consume sugarcane juice, a non-alcoholic energy drink. The juice contains a range of organic and inorganic substances, including 75-85% water, 10-21% sucrose (a non-reducing sugar), 10-15% fiber and 0.3-3% reducing sugars (glucose and fructose), according to Swaminathan (1995). Raw sugarcane juice and its byproducts have higher levels of flavonoids, glycosides, and phenolic acids than refined sugarcane juice. When ingested by the body, one hundred milliliters of sugarcane juice provides 40 calories, 10 milligrams of calcium, 1.1 milligrams of iron, and 6 micrograms of carotene. Among all the carbohydrates, the most prevalent monosaccharides were glucose and fructose, whereas the most prevalent disaccharide was sucrose. The amount of polysaccharides and oligosaccharides was influenced by age, harvest date, and degradation during cane delays. The juice also contains small levels of vitamin A and tiny amounts of vitamin D. Nelson and Jones (1930) discovered that sugarcane juice's vitamin C level dropped with time. Table 2 lists the specific components of the sugarcane juice.

Table 2: Nutritional composition of sugarcane juice

Composition	Parameters	Concentration
Minerals (Bx%)	Potassium (K_2O)	0.77-1.31
	Sodium (Na_2O)	0.01-0.04
	Calcium (CaO)	0.24-0.48
	Magnesium (MgO)	0.10-0.39
	Iron (Fe_2O_3)	0.006-0.04
	Aluminum (Al_2O_3)	0.005-0.17
	Copper (CuO)	0.002-0.003
	Zinc (ZnO)	0.003-0.012
	Manganese (MnO)	0.007
	Cobalt (CoO)	0.00007
	Silicon (SiO_2)	0.016-0.101
	Chloride (Cl)	0.16-0.27
	Phosphate (P_2O_4)	0.14-0.40
	Shulfate (SO_4)	0.17-0.52
Carbohydrates (g)	Fructose	0.55-1.00
	Glucose	2.27-3.00
	Sucrose	10.03-13.00
	Raffinose	0.03-0.08
Organic acids (ppm/Bx)	Oxalic	40-200
	Citric	900-1800
	Tartaric	10-180
	Malic	1200-1800
	Aconitic	5000-8000
	Succinic	100-200
	Glycolic	Trace-150
	Lactic (Formed during processing)	250-670
	Acetic (Formed during processing)	200-300
Amino acids (% dry solid protein)	Aspartic	0.06
	Glutamic	0.08
	Alanine	0.05
	Valine	0.04
	Aminobutyric	0.03
	Threonine	0.04
	Isoleucine	0.03
	Glycine	0.04
	All others	<0.03
Vitamins (mg)	Thiamine	0.03-0.09
	Riboflavin	0.04-0.10
	Niacin	0.14-0.20
	Pantothenic acid	0.07-0.15
	Pyridoxine	0.40-0.10
	Total ascorbic acid	2.00-5.10

Source: Arif *et al.,* 2019

4. Therapeutic properties of sugarcane juice

Ayurveda, a system of traditional medicine used in ancient India, makes use of sugarcane both alone and in conjunction with other plant and herbaceous materials (Anis and Iqbal, 1986; Vedavathy *et al*., 1991). Traditional medicine often prescribes sugarcane juice to patients suffering from jaundice due to its high therapeutic value. (Subbannaya *et al*., 2007; Karthikeyan and Samipillai, 2010). In Indian medicine, chewing raw sugarcane is suggested for a healthy physique. Sugarcane chewing promotes oral health and strengthens teeth. Sugarcane juice from chewing can be beneficial for weak teeth caused by a lack of exercise and a diet high in soft foods. The roots and stems of sugarcane are used in Ayurvedic medicine to cure a variety of illnesses (Kamad *et al*., 2008). Sugarcane juice generally boosts the protein level in the body, thus maintaining the functioning of the kidneys. It aids in cancer prevention as well. In addition to alleviating fever, sugarcane juice helps with weak urine, enhances the digestive system, cardiovascular system, kidneys, eyes, brain, and sexual organs. Not only does it cure eye problems, but it also helps prevent and cure colds, flu, and sore throats (Khare *et al*., 2012). Glycolic acid, an important component of sugarcane juice, has several beneficial effects on the skin. It keeps the skin nourished, prevents aging, decreases blemishes, and combats acne (Singh *et al.,* 2006). It also contains a high concentration of phytonutrients, proteins, soluble fiber, antioxidants, and many other compounds beneficial for health. It also helps in weight loss and is important to cure health problems like high acidity, gonorrhea, enlarged prostate, and cystitis (Parvathy, 1983). Its low glycemic index makes it safe for diabetics to consume, and it aids the body's hydration response to heat and prolonged physical exertion (Rawat and Pokhriyal, 2014). It is helpful to the lungs, purifies the blood, acts as an aphrodisiac, and is a diuretic, according to Unani medicine. Consuming a significant quantity of sugarcane juice is highly advised for fast treatment from jaundice, since it is believed to have positive effects on the liver (Khare *et al*., 2012). Sugarcane juice increases immunity against diseases brought on by bacteria, viruses, and protozoa (Lo *et al.*, 2005). Additionally, those with hypotension should consider this treatment option. In cases of infantile diarrhea, a decoction of stem is used (Nadkarni, 1976). As stated in Table 3, several of the therapeutic characteristics are now being research.

Table 3: Medicinal properties of phytochemicals in sugarcane juice

Phytochemicals	Medicinal properties	References
Sucrose	Antiophthalmic, antioxidant, atherogenic, flatugenic, hypercholesterolemic, preservative, triglycerigenic, uricogenic, vulnerary, collyrium demulcent	Duke (2016)
Allyl acetate	Fumigant activity	Kalaiselvan *et al*. (2012)
Oleic acid	Treatment of skin papillomas	Gustafsson *et al*. (2004)
3-Deoxy-d-mannoic lactone	Antifungal activity	Moharram *et al*. (2012)
9-Octadecenoic acid	Antiandrogenic, allergenic, hypocholesterolemic	Omotoso *et al*. (2014)
2,5-Dimethyl-4-hydroxy-3(2H)-furanone	Antimicrobial activity	Sung *et al*. (2007)
Melamine	Trypanocidal activity	Stewart *et al*. (2004)
2-Methoxy-1,4-benzenediol	Antibacterial, antidermatitic, antimutagenic, antioxidant, antiseptic, fungicide, *etc*.	Sangeetha and Vijayalakshmi (2011)
Syringol	Antioxidant activities	Zeng (2011)

