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Approaches and Technologies for Preservation of Sugarcanejuice: A Review

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Abstract: Every region of India has access to the cooling sweet soft drink known as sugarcane juice. It is an essential product on the world market since it has great health advantages. Sugarcane juice competes with other soft drinks in the market pushed by health-conscious consumers, and the sugarcane growers profit financially. To extend the shelf life of sugarcane juice, processing must be combined with the development of appropriate preservation methods. Researchers have looked into a variety of sugarcane juice preservation techniques, including chemical, thermal, and non-thermal techniques. Pasteurization is one of the many methods that are used for preserving sugarcane juice. Pasteurization, however, results in the loss of flavor, aroma, colour, taste, and vital nutrients. Non-thermal procedures, which can preserve the nutritional and sensory qualities of fresh juices, are now receiving more attention. This review article examines numerous preservation methods for sugarcane juice, analyses them, and suggests a course of action to assist determine the best method for doing so. Different criteria for different types of technologies are discussed with their advantages and drawbacks. Technologies which do not use chemical additives have also been discussed, while taking their industrial scalabilityand economical aspects under consideration. Prime focus is kept on developing a technology which is economical, industrially acceptable and greener for the environment.
Keywords: Sugarcane Juice; Preservation; Shelf-life; Thermal and non-thermal treatments.

1. Introduction

Sugarcane juice is well known as a refreshing beverage in subtropical and tropical countries and India was the second-largest producer of sugarcane after Brazil in 2016 [1]. In recent data of 2018-19 and 2019-20 as shown in fig 1, India was the largest producer of sugarcane in the world. Currently, Brazil is the world's largest producer which produced 42.05 million metric tons of sugarcane followed by India 31 million metric ton in 2020-21 [2].

Sugarcane is scientifically known as *Saccharum officinarum*, which originates from the Greek word *Saccharum* meaning sucrose, and belongs to the family Gramineae (Poaceae) [1]. The parenchyma cells contain a sugar-rich juice and can be easily ruptured to get the pure formof juice [5]. Sugarcane contains about 70-72% water which includes 13% sucrose and 1.5% other reducing sugars include glucose and fructose as shown in fig 2 [6]. While, other substances are held in solution, forming about 88% (w/w) of juice in the stem and the remaining12% represents the insoluble cane fiber component. In India, the sugarcane crop takes 10-18 months to mature. The most frequent crop period is 12 months. It grows well in warm, humid conditions in tropical climates. Sugarcane grows optimally at a temperature of 28-32ºC. The crop thrives in tropical climates with yearly rainfall of 75-120 cm. During the growing phase, a relative humidity of 70-85% is excellent, and during the ripening phase, a relative humidity of 55-75% is perfect. Sugarcane farming is not acceptable if relative humidity is less than 50%throughout the growth season. Only 70% of juice is extractable from cane [7]. Sugarcane juice is commonly consumed around India for its nutritional benefits and natural sweetness. It has good organoleptic characteristics like flavor, color, and taste with calorific and medicinal values and is rich in bioactive compounds. These bioactive active compounds are known to possess therapeutic activity including anti-inflammatory, analgesic, anti-hyperglycemic, and hepatoprotective effects [2, 8]. Traditionally, sugarcane juice has been considered for its effective medicinal value by various ancient medicinal systems [9]. In India, it is recommendedto cure a range of ailments like fever, jaundice as well as urinary disorders. It also strengthensthe stomach, kidneys, heart, eyes, brain, and sex organs and is useful in scanty urination to keep the urinary flow clear and helps the kidneys to perform their functions properly [10]. It has been proven helpful in the treatment of jaundice and regulation of bilirubin levels of the liver. A 100ml of sugarcane juice nearly provides 40 Cal of energy, 10 mg of iron, and 6 micrograms of carotene [5]. Thus, it is comparatively low in calorific value as compared to the processed and concentrated health drinks in the market with a high amount of added sugars and additives. Natural sugarcane juice is a rich source of antioxidants, soluble fiber and minerals such as phosphorus, potassium, magnesium, iron, and calcium. It also contains vitamin A (retinoids), Thiamin, Riboflavin, Niacin, Pantothenic acid, Pyridoxine, L-ascorbic acid, and alpha- tocopherol [11]. Sugarcane juice consists of some organic sugars which are in form of soluble solids such as starch, protein, waxes, and gums which vary in 0.85-1.45 % [12]. A few oligosaccharides are also formed on the spoilage of sugarcane juice, and they result in crystal deformation issues which indicate deterioration of juice more sensitively and effectively. Due to enzymatic browning of cane juice, it loses its antioxidant activity within a very short duration of time [6]. Due to microbial fermentation, storage temperature, storage time, chemical interactions and reactions, the juice spoilage occurs within a few hours of extraction [13]. Ethanol, a byproduct of microbial spoilage of the juice and other spoilage products are used topredict and regulate how long the juice is safe for consumption. Sugarcane juice turns a natural yellowish-green color and the enzymatic degradation of color reduces the acceptability of juice.The total soluble solids of sugarcane juice are tested by using a hand refractometer which is 18Brix [6,14]. Some of the impurities like gums, waxes, ash, coloring substances, and soil also contribute to shortening the shelf life of juices [15].

