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Neha Pradhan

Department of Agricultural
Processing and Food
Engineering, Indira Gandhi
Krishi Vishwavidyalaya, Raipur,
Chhattisgarh, India

Dilip Kumar

Division of Agricultural
Engineering, ICAR- Indian
Institute of Sugarcane Research,
Lucknow, Uttar Pradesh, India

Priyanka Singh

Division of Agricultural
Engineering, ICAR- Indian
Institute of Sugarcane Research,
Lucknow, Uttar Pradesh, India

S Patel

Department of Agricultural
Processing and Food
Engineering, Indira Gandhi
Krishi Vishwavidyalaya, Raipur,
Chhattisgarh, India

Correspondence

Neha Pradhan

Department of Agricultural
Processing and Food
Engineering, Indira Gandhi
Krishi Vishwavidyalaya, Raipur,
Chhattisgarh, India

Status of sugarcane juice preservation processes and technologies: A review

Neha Pradhan, Dilip Kumar, Priyanka Singh and S Patel

Abstract

Sugarcane (*Saccharum officinarum*), is a giant grass belonging to the family gramineae. Mythological texts of India dating back over 3000 years ago, mention the name of sugarcane and its products. Sugarcane juice is commonly used as a delicious drink in both urban and rural areas. Sugarcane juice is spoiled quickly due to the presence of simple sugars. The sugarcane juice can be introduced as delicious beverages by preventing the spoilage of juice with appropriate method. This review discusses the deterioration of sugarcane juice sources and indicator and their effect on sugarcane juice preservation. Common methods for preservation and processing of fruit juices include canning, pasteurization, freezing, evaporation, drying and addition of preservatives. The studies done for optimization of different pretreatment process conditions are also reviewed. This review gives complete overview of the processes and technological status of sugarcane juice preservation in present context.

Keywords: Sugarcane juice, preservation, pasteurization, high-pressure processing, microwave, Ohmic heating

Introduction

In India sugarcane is generally crushed to obtain juice which serves as a thirst quenching drink in hot summers. Sugarcane juice is great for recharging energy because it is rich in carbohydrate and iron. Being a nutritious product containing natural sugars, minerals and organic acids, sugarcane juice has many medicinal properties. It also possesses therapeutic values (Banerji *et al.*, 1997) [2]. It strengthens the stomach, kidneys, heart, eyes, brain and sex organs. The juice is beneficial in fevers. Sugarcane juice is very useful in scanty urination. For better results, it should be mixed with lime juice, ginger juice and coconut water. Mixed with lime juice, it can hasten recovery from jaundice. Sugarcane juice is a fattening food. It is thus an effective remedy for thinness. Rapid gain in weight can be achieved by its regular use (Karthikeyan and Samipillai, 2010) [21].

Sugarcane has been used as a sweetening agent for millennia and today mainly in the form of refined sugar (Phanikumar, 2011) [43]. The cane juice for final consumption is part of the informal food sector and it is sold mainly by street vendors, often in precarious sanitary conditions. If the cane juice is collected and preserved in a hygienic way, then it will easily meet up the nutritional problem of our large population.

The main problem associated with fresh sugarcane juice is its short shelf life and heat sensitivity of its flavour. Therefore, most of the attempts to preserve the sugarcane juice have been focussed on the use of refrigeration, mild heat treatment and preservatives. In circumstances where thermal processing is impractical, minimal processing employing different barriers to microbial growth can enhance product stability. Thus good sanitation is the first barrier to reduce microbial load and low storage temperature further retards growth. An acid environment of pH less than 4.5 restricts the growth of many organisms. Mostly fruit juices are acidic and can be used for acidification of sugarcane juice. Antimicrobial substances, either natural or chemical preservatives, also assist. It has been observed that low temperature storage is able to extend the shelf life of the juice.