5. Spoilage of sugarcane juice

The rate at which harvested cane deteriorates is influenced primarily by temperature, humidity, cane variety, and the stalk (Lionnet, 1986). After the harvesting of sugarcane, endogenous enzymes are activated and cause the deterioration of sugarcane (Thulasimani and Chidambaram, 2006). Sugarcane juice is a highly healthy and thirst-quenching drink, but its preservation is quite challenging because it quickly becomes dark after extraction and spoils due to fermentation within hours (Sangeeta and Khatkar *et al.,* 2013; Krishnakumar, 2003; Sachdeva *et al.,* 2003). Sugarcane juice has high water activity, low acidity, and high sugar content, hence it degrades rapidly even when refrigerated. Poor sanitary conditions during extraction also contribute to a fast deterioration of the product's quality, resulting in changes in appearance and flavor (Eissa *et al.,* 2010). The major loss of sugar occurs in raw sugarcane juice due to the inversion of sucrose by the invertase enzyme and other types of degradation of juice caused by bacterial activities, enzymes, and other biological factors (Solomon, 2009). Sugarcane juice has simple sugars, because of which it is highly fermentable, as it contains about 15.00-18.00% sucrose, 0.5% reducing sugars, and an adequate amount of organic nitrogen and mineral salts for microbial growth. Its pH ranges from 5.0 to 5.5, making it selective for acidophilic microorganisms, especially yeast and lactic acid bacteria, where a large population of yeast favors ethanol production at the expense of sucrose. The microbial contamination of the juice is extremely high, with typical viable counts of 108 to 109 cells per mL of juice. Thus, sugarcane juice can become a popular and delicious drink if its shelf-life is prolonged by preventing the spoilage of the juice using appropriate methods of preservation.

Invertases are the primary enzymes involved in sucrose metabolism in sugarcane plants. The sugarcane plants contain two types of invertases: neutral invertase and acid invertase. They have a good correlation with sucrose and lower sugar concentration during plant growth (Siswoyoa *et al.,* 2007). After the harvesting of sugarcane, the invertase enzyme is activated and acts as a cause of deterioration. These enzymes cause inversion in cane and milled juice (Sachdeva *et al.,* 2003). According to Solomon (2009), changes in invertase activity in harvested cane are associated with the loss of moisture from the cane and the hydrolysis of sucrose, which is converted into a mixture of glucose and fructose.

The quality of cane juice is also affected by chemical (acid) and enzymatic inversion (Singh *et al.,* 2006; Salleh Mack and Roberts, 1995), where polyphenol oxidase (PPO) is the major enzyme involved in the discoloration of sugarcane juice (Abhilasha and Pal, 2018). Extracted juice from canes quickly turns dark brown due to oxidation, and significant sedimentation occurs during storage. Polyphenol oxidases are copper-containing enzymes that, in the presence of oxygen, catalyze the oxidation of phenolics to quinones (Mayer and Harel, 1979). The highly reactive quinones can undergo secondary reactions and polymerize to form the brown pigments associated with the browning of juice (Mayer and Harel, 1991; Qudsieh *et al.,* 2002). Due to the oxidation of chlorophyll and polyphenols, the juice turns brown. The browning of juice is also increased by the action of bacteria (Prati *et al.,* 2005). Traditional thermal processing results in the introduction of jaggery flavor, which negatively impacts the delicate flavor of juice (Yasmin *et al.,* 2010).

Dry solids of sugarcane juice contain 0.5% protein. When the sugarcane is crushed, all the proteins stored in it are released into the raw sugarcane juice. The released protein becomes the source of amino acids for microorganisms to entail their growth. They may also be involved in the browning of juice when they react with reducing sugar in the Maillard reaction (Sensidone *et al*., 1999). Further, biodegradation of sugarcane juice is caused by microorganisms such as *Leuconostoc, Enterobacter, Flavobacterium, Micrococcus, Lactobacillus, Actinomyces, Aspergillus, Cladosporium, Monilla, Penicillum, Saccharomyces, Candida, and Pichia,* which are responsible for spoilage of sugarcane juice (Frazier and Westhoff, 2007; Kapur *et al*., 1978; Banerji *et al.,* 1997). These organisms convert sucrose into saccharides such as dextrans (Krishnakumar and Devadas, 2006; Bashari *et al*., 2013). Besides the loss of sucrose, the presence of dextran, even in small amounts, creates problems of filtration, clarification, and crystallization and alters the shape of sugar crystals, thereby affecting the quality of sugar (Khare *et al*., 2012). The action of *L. mesenteroides* and yeasts on sucrose is presented in Figure 1.