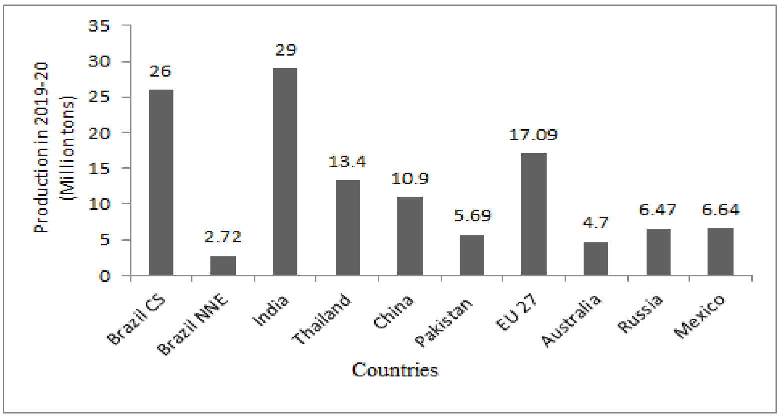

Fig. 1. Global Production trends of sugarcane [3]

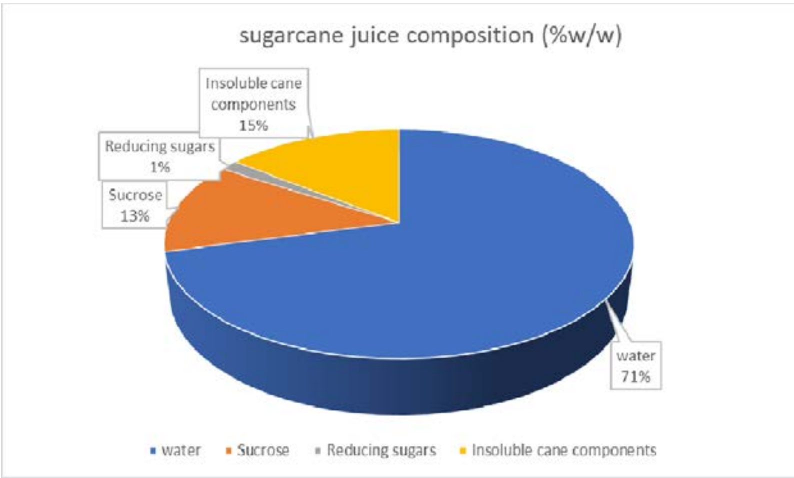

Fig 2. Composition of sugarcane (%w/w) [4]

From a commercial perspective, the deterioration of cane or juice is a major concern in theindustry. Sugarcane juice is highly perishable and hence to increase its availability and maintain its quality to an acceptable limit, various methods of preservation are employed to reduce or completely eliminate the factors responsible for its deterioration. If these treatments are efficient enough for control and can also maintain the composition and sensory acceptability of the juice for a good period of storage time, they are considered to be optimum methods for the preservation of sugarcane juice and can be applied during its processing. Titratable acidity increases gradually after a certain storage period [16]. pH of the juice decreases with storage and it might be dependent on enzymatic or microbial reactions [17,18].Brix content decreases with time, indicating that solid sugars are used as biomass sources for metabolic changes. Reducing sugar content increases storage. It is due to the hydrolysis of sucrose by acids in the juice to reduce sugars as products, or is due to the formation of monosaccharides from disaccharides. Sucrose content decreases on storage as it is converted to dextran [10]. Total plate count of microbial load increases on storage and its rate depends on incubation temperature, pre-treatment, and storage conditions. Bacterial, yeast and mold count increases on storage [19]. Currently, the major existing technologies in use for the preservation of sugarcane juice are pasteurization, use of chemical preservatives, anti-browning agents, drying technologies, ozonation process and membrane technology. The merits of using these advanced technologies in the preservation of sugarcane juice is prolongation of its shelf life. There are yet some hurdles and challenges of the current technologies suggested for the preservation of sugarcane juice. These technologies are quite expensive. They do not ensure the total destruction of heat resistant pathogenic microbes. Many of these processes increase the shelf life of the juice at the expense of nutrient content of natural untreated juice. Some of these methods involve the use of harmful chemical additives and preservatives, which may be considered deteriorative to our health in the long run. These processes may also reduce the quality of the overall processed juice. Though these techniques for enhancing the shelf life of sugarcane juice are a viable solution for preservation of sugarcane juice, permanent solutions are required in this aspect.

This review gives an insight about problems associated with preservation of sugarcane juice and many different techniques to increase the shelf life of sugarcane juice. As the modern world is focusing towards natural substances sugarcane juice is a handy alternative for soft drink and processed fruit juices. Preservation techniques, health hazards caused by some chemicals and economics for commercializing these methods are also discussed. Due to bulk availability in some parts of the world and scarcity in others, the preservation is a need of the hour and can play a crucial role to fulfill this scarcity. Our main objective in this review is to identify best economical and health concerning industrial technology by which stability of juice can be prolonged by confining its superior sensory qualities.

2. Thermal treatment methods

Sugarcane juice contains a considerable number of sugars. Fermentation in the juice begins as soon as the juice is extracted from the cane and change in organoleptic properties occur. The major bacteria responsible for the spoilage of sugarcane juice include *Leuconostoc,Enterobacter, Flavobacterium, Micrococcus, Lactobacillus,* and *Actinomyces,* and major yeast, mold responsible for the spoilage of sugarcane juice include *Aspergillus, Cladosporium, Mozilla, Penicillium, Saccharomyces, Candida, Pichia, and Torulopsis* [1]. *Leuconostoc mesenteroides* which are lactic acid-producing bacteria along with some yeast and molds are known to deteriorate sugarcane juice. This bacterium forms an alpha glucan polysaccharide and dextran in sucrose-rich medium by the action of the extracellular enzyme dextran sucrose that results in a change in viscosity of cane juice and negatively impacts its characteristics and consistency, leading to problems during its commercial processing for the preparation of further products. This is indicated by the glucose to fructose ratio, which decreases when dextran is formed at the expense of glucose utilization, leaving fructose sugar as a byproduct The major spoilage causing bacteria are capable of inverting sucrose into polysaccharides like dextrans [5]. After harvesting of cane endogenous invertase enzyme gets activated and acts as a cause of juice deterioration [5]. Looking at the problem of preservation a process that can help to increase the shelf life of the juice by inhibiting and deactivating the micro-organisms and enzymes present in it is required. Shelf-life extension of sugarcane juice has been investigatedby novel methods such as heating, microwave irradiation, ultrasonication, ohmic heating, pulsed electric field treatment, addition of preservatives and the conventional heat processingas shown in table 1 [7].