Various researchers and scientists have tried to develop various preservation processes and techniques to increase the shelf life of sugarcane juice, which includes use of natural preservatives, chemical preservatives, thermal treatments, non-thermal treatments and hurdle approach which are described in this review.

Nutritional and therapeutic aspects of sugarcane juice

Sugarcane contains iron and vitamins A, C, B1, B2, B3, B5, and B6, plus a high concentration of phytonutrients (including chlorophyll), antioxidants, proteins, soluble fibre and numerous other health supportive compounds. The estimated composition of fresh sugarcane juice is given in Table 1.

Table 1: Composition of fresh sugarcane juice

Constituents	Content, mg per 100 ml
Total sugars	11.5
Ascorbic acid	1.5
Phosphorus	6.8
Iron	0.5
Calcium	2.1

Working synergistically, these nutrients provide a supremely health promoting food which has been studied for its role in fighting cancer, stabilizing blood sugar levels in diabetics, assisting in weight loss, reducing fevers, clearing the kidneys, preventing tooth decay, and a host of other health benefits. It is also valuable in burning micturition due to high acidity, gonorrhea, enlarged prostate and cystitis. Sugarcane juice is a fattening food. It is thus an effective remedy for thinness. Rapid gain in weight can be achieved by its regular use (Karthikeyan and Samipillai, 2010) [21]. Sugarcane juice has been used in the Ayurveda and Unani systems of medicine in India, since time immemorial. Sugarcane extract has displayed a wide range of biological effects including immune stimulation (El-Abasy *et al.*, 2002) [11], anti-thrombosis activity, anti-inflammatory activity, vaccine adjuvant, modulation of acetylcholine release (Barocci *et al.*, 1999) [3] and anti-stress effects. Sugarcane juice has broad biological effects in raising innate immunity to infections (Lo *et al.*, 2005) [32].

Deterioration of sugarcane juice source and indicator

The quality loss of sugarcane after the harvest, transportation, extraction, and storage operations poses a major problem to the farmers, distributors, and food industries. The primary quality loss is due to the physical, chemical and biological changes in the juice.

Physicochemical degradation

Hanan *et al.* (2002) [17] determined the effect of sugarcane maturation on the contents of chlorophyll, tannin, and polyphenol oxidase (PPO) activity and on color change of sugarcane juice. The maturation period of the cane studied was between 3 and 10 months after planting. Different parts of the cane, namely, the top, middle, and bottom portions, were analyzed. Results obtained indicated that there were significant ($P < 0.01$) decreases in total chlorophyll a and b and tannin contents during maturity followed by slower rates of decrease of both parameters at the end of maturity stages. There were no significant differences ($P > 0.05$) in chlorophyll and tannin contents between the middle and bottom portions. On the other hand, the top portion of the stem had a significantly ($P < 0.01$) lower concentration of chlorophyll and a significantly ($P < 0.01$) higher content of tannin. PPO activity of sugarcane juice was determined using chlorogenic acid as a substrate. There was a highly significant difference ($P < 0.01$) in PPO activity of cane juice during maturity. PPO activity was high at the early development stage, decreased during maturation, and then remained relatively constant at the end of maturity.

Yusof *et al.* (1999) [61] studied the quality of sugar-cane juice extracted from stored canes, as well as changes in quality of fresh juice stored at different temperatures. Cane stems were stored at 10 ± 1 °C, 85–88% relative humidity (RH) and 27 ± 1 °C, 55–85% RH, while fresh juice was stored at 5 ± 1 °C, 61–84% RH and 27 ± 1 °C, 55–85% RH. The physicochemical parameters evaluated were juice yield, juice colour, total soluble solids, sugar content (sucrose, fructose, glucose), titratable acidity, pH, chlorophyll content and sensory evaluation for colour and flavour. Viscosity and total microbial count on stored cane juice were also determined. Results showed that low temperature storage (10 °C) of canes was able to maintain the quality of juice for up to 9 days while low temperature storage (5 °C) of juice could last for only 4 days. During storage, sucrose contents decreased while fructose, glucose and titratable acidity increased in both types of samples. The colour changes in juice extracted from stored canes was inconspicuous until day 9. Deterioration of cane stored at 27 ± 1 °C occurred faster than that stored at 10 ± 1 °C. Fresh sugar-cane juice became spoiled after 4 days when stored at 5 ± 1 °C and 1 day when stored at 27 ± 1 °C.