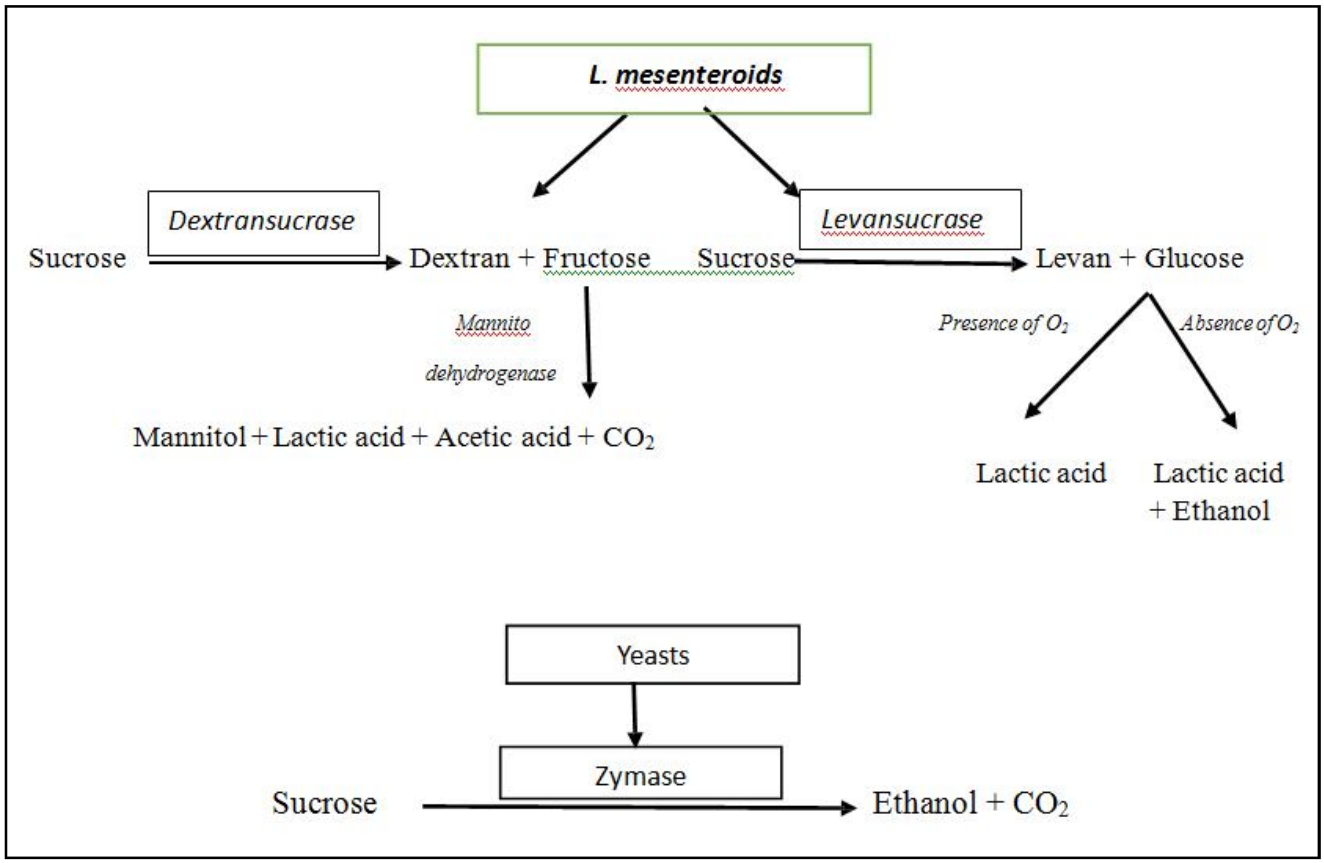


Figure 1: Major metabolites formed by *L. mesenteroides* and yeasts during the deterioration of sugarcane juice (Panigrahi *et al.*, 2021).

At last, enzymatic browning and spoilage by microorganisms due to the presence of simple sugar after extraction are responsible for its short shelf-life. So, preserving sugarcane juice for a long period of time for trading with consumers is a great challenge.

6. Processing and storage of sugarcane juice

The primary challenges in preparing and preserving sugarcane juice are browning and fast fermentation. Reducing chemicals inhibit enzymatic browning by either reducing o-quinones to colorless diphenols or interacting irreversibly with o-quinones to produce stable colorless products. These chemicals are efficient in controlling browning (Yoruk and Marshall, 2003). Ascorbic acid is an inhibitor of enzyme activity by lowering the pH of juice (Whitaker, 1994; Mao *et al.,* 2007). Citric acid is also one of the most commonly used acidulants, used to prevent browning in fruits and vegetables (at concentrations ranging from 0.50 to 2.00%). It inhibits PPO by

reducing the pH as well as by chelating the copper at the active site of the enzyme (Pizzocaro *et al*., 1993).

Bobadilla and Preston (1981) reported that sodium benzoate at a concentration of 0.05% was sufficient to delay fermentation for 2 to 3 days and 0.1% was enough to preserve the juice for 6 days, while the aqueous ammonia concentration of 0.32% and 1.28% preserved the juice for 2 days and 6 days, respectively. Likewise, Chauhan *et al.* (2002) preserved the sugarcane juice samples by adding citric acid (40 mg/100 ml), ascorbic acid (40 mg/100 ml), and potassium metabisulphite (150 ppm) and pasteurizing at 70^0C for 10 min, both at room temperature (30 ± 5°C) and refrigeration temperature (4 ± 2°C), for 90 days. Similarly, Kaur *et al*. (1995) observed that the processing of cane juice at 80°C for 10 min with the addition of 70 ppm KMS (potassium metabisulphite), followed by hot boiling and sterilization at 100°C, retained the quality of sugarcane juice. Further, Rao (1990) developed a process for the bottling of sugarcane juice comprising pasteurization for 10 min at 80°C with 125 ppm of potassium metabisulfite in glass bottles that were shelf stable for up to 10 to 12 weeks. Puspha *et al*. (2002) devised a method for producing sugarcane juice concentrate using citric acid (0.5%) alone and in combination with sodium benzoate (500 ppm), followed by packaging in glass bottles with a shelf-life of up to eight months. Kaur *et al.* (1995) reported the processing of cane juice at 80°C for 10 min with the addition of 70 ppm potassium metabisulphite (KMS), followed by boiling and sterilization at 100°C, which retained the quality of the sugarcane juice for more than 6 months. Mao *et al.* (2007) worked on maintaining the quality of sugarcane juice by blanching the stems before squeezing the juice and using ascorbic acid (0.1%), which prevented degreening or browning and reduced the activities of polyphenol oxidase in fresh sugarcane juice. Further addition of ascorbic acid appeared to be more effective than blanching. Yasmin *et al*. (2010) reported that sugarcane juice is pasteurized just after extraction by maintaining a pH of 4.3 with the addition of citric acid, followed by hot filling in pre-sterilized glass. These bottles, which could be stored at room temperature for about four months. The developed product had attractive color and flavor and was refreshing with uniform consistency.

Agarkar (2017) reported that there is enrichment in nutritional and phytochemical quality parameters by processing the blended sugarcane juice at 82°C for 5 min, preserving it with sodium benzoate (120 ppm), and storing it for more than 6 months. Garud *et al.* (2017) and Sivasubramanian and Pal (1994) studied the efficacy of ultrasonication in sugarcane juice for bacterial inactivation at two different temperatures, *i.e.*, 10°C and 50°C, and observed that a higher log reduction was obtained at 50°C as compared to 10°C ultrasonication.

Krishnakumar (2003) conducted experiments on the preservation and storage of pasteurized sugarcane juices in both glass bottles and flexible pouch packages (aluminium, polypropylene, and polyethylene) in both room and refrigerated conditions. Manikantan (2009) pasteurized the sugarcane juice at 80°C for 15 min, and the pouched juice was stored at ambient temperature for two months. Chauhan *et al.* (1997) formulated the sugarcane juice beverages with ginger, mint, and lemon extracts and found that a maximum shelf-life of 6 months was obtained using 2.58% lemon juice, ginger extract (2.0%), and mint extract (0.4%) at room temperature with slight changes in chemical composition, aroma, and flavor.

De Oliviera *et al.* (2007) found a reduction in the microbial load of sugarcane juice blended with fresh lemon and pineapple juice by subjecting it to heat treatment at 75°C for 25 min with a dose of 2.5 KGy gamma radiation and packing it in density polyethylene bottles. Bhucheli and Robinson (1994) and Kumar *et al.* (2013) reported that the addition of lemon and ginger, followed by pasteurization and preservation with KMS, reduced the physicochemical changes during storage of ready-to-serve bottled sugarcane juice. Sujatha *et al.* (2007) standardized the processing method for the preservation of sugarcane juice blends with grape and pineapple juice with the addition of KMS, which was found highly acceptable on sensory evaluation and could be stored for a period of 120 days in glass bottles. Panwar (2006) developed a sugarcane juice blend with amla juice comprising of various blend ratios, adjusted the pH at 4.2, 4.5, and 4.8, added a 7.00% citric acid solution or a 5.00% KOH solution, and pasteurized at 80°C for 10 min. He found no significant change in the organoleptic quality of the blended juice for 2 months. Damane *et al.* (2015) observed the reduction in spoilage and increase in shelf-life of milk whey blended sugarcane juice, where lemon juice, ginger juice, and milk whey were standardized in sugarcane juice and preserved by pasteurizing at 70°C for 10 min, along with KMS at 225 ppm. Sattar *et al.* (2016) standardized blended kinnow and sugarcane juice and filled in glass bottles, crown corked, and pasteurized at 95°C for 8 min, which showed storage stability of 3 months.