2.1 Pasteurization

Pasteurization is a mild thermal process which eliminates pathogens and deteriorative components in a food product so that its shelf life and safety is enhanced and involves application of heat for the destruction of pathogens in food products. It focuses on achieving a particular time-temperature condition. It is a specially designed process wherein every particle in food is heated until a certain pre-defined and specified temperature is reached and is held at or above that temperature for a certain holding time, and then quickly cooled down [27]. Earlier,pasteurization was done for a low temperature for a long time (LTLT), but this led to loss of nutrients and volatile vitamins. So, a high temperature short time (HTST) process wasdeveloped wherein liquid is heated quickly and at high temperature for a very small time for better microbial and enzymatic inactivation and lesser loss of nutrients [28]. The process is designed to achieve required lethality for pathogenic destruction. Though the overall process determines process lethality for pasteurization, lethality for heating and cooling time are considered negligible and the FDA (Food and Drug Administration) recognizes the lethality ofholding time only [32].

Table 1. Effect of Thermal, Non-thermal treatments on the shelf life of sugarcane juice

Sr no.	Method ofTreatment	Parameters	Shelf life	Reference
1.	Pasteurization	80 ºC for 10 min	60 days at room temperature and 90 daysat 4 ºC	[10]
2.	Pasteurization +citric acid	90 ºC for 5 min	120 days at roomtemperature.	[20]
3.	Ohmic heating	80 ºC for 10 minutes then optimized OH-treatment at 32 V/cm for 1 min.	10 and 30 days at roomand refrigerated temperature.	[16]
4.	Micro fluidization	124 MPa, 2 passes	6 days.	[8]
5.	High Pressure Processing (HPP)	600 MPa for 6 min	28 days at 4 ºC.	[12]
6.	Aseptic processing	110 °C for 10 sec	30 days and hot-packedones were stable for 60days.	[21]
7.	Microwavetreatment	5 minutes at 10 psiin autoclave then hot water bath of 80 ºC for 25 min	56 days at refrigeratedcondition	[4]
8.	Gamma radiation	citric acid (0.3%),sodium benzoate (0.015%), potassium sorbate (0.025%), sucrose (10%), and 5 kGygamma radiation dose	15 days under ambient temperature of 26 ± 2 ºC	[13]
9.	Thermo Chemical Processing	0.5ml lime juice,0.2ml ginger extract and 125 ppm of sodium metabisulphite per 100 ml of sugarcane juice andmicrowave pasteurization for 1min.	30 days	[22]
10.	Micro fluidization and natural polypeptides (nisinand polyline):	-	Initial 3.19 × 10^6 CFU/mlwas and remained within 50 CFU/ml ensuring the shelf life of 56 days	[21]
11.	Pulsed electric field (PEF) treatment	field strength 20 kV cm-1, 150pulses	7 days at 4 ºC.	[23]
12.	Blanching	13 minutes steam blanching at 100 ºCwith addition of 25 ppm. of ascorbic acid	16 days at 18 ºC.	[2]
13.	Bio-preservatives	Ginger Oleoresin100 µL/10 mL	35 days at 4 ºC.	[24]
14.	Naturally derived preservatives	Aonla extract (AE)and Moringa extract (ME) 5% each.	21 days at 2-6 ºC	[25]
15.	Nanocomposite packaging films	polypropylene packaging material is composed of 5% compatibilizer,2% nano clay, and 100-micrometer thickness.	60 days at 4 ºC.	[26]