Qudsieh *et al.* (2001) [46] conducted a study to determine the effect of sugarcane maturation on the contents of chlorophyll, tannin, and polyphenol oxidase (PPO) activity and on color change of sugarcane juice. The maturation period of the cane studied was between 3 and 10 months after planting. Different parts of the cane, namely, the top, middle, and bottom portions, were analyzed. Results obtained indicated that there were significant ($P < 0.01$) decreases in total chlorophyll a and b and tannin contents during maturity followed by slower rates of decrease of both parameters at the end of maturity stages. There were no significant differences ($P > 0.05$) in chlorophyll and tannin contents between the middle and bottom portions. On the other hand, the top portion of the stem had a significantly ($P < 0.01$) lower concentration of chlorophyll and a significantly ($P < 0.01$) higher content of tannin. There was a highly significant difference ($P < 0.01$) in PPO activity of cane juice during maturity. PPO activity was high at the early development stage, decreased during maturation, and then remained relatively constant at the end of maturity. There were also significant differences ($P < 0.01$) in juice color (L^* , a^* , b^* values) from different portions at different maturity stages. At the early stages, the color of extracted juice was dark, and then the juice turned to yellowish green during maturity. The decrease in green color or the increase in the yellow color could be associated with the decline in chlorophyll. The overall color change at maturity indicated that the color of the middle and bottom portions was lower than that of the top portion.

Microbiological and enzymatic degradation

Sugarcane juice is spoiled quickly by the presence of sugars (Krishnakumar and Devdas, 2006) [25]. Biodegradation which leads to the loss of sucrose by the formation of organic acid and ethanol caused by micro-organisms mainly *Leuconostoc* sp. (*L. mesenteroids* and *L. dextranum*). *L. mesenteroids* and *L. dextranum* converts sucrose into polysaccharide, such as dextran. Some species of yeast (eg. *Saccharomyces*) converts sucrose into ethanol (Chen and Chou, 1993) [7] while a few yeast species secrete acid invertase enzymes. Sucrose loss might occur due to its utilization by the microbes.

Eissa *et al.*, 2010 [10] studied the enzymatic browning changes in fresh sugarcane juice stored at room temperature 25°C and at refrigerator 4°C by determining juice colour as a capacity of browning and polyphenol oxidase (PPO) enzyme activity.

Deterioration of fresh sugarcane juice was demonstrated as a rapid increase of polyphenoloxidase enzyme activity and with an obvious browning.

Krishnakumar *et al.*, 2013 [25] conducted a study to determine the quality of sugarcane juice extracted from stored canes, as well as changes in quality of fresh juice stored at different temperatures. Cane stems were stored at 10°C and 30 °C, while the fresh juice was stored at 5°C and 30 °C. The parameters studied were juice yield, total soluble solids, total sugar content, titratable acidity, pH, viscosity, total microbial count and sensory evaluation for colour and flavour. Results showed that low temperature storage (10 °C) of canes was able to maintain the quality of juice for 10 days, while low temperature storage (5 °C) of juice could last for only 4 days. Spoilage of cane stored at 30 °C occurred faster than that stored at 10 °C. Fresh sugarcane juice became spoiled within a day when stored at 30 °C. Microbial count (bacteria, yeast, fungi) especially lactic acid bacteria count increased, during storage of cane juice.