The above review reveals that using sodium benzoate and aqueous ammonia at different concentrations for 2 to 6 days can extend the mean storage period of sugarcane juice. Similarly, with the use of KMS along with pasteurization at different temperatures for different times, the mean storage period of sugarcane juice recorded was 10 to 12 weeks. Further, by lowering the acidity with the addition of citric acid along with ascorbic acid and preservatives at different concentrations combined with heat processing, the juice can be stored for 3 to 8 months. However, by blending sugarcane juice with other juices, the mean storage period of blended sugarcane juice can be extended up to 120 days.

7. Polyphenol oxidase (PPO) and peroxidase (POD) activity

The activity of natural occurring enzymes in sugarcane juice, such as polyphenol oxidase (PPO) and peroxidase (POD), promotes undesirable changes in color, texture, flavor, aroma, and nutritional composition. POD is an enzyme inherently found in vegetables with high thermal resistance and is therefore is utilized to establish pasteurization conditions (Jakob *et al.,* 2010). PPO is an oxidoreductase enzyme that, in the presence of oxygen, catalyzes the oxidation of o-phenolic to quinones substrates, which are subsequently polymerized into dark-colored pigments (Icier *et al.,* 2008). Therefore, enzyme inactivation is desirable for the preservation of sugarcane juice. Qudsieh *et al*. (2002) found a significant difference (p<0.01) in PPO activity of cane juice during maturity, with high activity at early development stage, decreasing during maturation, and remaining relatively steady at the end of maturity. Zhao *et al.* (2011) reported that the optimum temperature for PPO is substrate-dependent, and the enzyme showed the highest activity at 40°C with catechol, 30°C with 4-methycatechol and caffeic acid, and 25°C with chlorogenic acid and ferulic acid. PPO activity was quite stable between 20°C and 30°C and unstable at temperatures above 70°C. Kunitake *et al.* (2014) studied that the PPO and POD activities in

fresh sugarcane juice varied between 40.3 and 40.9 U ml^{-1} and 100.2 and 226.1 Uml^{-1}, respectively. Bhucheli and Robinson (1994) studied the contribution of polyphenol oxidase (PPO) and peroxidase (POD) to enzymatic browning in sugarcane juice, where POD was found to be more heat-stable than PPO, and inactivation of these enzymes with heat resulted in juice of a lighter color.

Mao *et al*. (2007) observed that the browning of sugarcane juice was due to the activity of the PPO enzyme, which converts phenolic compounds into brown-colored polymers. Blanching of stems and the addition of ascorbic acid considerably decreased PPO activity in fresh sugarcane juice, and the effect of blanching was much more pronounced than the addition of ascorbic acid. The PPO activity of fresh sugarcane juice from unblanched stems was approximately seven times higher than that of blanched stems. On the other hand, the addition of 0.1% ascorbic acid caused a 12.7% decrease in PPO activity. Blanching treatment together with the addition of ascorbic acid caused the lowest PPO activity, which was hardly detected throughout the storage. Similarly, Eissa *et al*. (2010) reported that the thermal and chemical pre-treatments of stems before squeezing reduced the juice browning by 100.00%. Further thermal treatment of stems and the addition of citric acid and SO_2 had significant effects on preventing color changes and reducing PPO activities. PPO activity is markedly inhibited by metal ions (Cu^{2+}, Al^{3+}, and Mg^{2+}) at concentrations of 1 and 10 mmol/l, with $NaHSO_3$ and ascorbic acid at 1 mmol/l being the most effective inhibitors, as reported by Zhao *et al.* (2011). Manohar *et al*. (2014) reported that ascorbic acid alone inhibited PPO activity by 35.00% and to an extent of 85.00% combined with heating. Further, it was also observed that juice holding time for 10-15 min increases enzymatic browning; hence, heating the juice instantly on extraction could reduce the color formation to an extent of 40.00%. The addition of passion fruit pulp reduced PPO activity to between 17.20 and 27.80 Uml^{-1}, while POD activity was between 107.90 and 163.40 Uml^{-1}. PPO was inactivated by all the pasteurization temperatures (85, 90 and 95%) since no residual activity was detected in the processed samples. On the other hand, POD presented residual activities between 0.10 and 17.90 μml^{-1}, as studied by Kunitake *et al.* (2014). Abhilasha and Pal (2018) studied that the residual PPO activity was less with less color change in ohmic-heated samples treated with 70°C for 3 min of holding time. Sreedevi *et al.* (2017) observed that the percentage decrease of PPO activity was prominent with increasing pressure (300-400 MPa) and time from 10 to 25 min.

8. Microbial studies

The quality of sugarcane juice was based on the number and type of microorganisms present, which may be examined using serial dilution and plating procedures for the differential enumeration of bacteria, yeast, and fungi (Abhilasha and Pal, 2018). The microbial count of different samples of sugarcane juice stored at room and refrigerated temperatures was determined by the total plate count method (TPC) (Sangeeta and Khatkar *et al*., 2013). The microbiological population (total plate count, yeast count, and mould count) increased during the storage of sugarcane juice. The extent of the increase in microbial population was also higher at room temperature as compared to refrigeration temperature (Chauhan *et al*., 2002). Raw sugarcane juice was found to have 2.7×10^6 bacterial colonies per ml and 4.8×10^5 yeast and mould counts per ml of sample, while *E. coli* counts were found to be 4.99×10^4 cfu/ml, as reported by Nagalakshmi (1995). Yasmin *et al*. (2010) observed that fresh sugarcane juice had a total plate count of 3×10^3 cfu/ml. However, after pasteurization, no growth of these microbes was found in the sample. Krishnakumar and Devadas (2006) observed that the bacterial population in fresh sugarcane juice was 4.5×10^6 cfu and increased during storage periods. The maximum increase was noticed in juice samples stored at room temperature (3.0×10^4 cfu's) even after 10 days as compared to refrigeration temperature (1.0 × 104 cfu's) in fresh sugarcane juice. Subbannayya *et al*. (2007) stated that the bacterial count in juice ranged from 10^5 to 10^7 cfu/ml, where *Salmonella, Shigella,* and *Vibrios* were not isolated. While the presence of *E. coli*, other coliforms, and *enterococci* indicated faecal contamination of juice.

Raw sugarcane juice had 10 to 20 colonies of coliform per 10 ml. Chauhan *et al.* (2002) observed that the addition of potassium metabisulphite to sugarcane juice significantly decreased the numbers. The coliforms disappeared completely after pasteurization.