For preservation of sugarcane juice, pasteurization for different temperature-time scalesalong with addition of preservatives was employed in various studies. In a study, Variety CoP92226 sugarcane juice was treated at 70 °C for 10 minutes and citric acid (40 mg/100 mL), ascorbic acid (40 mg/mL) and potassium metabisulphite (150 ppm) were added to it. The treated juice was stored at room temperature (30-35 °C) and refrigerated temperature (2-6 °C).The results showed an increase of shelf life of 90 days at both the temperatures [29]. A study conducted with thermal treatment (pasteurization) at 72 °C for 15 seconds along with natural antimicrobial preservatives lemon (3 mL) and ginger (0.6 mL) proved to be a promising method for shelf-life enhancement of sugarcane juice [5,30]. The other work on preservation of sugarcane juice extracted from variety Cos 767 was carried out in an experiment with the addition of preservative potassium metabisulphite (KMS) in four concentrations (150, 175, 200, 225 ppm), spices like lemon (3 mL), salt (1 gm) and ginger extract (0.6 mL) and the juicewas filled in sterilized glass bottles. This juice was subjected to mild heat treatment at 75 °C for 10 minutes and the treated juice was refrigerated for its preservation. The addition of preservatives resulted in acidic, preservative and antioxidant effects (lemon) and antimicrobialeffects (KMS) and the juice cold be stored for 60 days without extreme sensory changes or microbial and enzymatic spoilage [11]. Sugarcane stems, peeled and cut were subjected to thermal treatment by immersing in steam for 10 min, autoclaving at 126 °C and 121 °C for 10 minutes. Citric acid (0.5, 1 and 2% (w/w)) and sodium meta bi sulphite (0.05, 0.1 and 0.3% (w/w)) were added to inhibit the browning activity of polyphenol oxidase. Potassium sorbate (0.1%) was also added. Juice was stored in 250 mL glass bottles at 25 deg. C and 4 °C. The combination of thermal treatment and addition of chemical preservatives proved effective in preserving the juice stored at 4 °C up to four weeks [23]. A pasteurization process was carriedout at 80,85,90,95 °C for 2 minutes and stored at 25 °C and 4 °C. Out of these, the one for 90 °C was found to be the most optimum process and was further tested for 30 seconds, 1, 2 and 5 minutes and stored at 4 °C. Based on the study, sugar cane juice pasteurized at 90 °C for 5 minutes and stored at 4 °C for 25 days had desired properties and remained intact for the stipulated period of time. There was no significant change in parameters like vitamin C concentration, microbial count, brix, acidity and low pH enough to inhibit growth of most pathogens [5]. Sugarcane juice was pasteurized at 90 °C for 5 minutes and citric acid was added to it to adjust the pH of juice at 4.30. The juice was hot-filled into sterilized glass bottles of 250 mL and the bottles were immersed in hot water for 25 minutes. The bottles were stored at room temperature and analyzed at a time interval of 15 days for 120 days. The pasteurization processand addition of preservatives rendered the juice unspoiled till 120 days after the treatment [26].A study was conducted to check for the effect of microfiltration and pasteurization onsugarcane juice and 5% (w/w) passion fruit pulp added to induce acidity. Two pasteurization processes were carried out, one at 90 °C for 30 seconds and other for 95 °C for 30 seconds. The juice was microfiltered through an organic polyimide membrane using tangential flow across a hollow fiber configuration. The treated juices were stored in PET bottles at about 5 °Crefrigeration temperature. The juices were tested for physico-chemical, microbiological, rheological and sensory properties. From the results, microfiltration was suggested as a viable alternative to thermal processes in sugar cane juice conservation. Through microfiltration, the nutritional properties of sugarcane juice were retained and it was considered a milder process as compared to thermal treatments [20]. Hurdle technology consisting of thermal (pasteurizationand potassium metabisulphite) and non-thermal treatment (micro fluidization and natural polypeptides (nisin and polyline)) was done in sugarcane juice and comparative analysis of thejuice showed 100% reduction in microbial load of the juice and a shelf life of 56 days. Upon storage, no changes were observed in the non-thermally treated sample while some changes in pH and color were observed in the thermally treated sample [11]. For experimental examination, street vended juice samples were collected and many of these were found to be highly contaminated with E. coli and had a high bacterial, yeast and mould count. So, juice was pasteurized at 90 °C for 5 min after extraction and citric acid was added to lower the juice pH to 4.3. The pasteurized samples were hot filled in sterilized bottles and stored at room temperature for a month. After pasteurization, the juice had acceptable appearance, taste, was unspoiled for a month and fit for consumption [32]. In a study, pasteurization with a process temperature of 72 °C and holding time of 15 seconds was carried out. Sodium benzoate (0.1%vol/vol) and sodium metabisulphite (0.5% vol/vol) were added to the pasteurized juice.Moringa seed and leaf extracts (10 mL), lemon (3 mL) and ginger extracts (0.6 mL) were also added as natural preservatives [33]. The pH of the juice was brought down to 3.01 and it was filter sterilized under aseptic conditions. The optimum conditions obtained were 10% concentration of the extracts in pasteurized sugarcane juice and it could be stored at 2 °C for a period of 8 days [34]. Thus, novel methods for shelf-life enhancement of sugarcane juice were carried out through various pasteurization treatments in combination with addition of preservatives or other preservation processes.

2.2 Blanching

Blanching is considered as one of the most widely used methods for delaying deterioration in sugarcane juice. In this process, vegetables or fruits are exposed to hot or boiling water for several seconds to minutes. The addition of antioxidants makes blanching amore effective method.

The study was conducted to evaluate the combined effect of blanching and ascorbic acid for maintaining the quality of fresh squeezed and unpasteurized sugarcane juice the qualityparameters considered were color, reducing sugar, titratable acidity, polyphenol oxidase, sucrose neutral invertase activities and total microbial count. Researchers used mature sugarcane stems for the experiments. Peeled stems were used for blanching by immersing in boiling water (40:1 ratio of water to stems, w/w) for five min. Juice yield in unblanched stemswas 70.83 ± 2.9%, but it decreased to 65.06 ± % when stems were previously blanched. It wasfound that the yield of extracted juice was decreased significantly by the treatment of blanchedstems. But ascorbic acid had a significant influence on total microbial counts in stored sugar cane juice. These treatments had significant effects on preventing color change, delaying the rise of reducing sugar, titratable acidity, viscosity and total microbial count, reducing PPO and SNI activities. The combination of blanching of sugarcane stems and addition of vitamin C would produce the most effective quality of sugarcane juice [36]. Blanching of juice isineffective in case of enzymatic browning as this process is very quick and immediately occurs after extraction of juice, the PPO comes in the contact of atmospheric oxygen and accelerates the browning process. As a result, the effect of blanching sugarcane stalks on antioxidant qualities and color values of sugarcane juice was investigated. The relationship between sugarcane juice's enzymatic browning and antioxidant qualities was investigated. Blanching was performed on sugarcane stems at 80 °C for 10-, 20- and 30-minutes. Sugarcane juice extracted from cane blanched at 30 minutes showed slightly extra reddish color. Activity of polyphenol oxidase and peroxidase enzyme was inhibited significantly by blanching the cane stalks at 80 °C for 20 minutes. The research concluded that juice collected from unblanched cane stems degrades in quality and discolors quickly, becoming unsuitable for eating before two hours due to its dark tint. However, the color of sugarcane juice derived from blanched cane stems after 20 and 30 minutes did not reveal any additional deterioration or browning. It was noted that sugarcane juice's antioxidant effectiveness diminishes with enzymatic browning, which might be linked to the oxidation of phenolic molecules by the polyphenol oxidase enzyme. The oxidation of phenolic chemicals in sugarcane juice can be a quick response, resulting in enzymatic browning and browning. Its juice loses its antioxidant potential very quickly as a result of this enzymatic browning, which is usually retained by blanching sugarcane stalks before juice extraction [6].