Degradation due to unhygienic practices used by sugarcane juice vendors

Oliveira *et al.*, 2006 [39] tested twenty-four samples of point-of sale juice by standard methods to determine heterotrophic bacteria, total and thermo-tolerant coliform counts, *Salmonella*, and parasites in the juice. 25% of samples showed poor sanitary conditions, with thermo-tolerant coliform. *Salmonella* spp. and parasites were absent in all samples. Thermo-tolerant coliforms were detected on the hands of 37% of juice handlers, and heterotrophic bacterial counts reached 2.0×10^3 cfu/per hand. *Escherichia coli* were detected in one hand sample, and no *Salmonella* spp. was detected.

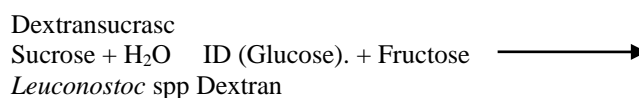
Mahale *et al.*, 2008 [34] analyzed the fresh squeezed juices of sugarcane, lime and carrot sold by street vendors in Mumbai city, for their microbial contents during the months of June 2007 to September 2007. The total viable counts of all 30 samples were approximately log 6.5 cfu/100ml with significant load of coliforms, faecal coliforms, *Vibrio* and *Staphylococcal* counts. Qualitative counts showed the presence of coagulase positive *S. aureus* in 5 samples of sugarcane and 2 samples of carrot juice. Almost 70% of the ice samples collected from street vendors showed high microbial load ranging from log 5- 8.5.

Rahman *et al.* (2010) [49] conducted a study to assess the microbial quality of fresh and commercially packed available juices collected from different locations of Dhaka city. A total of six fresh juice and nine commercially packed juice samples were collected. Standard culture techniques were followed to assess total viable count (TVC), total staphylococcal count (TSC), total Bacillus count (TBC) and total fungal count (TFC) on different culture media. The TVC varied from the range of 102 to 105 cfu/ml with the highest of 2.4×10^5 cfu/ml. A large number of staphylococci and Bacillus was also found from several samples. Total coliform and fecal coliform was found in six and five (out of fifteen) samples, respectively. Among total coliforms, Klebsiella, Enterobacter along with E. coli were detected. From all the assessment it was determined that the microbial quality of commercially packed juice was fairer than that of fresh juice collected from local market.

Ali *et al.*, 2015 [1] examined forty samples of sugar cane juice which were collected from selected areas and analyzed for total plate count, total coliform bacteria, faecal coliform bacteria, *Escherichia coli*, yeast and mould. The results

showed that in all the localities the street vended sugar cane juices remained hygienically poor as indicated through high bacterial load i.e. 4×10^2 - 3×10^7 cfu/ml. All samples were contaminated with coliform bacteria ranged from 46-1100 MPN/ml. Seventy-five percent of samples were contaminated with confirmed *Escherichia coli*. All the examined samples were contaminated with yeast and mould. Total coliforms were present in all analyzed samples of ice whereas confirmed *Escherichia coli* were present in 37% of samples and total plate count of ice samples ranged from 1×10^2 - 2×10^4 cfu/ml.

Dextran polysaccharide (formed mainly by leuconostocbacteria) has often been reported as a cane deterioration indicator, and is responsible for many of the numerous negative impacts that cane deterioration has on factory processing, mostly associated with the rise in viscosity from this polysaccharide. Oligosaccharides are also products of cane deterioration (Eggleston *et al.*, 2001; Morel du boil, 1995; Ravelo *et al.*, 1995) [14, 38, 53] and are responsible for crystal deformation problems (Morel, 1991) [37]. Ravelo *et al.* (1991) [52] reported that the formation of total oligosaccharides was greater than the formation of dextran and ethanol in cane subjected to delays and is, therefore, a more sensitive indicator of cane deterioration. A number of cane deterioration products including high invert sugars, polysaccharides (e.g. Dextran) and microbial contamination (e.g., ethanol and lactic acid formation) have been reported to predict and control processing problems at the factory (Solomon *et al.*, 2006, Eggleston *et al.*, 2001, Lionnet, 1996, Morel du boil, 1995) [55, 14, 28, 38], but not all deterioration products effect factory processing. Polysaccharide producing soil borne bacteria such as *Leuconostoc* spp. From cane field enters inside the cane through cut ends or damaged sites and thrives at the expense of stored sucrose, further reduces quality of milled juice. The *Leuconostoc* bacteria have the ability to synthesize alphanoglucan polysaccharide (dextran) from sucrose through an extracellular enzyme called dextran sucrose as shown below.