Karmakar *et al.* (2011) reported that bacterial contamination may occur at different stages of juice processing, such as by contamination of sugarcane, roller, crusher, collecting vessels, hands of the personnel, ice, and filter cloth. The low temperature of storage may have retarded the growth of the organism. The growth of yeast and fungi in juice stored at 30°C increased significantly after 6 days, but bacteria were observed to decrease at the later stage of storage. Solomon (2009) found that microbial contamination of the sugarcane juice is usually extremely high, with typical viable counts being 108-109 cells/ml of juice.

Summarizing, sugarcane juice is widely spoiled by bacteria such as *Leuconostoc, Enterobacter, Flavobacterium, Micrococcus, Lactobacillus, and Actinomyces*. Among yeasts and molds, *Aspergillus, Cladosporium, Monilla, Pencillium, Saccharomuces, Candida, Pichia, and Torulopsis* are responsible for spoilage.

9. Conclusion

Sugarcane juice possesses highly nutritious and medicinal value but could not achieve commercial popularity due to inadequate processing. The main objective of this review is to provide hygienic sugarcane juice to the people and encourage them to start sugarcane juice processing on a commercial scale. Moreover, to increase the availability of sugarcane juice during the off-season. Therefore, heat treatment, irradiation, the use of preservatives, and different packaging materials were found to be good hurdles for the preservation of sugarcane juice. Mostly, non-thermal processing with aseptic packaging cannot affect the delicate flavor of the sugarcane juice and also preserve the juice for longer durations with the retention of bioactive compounds. Moreover, efforts should be undertaken on the implementation of these approaches and, hence, the successful commercialization of sugarcane juice by surmounting the aforementioned challenges with the aim of supplying stable, clean, and high-quality nutritious juice for human consumption.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

References

Abhilasha, P and Pal, U.S. (2018). Comparison of different techniques on quality storability of sugarcane juice. Int. J. Pure App. Biosci., **06**(01):339-352.

Agarkar, B.S. (2017). Development of carbonated and non-carbonated sugarcane juice beverages. M.Sc. Thesis. Department of Food Science and Technology. Punjab Agricultural University, Ludhiana. pp:91.

Andrade, L.M.; Bettani, T.R.; Nobile, P.M.; Goldman, MH.; Figueira, A.; Marin, A.L.A.; Brito, MDS.; Silva, J.D. and Creste, S. (2014). Characterization, isolation and cloning of sugarcane genes related to drought stress. BMC Proceedings., **8**(4):110-112.

Anis, M. and Iqbal, M. (1986). Antipyretic utility of some Indian plants in traditional medicine. Fitoterapia, **57**(01):52-55.

Arif, S.; Batool, A.; Nazir, W.; Khan, R.S. and Khalid, N. (2019). Physiochemical characteristics nutritional properties and health benefits of sugarcane juice. In Non-alcoholic beverages. Woodhead Publishing. pp:227-257.

Azhari, S.; Shahruddin, S. and Rahim, M.H.A. (2018). The effect of heat treatment and sonication on physicochemical and colour attributes of yellow sugarcane juice. Malaysian Society of App. Biology, **47**(05):129-134.

Banerji, R.; Madan, VK. and Misra, SR. (1997). Preservation of sugarcane juice : An overview. Indian Sugar, **47**(03):195-200.

Bashari, M.; Lagnika, C.; Ocen, D.; Wang, J.; Xu, X. and Jin, Z. (2013). Separation and characterization of dextran extracted from deteriorated sugarcane. Int. J. of Biology Macromolecules, **59**(1):246-254.

Bhagwan, D. and Awadhesh, K. (2014). Development and storage of sugarcane juice. Int. J. Food Agric. Vet. Sci., **4**:15-20.

Bhucheli, C.S. and Robinson, S.P. (1994). Contribution of enzymatic browing to colour in sugarcane juice. J. of Agriculture and Food Chemistry, **42**(2):257-261.

Bhupinder, K.; Sharma, K.P. and Harinder, K. (1991). Studies on the development and storage stability of ready-to-serve bottled sugarcane juice. J. Trop. Agric., **9**(2):128-134.

Bobadilla, M. and Preston, T.R. (1981). The use of sodium benzoate and ammonium hydroxide (aqueous-NH_3) as preservative for sugarcane. Tropical Animal Production, **6**(4):345-349.

Brochier, B.; Mercali, G.D. and Marczak, L.D. (2016). Influence of moderate electric field on inactivation kinetics of peroxidase and polyphenol oxidase and on phenolic compounds of sugarcane juice treated by ohmic heating. Food Science and Technology, **74**(1):396-403.

Chauhan, K.; Joshi, K. and Lal, B.B. (1997). Preparation and evaluation of a refreshing sugarcane juice beverages. J. Sci. Research, **56**(1):220-223.

Chauhan, O.P.; Singh, D.; Tyagi, S.M. and Balyan, D.K. (2002). Studies on preservation of sugarcane juice. Int. J. Food Prop., **5**(1):217-229.

Chauhan, O.P.; Singh, D.; Tyagi, S.M. and Balyan, D.K. (2002). Studies on preservation of sugarcane juice. Int J Food Prop., **5**(1):217-229.

Chen, J.C.P. and Chou, C.C. (1993). Microbiological control in sugar manufacturing and refining. In: Cane Sugar Handbook. 12th ed. John Wiley and Sons, New York. pp:64.

Chew, S.K.; Noor, N.A.; Maizura, M.; Tan, T.C. and Rusul, G. (2018). Effect of pasteurization treatment and calamansi (*Fortunella japonica*) juice on the physicochemical, microbiological and sensory characteristics of black stem sugarcane juice. Int Food Res J., **25**(3):1007-1015.

Combes, G.F. (2001). The vitamins fundamental aspects in nutrition and health. Academic Press, New York., pp:245-272.

Damane, P.T.; Sonkar, C. and Darade, R. (2015). Development and formulation of milk whey blended sugarcane juice and its physicochemical analysis. Int. J. of Science, **3**(3):830-833.

Dias, M.O.S.; Cunha, M.P.; Charles, D.F.J.; Mirna, I.G.S.; Carlos, E.V.R.; Filho, R.M. and Bonomi, A. (2010). Simulation of ethanol production from sugarcane in Brazil: economic study of an autonomous distillery. Comput. Aided Chem. Eng., **28**:733-738.

Duarte-almeida, J.M.; Novoa, A.V.; Linares, A.F.; Lajolo, F.M. and Genovese, M.I. (2006). Antioxidant activity of phenolics compounds from sugarcane (*Saccharum officinarum* L.) Juice. Plant Foods Hum Nutr., **61**(4):187-192.

Duke, J. (2016). Duke's phytochemical and ethnobotanical databases. Accessed Available at: www.ars-grin.gov/duke. (Accessed 12/03/2024).

Eissa, H.A.; Shehata, N.; Ramadan, M.T. and Ali, H.S. (2010). Preservation of sugarcane juice by canning. Effect of thermal and chemical pre-treatments on the enzymatic browning of sugarcane juice. J. of Applied Mathematics Science, **6**(9):883-888.