2.3 Naturally added preservatives

Preservatives are substances added to food to prevention of its spoilage [35,37]. Natural food preservatives are derived from substances available in nature and are comparatively safer to humans and the environment than chemical or synthetic preservatives. They can be easily sourced and obtained from animal, plant or microbial sources [38]. In a study, naturally derived preservatives like aonla and moringa extract powders were dissolved in ethanol and added to sugarcane juice. When stored at refrigerated temperature (2-6 °C), the sepreservatives could keep the quality, low microbial count and enhance the shelf life of the juicefor 21 days and were considered as a better alternative to chemical preservatives. The additionof these natural preservatives helped in improvement of pH and retainment of total phenolic content in the juice. It was suggested to add these preservatives in different proportions as natural antioxidants and also as an alternative source of chemical preservatives to preserve quality and microbes for effectiveness. Also, addition of moringa extract was found to be more effective and stable than aonla extract. The study showed that these natural preservatives helped to reduce microbial growth and enhance quality and were good in removing the chemical dependency constraint for the preservation [21]. An attempt to preserve sugarcane juice was done using mucilage extracted from the stem of ladies' fingers plant as herbal clarifiant. Juice was boiled at 100 °C for 10 minutes to reduce bacterial activity during which mucilage collected from the plant was added to it. The mucilage helped in clogging the fiber and dirty substances present in the juice which could be removed to get a clear, transparent juice. The juices were then stored for four months in germ-free air-tight bottles using laminar air flow for a period of four months. This experiment was carried out for six different varieties of sugarcane for six months from October to March. The juices collected and stored in the months of December and January showed the best results using mucilage extract of ladies' finger as a clarification [39]. Bio-preservatives were also used in an experimental study for preservation. Oleoresin, a biomolecule in ginger which exhibits antifungal and antibacterial properties to foodborne pathogens of the minimum inhibitory concentration for bacteria and fungi was used as a bio preservative and added to fresh sugarcane juice refrigerated at 4 °C temperature and could be stored up to 35 days [40]. Ginger oleoresin (100 μL/10 mL) was considered as an optimum quantity for treatment and storage of juice [13]. In a study, antimicrobial substances thymol and nisin were used for tested for their antimicrobial activityagainst four species of Shigella including S. boydii, S. dysenteriae, S. flexneri and S. sonnei inoculated in sugarcane for preserving and disinfecting juice. Results showed that nisin and thymol when added in a combined manner gave better results than the individual use of the preservatives. They inhibited the bacterium at 30◦ C more efficiently than at 4◦ C when both substances were used, as the sensitivity of the bacterium to both compounds decreased as the temperature lowered from 30◦ C to 4◦ C. The sensory appeal of the juice was also acceptable to consumers [25]. Natural and naturally derived preservatives can be used in juice preservationin replacement of chemical preservatives and they have proven to be as effective as their chemical counterparts or thermal treatment options in preservation of sugarcane juice.

2.4 Ohmic heating

Ohmic heating is the process in which electric currents are used to generate the heating ofthe material while this process depends on the dielectric properties of food material, as shownin figure 3. Ohmic heating is an effective method of processing and handling foods including large solid particulates, unlike conventional aseptic processing which depends on the intensity of heat penetration while its applicability relies on the electrical conductivity of a particular item and product properties (like its conductor or insulator) [3,41]. The advantage of ohmic heating is that the food particles can be heated without heat damage due to excessive surface heating as they do not experience a significant temperature difference between inside andoutside.

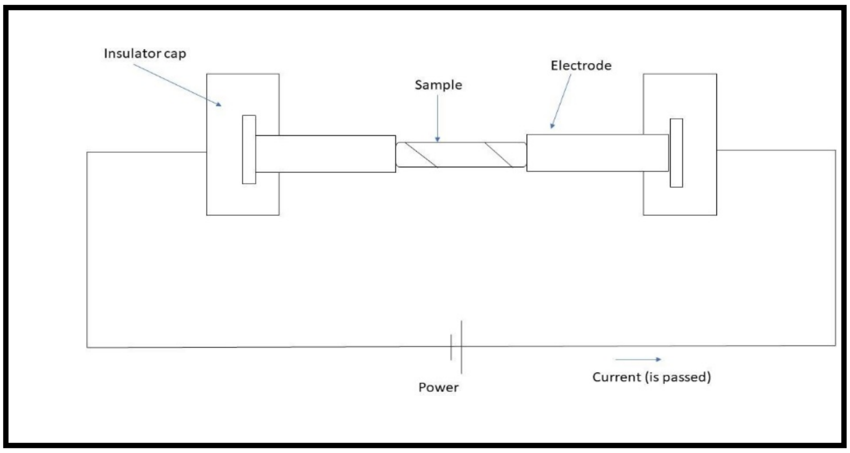

Fig. 3 General process for ohmic heating [39]

Polyphenol oxidase is thermolabile enzyme and peroxidase gets inactivated at 80 °C bythis method. The maximum total phenolic and flavonoid degradation were approximately 23- 39% respectively. For 60 °C, close to the optimum temperature of the enzyme, a moderate electric field (MEF) influenced the increase of peroxidase (POD) activity. For 80 °C, MEF increased the inactivation rate. On the other hand, for 70 and 75 °C, non-thermal effects were not observed during heating [42]. In contrast to traditional heating, ohmic heating can be usedto heat sugarcane juice up to 80 °C without decreasing the content of phenolic antioxidant chemicals. The studies revealed that 32 V/cm electric field strength and 1 minutes holding time was found to be the optimum condition for the preservation of sugarcane juice. The setreatments were then evaluated for the various parameters for 10 days and 30 days at room and low temperature respectively. Ohmic heating was more efficient at reducing microbial content than conventional heat treatment and the treatments resulted in a shelf life of 30 days at room and refrigeration temperatures. During refrigerated storage, the quality attributes of ohmic heating process treated juice remained relatively stable in comparison to conventional heat treatment process treated juice. Therefore, the time efficiency of the ohmic heating renders theprocess applicable to food processing industries [15].

In conclusion, by inhibiting PPO activity in a shorter holding time than the traditional treatment, the ohmic heating treatment preserved the juice's potential quality and features. According to Abilasha and Pal (2018), ohmic heating of sugarcane juice at 70 °C for 3 minuteswith a 48 V/cm electrical field intensity resulted in higher PPO inactivation and microbiological decrease, and the juice can be securely kept for up to 10 days under refrigeration.

2.5 Other heat treatments

Numerous thermal technologies in the food processing industry have been developed to extend the shelf life of sugarcane juice which includes Gamma radiation and microwave spray drying. All of these heat treatment technologies are effective in case of microbial inactivationof sugarcane juice.

Researchers also looked at the effects of combining heat treatment with gamma radiation. They tested the physicochemical, microbiological, and sensory stability of pure sugarcane juiceand sugarcane juice blended with fresh lemon and pineapple juice, using heat treatment (70 °C/25 min) and gamma radiation as process parameters (2.5 kGy). When compared to control,heat treatment coupled with gamma radiation resulted in the lowest numbers of psychotropic, lactic acid bacteria, filamentous and yeast-like fungi. Fresh juice was used as a control. Lactic acid bacteria, filamentous and yeast-like fungi, and filamentous and yeast-like fungi were all decreased when sugarcane juice was processed with 4% lemon juice. The polyphenol oxidase activity in the processed juice was considerably lower compared to the control [43]. Microwave energy can also be used in sugarcane juice preservation applications because of its heating properties. If microwaves are reflected or transmitted by the material, the energy is absorbed by water molecules, including those of food ingredients. When sugarcane juice is treated withmicrowaves, the energy is absorbed by water molecules and other polar molecules, which align themselves in a precise orientation with regard to the electric field. The molecules start oscillating at 2.45 GHz, which causes intermolecular friction, leading to heating the juice [44].Sugarcane juice of the cultivar CoLk 94184 was found to have a storage stability of 56 days at refrigeration after being microwave treated without the use of preservatives [45]. The microwave treatment in the juice for 3 minutes improved the storage of the juice for 21 days under ambient conditions and 56 days under refrigerated temperatures [14]. The combined impact of ozone and heat treatment for color reduction in sugarcane juice was investigated. It had been discovered that if the juice is heated before ozonation, settling is more successful after ozonation. Boiling (about 98°C) for 20 minutes had been a traditional method of purifying sugarcane juice since the juice cools to room temperature after boiling, resulting in precipitation of waxes and proteins which ensures prolonged shelf life and safety of juice [44].

Traditional thermal processing methods ensure prolonged shelf life and food safety of sugarcane juice [33]. The downside of these processing procedures is that they can cause nutritional, physicochemical, and bioactive substances in sugarcane juice to degrade. Microwave heating and thermo sonication, on the other hand, have been shown to retain the nutritional characteristics and freshness of foods [46]. Microwave heating and thermo sonication have both shown to be excellent alternatives to traditional thermal processing for preserving sugarcane juice. When compared to the other treatments, microwave heating was shown to be the best treatment since it fully suppressed microbial growth while having no significant influence on the sugarcane juice quality. Furthermore, microwave heating was alsoable to maintain the level of pH, clarity, and antioxidant activity when compared to conventional thermal processing [47].

3. Non-thermal treatment

In recent decades, there has been a great demand for fresh and natural juices. In pasteurization treatment, the nutrients are not retained due to high temperature and some heat resistant pathogens can sustain. The interest in non-thermal technology has been increasing nowadays due to the advantages like retention of sensory, nutritive properties and minimum loss of the organoleptic properties of the product. Thermal treatment can lead to undesirable changes in product properties [47,48]. The non-thermal technologies are promising and include high hydrostatic pressure (HHP), Pulsed electric field (PEF), gamma irradiation [49].

3.1 High-pressure processing (HPP)

HPP is an innovative and novel technique with several commercial processing applications.A wide variety of foods including cooked meat, shellfish, fruit juices, vegetable squeezes, andsauces are being subjected to HPP preservation [50]. HPP helps to eliminate high-pressure pathogenic microorganisms and some enzymes get inactivated from sugarcane juice at room temperature [9]. This technique is highly effective for shelf life extension and prevention of damage to heat-sensitive components in the food [51] while it irreversibly damages the microorganisms by rupturing cell membranes or altering the cell permeability [10]. High- pressure processing is considered to be an effective technology for the inactivation of POD (Peroxidase) and PPO (Polyphenol Oxidase) in fruit juices. Four hundred MPa pressure in combination with heat can be applied to accelerate PPO inactivation [52] Sugarcane juice treated with HPP resulted in a significant color difference. The juice reserved a greater amount of antioxidants. High-pressure processing does not affect the covalent and hydrogen bonding.And the sucrose neutral invertase activity was inhibited. The sugarcane juice treated at 600 MPa pressure at 60 C in 6 minutes inactivated total plate count, yeast count, mold count, and also coliform. Inactivation of enzymes (polyphenol oxidase (PPO) and peroxidase) was foundat 600MPa at 60C in 8 min. The inactivation of PPO increased with pressure level or dwell time [9,48]. In an experiment, sugarcane juice was treated with HPP at 523 MPa and 50 °C for11 minutes and another sample of cane juice was treated with conventional pasteurization 90 °C for 5 minutes and then packed into multi-layered (ML-PET) polyethylene terephthalate andreserved under refrigerated condition. This gave results that the sensory acceptability of HPP juice was more remarkable than for pasteurization and HPP sample showed shelf life of 100 days whereas pasteurized sample showed shelf life of 45 days under refrigeration. This result tells us that HPP is a preferable process to pasteurization and other thermal processes [7].