Franco, H.C.J.; Pimenta, M.T.B.; Carvalho, J.L.N.; Magalhaes, P.S.G.; Rossell, C.E.U.; Braunbeck, O.A.; Vitti, A.C.; Kolln, O.T. and Neto, J.R. (2013). Assessment of sugarcane trash for agronomic and energy purposes in Brazil. Scientia Agricola, **70**(5):305-312.

Franke, A., Custer, L.; Arakaki, C. and Murphy. S.P. (2014). Vitamin C and flavonoid levels of fruits and vegetables consumed in Hawaii. J. Food Compos. Anal., **17**(1):1-35.

Frazier, W.C. and Westhoff, C.D. (2007). Food Microbiology. Tata M.C Graw-Hill Publishing Company Limited, New Delhi., pp.187-262.

Garud, S.R.; Belagola, S.K. and Negi, P.S. (2017). Effect of thermosonication on bacterial count in artificially inoculated model system and natural microflora of sugarcane juice. Journal of Food Processing and Preservation, **41**(2):12-14.

Gustafsson, L.; Leijonhufvud, I.; Aronsson, A.; Mossberg, A.K. and Svanborg, C. (2004). Treatment of skin papillomas with topical α-lactalbumin–oleic acid. N. Engl. J. Med., **350**(26):2663-2672.

Huang, H.W.; Chang, Y.H. and Wang, C.Y. (2015). High pressure pasteurization of sugarcane juice: Evaluation of microbiological shelf-life and quality evaluation during refrigerated storage. Food and Bioprocess Technology, **8**(2):2483-2494

Huang, H.W.; Chang, Y.H. and Wang, C.Y.; (2015). High pressure pasteurization of sugarcane juice: Evaluation of microbiological shelf-life and quality evaluation during refrigerated storage. Food and Bioprocess Technology, **8**(6):2483-2494.

Hudson, B. (1990). Food Antioxidants. 1st ed. Elsevier Science Publishers Ltd., New York. pp:317.

Icier, F.; Yildiz, H. and Baysal, T. (2008). Polyphenoloxidase deactivation kinetics during ohmic heating of grape juice. Journal of Food Engineering, **74**(3):424-429.

Jakob, A.; Bryjak, J.; Wottowicz, H.; Iileova, V.; Annus, J. and Polakovic, M. (2010). Inactivation of kinetics of food enzymes during ohmic heating. Food Chemistry, **15**(2):369-376.

Kadam, U.S.; Crhost, S.B.; Agarwal, S. and Penna, S. (2008). Antioxidant activity in sugarcane juice and its protective role against radiation induced DNA damage. Food Chemistry, **106**(3):11-54.

Kalaiselvan, A.; Gokulakrishnan, K. and Anand, T. (2012). Gas chromatography-mass spec trum analysis of bioactive components of the ethanol extract of Andrographis panic ulata. J. Pharm. Biomed. Sci., **15**(20):1-3.

Kapur, K.L.; Singh, V.P. and Garg, R.G. (1978). Preliminary studies on preservation of sugarcane juice. Int J Food Prop., **5**(1):217-229

Karmakar, R.; Ghosh, K.A. and Gangopadhyay, H. (2011). Effect of pretreatments on physicochemical characteristics of sugarcane juice. Sugar Tech., **13**(1):47-50.

Karthikeyan, J. and Samipillai, S.S. (2010). Sugarcane in therapeutics. J. Herb. Med. Toxicol., **4**(1):9-14.

Kaur, B.; Singh, T. and Kaur, H. (1995). Recent advances in the processing and preservation of sugarcane juice. Sugarcane Agro-Industrial Alternatives, 1:325-331

Kennedy, J.F.; Rivera, Z.S.; Lloyd, L.L.; Warner, F.P. and Jumel, K. (1990). Studies on non-enzymic browning in orange juice using a model system based on freshly squeezed orange juice. J. Sci. Food Agric., **52**(1):85-95.

Khare, A.; Lal, A. and Singh, A. (2012). Shelf-life enhancement of sugarcane juice. Hr. J. Food Technol. Biotechnol. Nutr., **7**(3-4):179-183.

Kong, F.; Yu, S.; Zeng, F. and We, X. (2015). Preparation of antioxidant and evaluation of antioxidant activities of antioxidants extracted from sugarcane products. Journal of Food and Nutrition Research, **3**(7):458-463.

Krishnakumar, T. (2003). Studies on packaging techniques of sugarcane juice. M.Sc. Thesis. Faculty of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore. pp:224.

Krishnakumar, T. and Devadas, C.T. (2006). Microbiological changes during storage of sugarcane juice in different packaging materials. Beverage and Food World, **33**:82-83.

Krishnakumar, T.; Thamilselvi, C. and Devadas, C.T. (2013). Effect of delayed extraction and storage on quality of sugarcane juice. Afr. J. Agric. Res., **8**(10):930-935.

Kumar, D. and Siand, P. (2016). Effect of some Indian herbs and chemical on shelf-life of sugarcane juice. Asian J. Hortic., **11**(1):189-193.

Kumar J.V. and Choudhary G.P. (2023). Phytochemical analysis, antioxidant and antiobesity potentials of the ethanolic extracts of *Ziziphus mauritiana* Lam. Fruits. Ann. Phytomedicine., **12**(2):745-755.

Kunitake, M.; Ditchfield, C.; Silva, C. and Petrus, R. (2014). Effect of pasteurization temperature on stability of an acidified sugarcane juice beverage. Scientific J. of Agriculture and Technology, **38**(6):554-561.

Lee, H.S. and Nagy, S. (1988). Relationship of sugar degradation to detrimental changes in citrus juice quality. Food Tech., **42**(11):91-94

Lionnet, G.R.E. (1986). Post-harvest deterioration of whole stalk sugarcane. Proceeding of the South African Sugar Technologists Association, **60**(6):52-57.

Lo, D.Y.; Chen, T.H.; Chien, M.S.; Koge, K.; Hosono, A. and Kaminogawa, S. (2005) Effects of sugarcane extract on modulation of immunity in pigs. J. Vet. Med. Sci., **67**(6):591-597.

Lo, W.M.; Chua, L.S.T.; Alkharki, A.F. and Azhar, M.E. (2007). Evaluation of freeze-concentrated sugarcane juice. J. Trop. Agric and Food Science, **35**(1):121-129.

Manikantan, M.K. (2009). Development and evaluation of high barrier nanocomposite films for food packaging. Ph.D. Thesis. Department of Food and Agricultural Process Engineering, Tamil Nadu Agriculture University, Coimbatore., pp:261.

Manohar, M.P.; Nayaka, M.A. and Mahadevaiah. (2014). Studies on phenolic content and polyphenol oxidase activity of sugarcane varieties with reference to sugar processing. Sugar Tech., **16**(12):385-391.

Mao, L.C.; Xu, Y.Q. and Que, F. (2007). Maintaining the quality of sugarcane juice with blanching and ascorbic acid. Food Chem., **104**(2):740-745.