3.2 Pulsed electric field

PEF is a novel non-thermal process which is effective for inactivation of all the vegetativeyeast and bacterial cells including the food-borne pathogens. Along with microbial inactivation, this process maintains the flavor, color, nutrition, value, and sensory attributes ofthe food. The effectiveness of PEF depends on the type of food matrix, frequency, field strength, and intensity of pulses. The inactivation of microbes in PEF has mainly been caused by external electric fields and changes in the electric potential of the cell membrane [53]. Fresh sugarcane juice can be stored for 14 days when being treated with the pulsed electric field. There were no significant changes in nutrient content and microbial contaminants of treated juice under the storage condition of 4 ºC [28]. PEF processing significantly enhances the microbiological safety and stability of the juice by reducing unfavorable changes and maintaining the nutritional, sensory attributes of the beverage [54].

3.3 Gamma irradiation

In gamma irradiation, gamma rays X-rays or electrons are used to irradiate the food this exposure to gamma irradiation helps to eliminate the pathogenic organisms found in food products. Radiation is most widely used for the sterilization of food products. The 1 kGy of radiation increases the heat of the product by 0.36 ºC [55]. The sources of rays are gamma and X-rays with a short wavelength of less than 300 nm. Electron beams that have less penetration power than the gamma rays of 10 MeV and X-rays of 5 MeV are permitted for irradiation of food packages [56]. The shelf life of sugarcane juice was extended up to 15 days under the storage temperature of 26°C and the sensory scores revealed that the acceptability of the juice was high with no significant changes in phenolics and flavonoids contents. Microbiological (lactic bacteria, molds, and psychoactive count), physicochemical (color, pH, solids ratio, titratable acidity, and PPO activity), and sensory criteria were used to determine the stability of sugarcane juice. The sensory analysis research concluded that, the best mixture of sugarcane juice was with 4% of lemon juice and 10% of pineapple juice. Sugarcane juice added with 4%of lemon juice subjected to gamma radiation and heat treatment resulted in satisfactory microbiological, sensory, and physicochemical characteristics until 28, 35, and 42 days,respectively, after processing. The scientists discovered that ascorbic acid, moisture content, viable yeast, bacteria, and mold count in sugarcane juice all fell dramatically, whereas total andreducing sugars did not affect.

3.4 Ozonation

Ozone is an oxidizing agent which impacts as a decontaminating agent which reduce pathogen microorganisms at low concentrations and short time contact. Fast disintegration and lack of residues during food preservation makes ozonation an appealing process to the food sector [57]. Its application as an antibacterial agent on processed foods is generally recognizedas safe (GRAS) [58]. Using an oxygen concentrator and an ozone generator, ozone may be manufactured on-site to provide a constant supply [57]. The majority of ozone applications in the sugarcane industry are for color reduction and sugarcane juice preservation. Advanced Fenton oxidation in combination with lime carbonation improves qualitative features of the purified juice's [59]. Ozonation is accomplished by injecting a gas mixture of oxygen and ozone under constant agitation of 100 rpm (revolution per second) into the juice through a pipe fitted with a diffuser dipped in it creating bubbles and gas distribution. These treatments were carriedout at room temperature (25ºC) and the extrinsic process parameters, like, gas flow rate, ozone concentration, and the exposure time was calculated while the independent variables like gas flow rates (x1): 3, 6.5, and 10 L/min; ozone concentrations (x2): 10, 20, and 30% (wt./wt.); and exposure time (x3): 5, 12.5, and 20 minutes were noted. The ozone treatment had a significant effect on the microbial count of sugarcane juice. After 20 minutes of processing, the flow rateof 6.5 L/min provided higher microbial destruction than 3 and 10 L/min at the fixed ozone concentration. Also, the increase in exposure time resulted in a greater lethal effect while the flow rate of 5.6 L/min, 26.4% concentration, and time 20 minutes were considered optimum. The ozone treatment caused a significant reduction in microbial count (3.72 logs in TPC and 2.43 logs in YMC) [60] reported the reduction of total bacterial count by 3.9 logs after ozonation [39]. If the juice is heated before ozonation, settling becomes more effective after ozonation and boiling juice for approximately 98°C for 20 minutes is been a common practice to purify sugarcane juice, because after boiling, the juice cools down to room temperature, leading to the precipitation of waxes and proteins [44, 61]. The researchers looked into the impact of ozone on sugarcane juice color and turbidity. They discovered that the ozonation time and temperature affect the turbidity of sugarcane juice. Ozone was able to reduce the colorof the juice which is a positive effect for the clarification process because the sugars with lowercolor are more valuable.

3.5 Hurdle technology

The effect for the hurdle technology is the same in both cases with the combination of ozone, lactic acid, and with ozone, lactic acid pasteurization. The researcher used a combination of ozone (1.2 g/h for 10 min), lactic acid (0.5 percent), and pasteurization (85 C for 15 min) to reduce the overall bacterial count by 4.3 logs and inhibit 60 and 72 percent polyphenol oxidase and peroxidase activity in sugarcane juice, respectively [62]. The above-mentioned procedure preserved the microbiological and sensory quality of sugarcane juice fora month when stored at chilled condition. Total plate count was decreased from 6.1 log cells to 2.2 log cells within 10 minutes of ozone treatment. Ozone exploration up to 20 minutes did notresult in any significant ($p < 0.05$) increase in microbial reduction. No significant ($p < 0.05$) decrease in aerobic mesophilic bacterial count beyond 10 minutes of ozone treatment was observed and the corresponding PPO and POD residual activities were 58% and 25%, respectively [50].

Hurdle technology was used in a study where in standardized cane juice with 19.4 °Brix,0.085% acidity, and pH 4.35 was pasteurized at 95 °C/30 sec and stored under refrigeration. In this method, combination of processing and clean filling techniques was done for controlling enzyme activity and reducing microbial contamination. The results obtained were - juice stored at 4,8,12 °C had a shelf life of 94,74 and 26 days respectively. Thus, products stored at 4 and 8 °C were more effective in maintaining the quality of sugarcane juice and had good sensory acceptance [51]. Sugarcane juice was subjected to pasteurization at 80 °C for 10 minutes and chemical preservatives like citric acid (0.5 g/1,000 ml) and KMS (150 ppm) were added to the juice. Another sample with sterilization at 80 °C for 20 minutes in addition to the above- mentioned treatments was also compared [63]. The samples were packaged in various packaging materials and then underwent an irradiation process for 0.25, 0.5 and kGy. After storage, treatment with pasteurization, addition of chemical preservatives, sterilization and irradiation at 1 kGy was found to be an optimum process and the juice could be stored at room temperature for 60 days and at refrigerated temperature for 90 days [64]. Also, packaging material played an important role in shelf-life enhancement of the juice. PET (polyethylene terephthalate) and glass storage containers were found to increase the shelf life of sugarcane juice more than LDPE (low density polyethylene pouches) pouches. Thus, hurdle technology proved to be an important juice preservation technology [8]. An experiment was conducted in which sugarcane stalk was washed and blanching treatment was done on it at 100 °C for 5 minutes to inactivate the enzymatic activity. The juice was filtered and ascorbic acid, citric acid, deola and pectin were added to the juice and homogenization was done. The juice was heated to a temperature of 80 °C in a closed chamber for preventing the loss of flavor and aroma and immediately filtered and transferred into borosil glass bottles while hot and quicklycooled to 20 °C. The juice was then incubated at 10 °C, 20 °C and 30 °C. An optimum combination of all these treatments gave a storage period of 180 days and a sensory acceptability greater than 7 [24].

3.6 Other technologies

Some other technologies which can be used to preserve sugarcane juice are maintaining a certain level of pH by adding carbonates at certain temperature and pressure conditions which are an unfavorable condition for the growth of pathogens and enzymes. As carbonates are added to increase the pH of sugarcane juice up to 11 and temperature 55 ºC these values were favorable for the preservation of sugarcane juice. Initially, the process requires 7g $Ca(OH)_2$ for the first two weeks which went on decreasing up to 0.0301 g of Ca(OH)2 for 100g of sucrose to preserve under sensory quality [65]. Several researches have been carried out on different materials to reduce microbes and CFU count in sugarcane juice. Similar technology is used to increase the shelf life of sugarcane juice they used different materials out of which polypropylene nanomaterial film showed exceptional results for increasing shelf life and extended shelf life up to 60 days at 4 ºC [66].

4. Economical and future aspects

There are many cold drink industries in the world that use harmful preservatives to increaseshelf life which makes it costly and unhealthy for health in the long run. Sugarcane juice has become an excellent substitute in terms of cost and health. New promising technologies are arising which will make it more affordable option and can increase shelf life up to a great extent.

Presently many technologies are available which use chemical additives and heat to deactivate enzymes and pathogens like pasteurization, ohmic heating, etc. Results shown by these technologies are acceptable but are not up the mark. There is still a lot of scope for improvement to decrease CFU count and also decrease the nutrient level of sugarcane juice and are exorbitant. Thus, there is a lot of research going on to develop a technology which is not only cost effective but also should substantially decrease CFU count and provide highly stable sugarcane juice after treatment without any need to add chemical additives and which is applicable at industrial scale. Further development in hydrodynamic cavitation, membrane technology, coal bed, and food drying technologies can be a preferable alternative technology which can provide all the above-mentioned results. In coal bed technology there will be decolorization of sugarcane juice but not only it will kill pathogens and microbes but also it will retain taste and sensory quality of sugarcane juice. Food drying technology can also play a handy role for the global sugarcane juice market if we are able to decrease the cost of treatment. So that it can be easily packed in small containers and dispatched to further distant places without the requirement to maintain temperature. Looking at the current scenario thereis a demand for new technology which comes under green chemistry.

5. Conclusion

Sugarcane juice is healthy for consumption and has many medicinal properties and is cost effective but, a problem appears that cannot store sugarcane juice for much time without treating it. Presently few technologies are available in the market to treat sugarcane juice like pasteurization, ozonation, bio-preservatives, hurdle technology, etc. In this review pros and cons are discussed for different technologies. Pasteurization kills the pathogen and decreases CFU count but, it also decreases nutrient content and heat resistant pathogens also remains unaffected by this process. Overall, it comes to the shelf life of sugarcane juice which depends on the stability of juice after treatment. The main focus of this paper is to increase shelf life of sugarcane juice with the good sensory quality. The demand for sugarcane juice treatment without chemical additives, which supports cost effectiveness and are applicable at industrial scale. Production of sugarcane juice on a commercial scale by overcoming numerous challenges mentioned above in review in order to provide clean high quality, stable sugarcanejuice for people’s consumption is the need of hour.

6. References

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