Mathew, B.; Mini, V.; Jessy, M.K.; Shajan, V.R. and Jayakumar, G. (2016). Effect of thermo chemical processing on storability of sugarcane juice. International Journal of Environment, Agriculture and Biotechnology, **1**(3):526-530.

Mayer, A.M and Harel, E. (1979). Polyphenoloxidase in plants. Phytochemistry, **18**(0):193-215.

Mayer, A.M. and Harel, E. (1991). Phenoloxidases and their significance in fruit and vegetables. In: Food Enzymology. PF Fox, New York., pp:373-398.

Moharram, A.M.; Mostafa, M. and Ismail, M.A. (2012). Chemical profile of Monascus ruber strains. Food Technol. Biotechnol., **50**(4):490-499.

Mthembu, L.D. (2018). Production of levulinic acid from sugarcane bagasse. M.Sc. Thesis, Department of Chemistry, Durban University of Technology Durban, South Africa. pp:138.

Nadkarni K.M. (1976). Indian Materia Medica, Bombay Popular Prakashan, Mumbai. pp:1085-1089.

Nagalakshmi, A.V.D. (1995). Quality analysis of selected fruit juices sold by street vendor in Hyderabad. M.Sc. Thesis. Department of Home Science, Acharya NG. Ranga Agricultural University, Hyderabad. pp:124.

Nagymate, E.J. and Fodor, P. (2008). The stability of vitamin C in different beverages. Br Food J., **110**(3):296-309.

Nelson, E.M. and Jones, D.B. (1930). Vitamins in Sugarcane Juice and in Some Cane-Juice Products. US Government Printing Office, Washington. DC.

Noor, N.A.M.; Murad, M. and Esah, E.M. (2018). Physicochemical, antioxidant and microbial properties of fresh black stem sugarcane juice with addition of calamansi juice. Sains Malays., **47**(9):2047-2054.

Omotoso, A.E.; Kenneth, E. and Mkparu, K.I. (2014). Chemometric profiling of methanolic leaf extract of Cnidoscolus aconitifolius (Euphorbiaceae) using UV-VIS, FTIR and GC-MS techniques. J. Med. Plants Res., **2**(1):6-12.

Panwar, K. (2006). Clarification and preservation of amla blended sugarcane (*Saccharum officinarum*) juice. M.Sc. Thesis. Department of Food Science and Technology, Choudhary Charan Singh Haryana Agricultural University, Haryana. pp:16-17.

Parvathy, K. (1983). Bottling of sugarcane juice. Proceeding of the Schemes of Studies on Harvest and Post Harvest Technology (ICAR), Coimbatore Center, Annual Report., pp:13-16.

Patil, J.P.; Jadhv, H.D.; Wandre, S.S. and Hasabnis, A.B. (1994). Screening of different sugarcane varieties for quality jaggery and storability. Indian Sugar, **44**(2):123-127.

Pizzocaro, F.; Torreggiani, D. and Gilardi G. (1993). Inhibition of apple polyphenol oxidase by ascorbic acid, citric acid and sodium chloride. J. Food Process. Preserv., **5**(1):17-30.

Prasad, K. and Nath, N. (2002). Effect of pretreatments and clarificants on sugarcane juice characteristics. Asian J. Chemi., **14**(2):723-731.

Prati, P.; Moretti, R.H. and Cardello, H.M.A.B. (2005). Elaboration of beverage composed by blends of clarified-stabilized sugarcane and juice acid fruits. Food Sci. Technol., **25**(1):147-152.

Puspha, S.; Shashi, H.N.; Archnna, S.; Jain, P.C.; Singh, P. and Suman A. (2002). Sugarcane juice concentrate preparation and storage. J. Food Sci. Technol., **39**(1):96-98.

Qudsieh, H.Y.M.; Yusof, S.; Osman, A. and Rahman, R.A. (2002). Effect of maturity on chlorophyll, tannin, colour and polyphenol oxidase (PPO) activity of sugarcane juice (*Saccharum officinarum* var. Yellow cane). J. Agric. Food Chem., **30**(6):1615-1618.

Rajendran, P. and Bharathidasan R. (2018). Standardization and preparation of sugarcane juice by hurdle technology. Int. J. Adv. Agric. Sci. Technol., **5**(02):77-87.

Ramachandran, C.; Rani, SR.; Lavanya, K. and Nivetha, S. (2017). Optimization of shelf stability of sugarcane juice with natural preservatives. J. Food Process., **41**(1):1-11.

Rawat, K. and Pokhriyal, S. (2014). Preservation of sugarcane juice using hurdle technology. Int. J. Eng. Sci. Technol., **3**(12):1455-1458.

Rupinder, S. (2018). Processing and packaging of sugarcane juice kheer. M.Sc. Thesis. Department of Food Science and Technology, Punjab Agricultural University, Ludhiana., pp:54.

Sachdeva, M.; Mann, A.P.S. and Batta, S.K. (2003). Multiple forms of soluble invertases in sugarcane: Kinetic and thermodynamic analysis. Sugar Tech., **5**(1):31-35.

Salleh-Mack, S.Z. and Roberts, J.S. (1995). Ultrasound pasteurization: the effects of temperature, soluble solids, organic acids and pH on the inactivation of *Escherichia coli* ATCC 25922. Ultrason Sonochem., **14**(3):323-329.

Sangeeta, Hathan, B.S. and Khatkar, B.S. (2013). Studies on stability of sugarcane juice blended with anola juice at refrigerated and room temperature. Int. J. Food Sci. Technol., **4**(10):1027-1036.

Sangeetha, J. and Vijayalakshmi, K. (2011). Determination of bioactive components of ethyl acetate fraction of Punica granatum rind extract. Int. J. Pharm. Sci. Drug Res., **3**(2):116-122.

Saxena, J.; Makroo, H. and Srivastava, B. (2016). Optimization of time-electric field combination for PPO inactivation in sugarcane juice by ohmic heating and its shelf-life assessment. Food Sci. Technol., **71**(1):329-338.

Sensidone, A.; Peressini, D. and Pollini, C.M. (1999). Study of the maillard reaction in model systems under conditions related to the industrial process of pasta thermal VHT treatment. J. Sci. Food Agric., **79**(1):317-322.

Shahid, F. and Wanasundara, P.D. (1992). Phenolic antioxidants. Crit. Rev. Food Sci. Nutr., **32**(1):67-103

Sharma, K.P. and Kanwar, R.S. (1985). Effect of micronutrients on some biochemical indicators. Sugar Tech., **8**:128-131.

Sharma, R.K.; Nema, G.K. and Verma, H.D. (1997). Intercropping of different crops in autumn- sugarcane (*Saccharum officinarum*). Indian J. Agron., **42**(1):422-424.

Silva, C.O.; Gallo, F.A.; Bomdespacho, L.Q.; Kushida, M.M. and Petrus, R.R. (2016). Sugarcane juice processing: Microbiological monitoring. J Food Process Technol., **7**:1-5.

Singh, I.; Solomon, S.; Shrivastava, A.K.; Singh, R.K. and Singh, J. (2006). Post-harvest quality deterioration of cane juice: physico-biochemical indicators. Sugar Tech., **8**(2):128-131.

Singh, R.K.; Jha, A.; Singh, C.K. and Singh K. (2012). Optimization of process and physico-chemical properties of ready-to-serve (RTS) beverage of cane juice with curd. Sugar Tech., **14**(2):405- 411.

Singh, R.K.; Jha, A.; Singh, C.K. and Singh, K. (2012). Optimization of process and physico-chemical properties of ready-to-serve (RTS) beverage of cane juice with curd. Sugar Tech., **14**(4):405-411.

Siswoyoa, T.A.; Ika, O.; Murdiyantob, D.V. and Bambang, S. (2007). Changes of sucrose content and invertase activity during sugarcane stem storage. Indones. J. Agric. Sci., **8**(2):75-81.

Sivasubramanian, C.G and Pal, J.S. (1994). Effect of heat treatment on the quality of sugarcane juice. Sivasubramanian. Indian Food Packer., **48**(1):51-51.

Solomon, S. (2009). Postharvest deterioration of sugarcane. Sugar Tech., **11**(2):109-123

Sornpoon, W.; Bonnet, S.; Kasemsap, P.; Prasertsak, P. and Garivait, S. (2014). Estimation of emission from sugarcane field burning in Thailand using bottom-up country specific activity data. Atmosphere, **5**(3):669-685.

Sreedevi, P.; Jayachandran, L.E. and Rao, P.S. (2018). Browning and bioactive composition of sugarcane juice (*Saccharum officinarum*) as affected by high hydrostatic pressure processing. J. Food Meas. Charact., **12**(4):1962-1971.

Sreeramulu, D. and Raghunath, M. (2011). Antioxidant and phenolic content of nuts, oil seeds, milk and milk products commonly consumed in India. Food Nutrition Sci., **2**(5):422-427.

Stewart, M.L.; Bueno, G.J. and Baliani, A. (2004). Trypanocidal activity of melamine based nitroheterocycles. Antimicrob. Agents Chemother., **48**(5):1733-1738.

Subbannayya, K.; Bhatt, G.K.; Shetty, S. and Junu, V.G. (2007). How safe is sugarcane juice. Indian J Med Microbiol., **25**(1):73-74.

Sujatha, K.; Thangaraj, T.; Ramaswami, N. and Padmini, T. (2007). Standardization and evaluation of preserved sugarcane juice blends with other fruit juices. Indian J. Nutr. Diet., **44**(5):270-278.

Sung, W.S.; Jung, H.J.; Park, K.; Kim, H.S.; Lee, I.S. and Lee, D.G. (2007). 2,5-dimethyl-4- hydroxy-3(2H)-furanone (DMHF); antimicrobial compound with cell cycle arrest in nosocomial pathogens. Life Sci., **80**(6):586-591.

Swaminathan, V. (1995). Food Science Chemistry and Experimental Foods. Bangalore Printing and Publishing Cooperation Limited, Bangalore. pp:472.

Teng, D.; Tai, C.Y.; Chai, Y.C.; Lin, Y.P. and Ou, S.M. (2009). Investigation of fermenting conditions for sugarcane (*Saccharum officinarum* L.) wine using response surface methodology. J. Food Process. Preserv., **33**(3):330-346.

Thakur, B.; Singh, R. and Nelson, P. (1996). Quality attributes of processed tomato products: A review. Food Rev. Int., **12**(3):375-401.

Thakur, N.S.; Kashyap, S.; Thakur, A.; Sharma A.; Gautam, S. and Hamid. (2021). Development of dehydrated pomegranate arils from unmarketable pomegranates and evaluation of their functional and organoleptic attributes during storage. Ann. Phytomed., **10**(2):335-340.

Thulasimani, K. and Chidambaram, D. (2006). Microbiological changes during storage of sugarcane juice in different packing materials. Beverage Food World, **33**(10):82-83.

Vedavathy, S.; Rao, K. N.; Rajaiah, M. and Nagaraju, N. (1991). Folklore Information from Rayalaseema region, Andhra Pradesh for family planning and birth control. Int. J. Pharmacogn., **29**(2):113-116.

Verma, R.; Karakannavar, S.J. and Ashwini, M. (2023). Preparation and characterization of physicochemical, functional and antioxidant properties of oyster mushroom, *Pleurotus ostreatus* (Jacq. ex Fr.) P. Kumm. Powder. Ann. Phytomed., **12**(2):834-841

Vijerathna, M.P.G.; Wijesekara, R.; Perera, SM.T.A.; Maralanda, M.; Jayasinghe. and Wickramasinghe I. (2019). Physico-chemical characterization of cookies supplemented with sugarcane bagasse fibres. Vidyodaya Journal of Science, **22**(1):29-39.

Whitaker, J.R. (1994). Principles of Enzymology for the Food Sciences. 2nd ed. Marcel Dekker, New York. pp:271-556.

William, S.S.; Juliana, A.S.S. and Claudio, L.A. (2015). Combination Effect of ozone and heat treatment for the color reduction in sugarcane juice. Chem. Process Eng., **35**:75-83.

Yadira, R.; Elsa, V. L. and Humberto, H. S. (2005). Characterization of wine like beverage obtained from sugarcane juice. World J. Microbiol. Biotechnol., **21**(4):447-452.

Yasmin, A.; Masood, S. and Hamida, A. (2010). Biochemical analysis and sensory evaluation of naturally preserved sugarcane juice. J Biochem Mol Biol., **43**(3):144-145.

Yoruk, R. and Marshall, M.R. (2003). Physicochemical properties and function of plant polyphenol oxidase: A review. J. Food Biochem., **27**(5):361-422.

Yusof, S.; Shian, L.S. and Osman, A. (2000). Change in quality of sugarcane juice upon delayed extraction and storage. Food Chem., **68**(4):395-401.

Zeng, L. (2011). An Investigation on the Bioactive Properties of the Chemical Components and Endophytic Fungi of Cephalotaxus oliveri Mast. City University of Hong Kong.

Zhao, Z.; Zhu, L.; Yu, S. and Saska, M. (2011). Partial purification and characterization of polyphenol oxidase from sugarcane (*Saccharum officinarum* L.). Sugar Industry, **136**(5):296-301.

Citation **Priyanka Chauhan, Manisha Kaushal, Devina Vaidya, Anil Gupta, Faruk Ansari, Sanjay Patidar and Shreya Kashyap (2024). Review of sugarcane juice: Phytochemicals, therapeutic properties, and spoilage with its preservative measures. Ann. Phytomed., 13(1):449-460. http://dx.doi.org/10.54085/ap.2024.13.1.45.**