Sugarcane Juice Preservation: Processing and marketing of sugarcane juice is limited by its rapid deterioration. The main objective of sugarcane juice preservation is the development of effective treatments or procedures to maintain the freshness of sugarcane juice. This would allow it to be more widely marketed, and would enhance its quality and safety as well. The preservation of the sugarcane juice would be discussed under the following sub-headings:

1. Pre-treatment of sugarcane
2. Use of natural antimicrobials for preservation
3. Use of chemical antimicrobials for preservation
4. Use of Thermal Treatment for preservation
5. Use of Nonthermal Treatment for preservation
6. Recent Advances in the preservation of sugarcane juice

Pre-treatment of sugarcane

Effect of thermal and chemical pretreatments on changes of colour characteristics in sugar cane juice

Fresh sugarcane juice appeared olive-green and showed clear signs of degreening during processing and storage at room temperature 25 °C and at refrigerator 4 °C. Visually, juice extracted from untreated stems was a darker in colour than

that from treated stems. Degreening appeared with a rapid increase of a^* -value in sugarcane juice. However, thermal pretreatment of sugarcane stems before squeezing and/or addition of citric acid and SO₂ significantly inhibited the occurrence of degreening in juice during storage. Both the thermal treatment of stems and addition of citric acid and SO₂ showed an enhanced effect in preventing colour change by indicating the lowest a^* - value especially during the late period of storage at room temperature 25 °C and at refrigerator 4 °C. Browning was observed in the control with a rapid increase of a^* - value within the first 5 days. Afterward, juice colour became lighter with decreasing a^* -values during storage at room temperature. This result indicated that thermal and chemical pretreatments inhibited browning. The decrease of a^* - values during the late period of storage would be related with sedimentation of juice.

Maintaining the quality of sugarcane juice with blanching and ascorbic acid

Lin Chun Mao *et al.*, (2007) observed that physicochemical changes in fresh sugarcane juice stored at 10 °C were studied by determining juice yield, color, reducing sugar, titratable acidity, viscosity, pH, polyphenol oxidase (PPO), sucrose neutral invertase (SNI) and total microbial count. Results showed that blanching of stems before squeezing effectively prevented degreening and/or browning, and reduced activities of PPO and SNI in fresh sugarcane juice. Added ascorbic acid delayed the increase of reducing sugar, titratable acidity, viscosity and total microbial count, and also prevented degreening and/or browning with reduced PPO and SNI activities in fresh sugarcane juice during storage. Addition of 0.1% ascorbic acid seemed to be more effective than blanching of sugarcane stems, and was able to maintain the quality of fresh sugarcane juice for up to 5 days at 10 °C. Deterioration of fresh sugarcane juice was demonstrated as a rapid increase of titratable acidity and viscosity with an obvious browning.

Use of natural antimicrobials for preservation

The demand for natural preservatives has been increasing as they are less expensive, more nutritious, can be obtained easily, and they do not cause any health hazards. The natural preservatives commonly used are salt, sugar, lemon, and ginger for fruit juice preservation (Speranza and Corbo, 2010). Ginger, lemon, and salt are originally added to improve the taste but due to the antimicrobial activities; it enhances the shelf life of juice. Phenolic components present in natural preservatives are responsible for antimicrobial action (Rasooli, 2007) [47].

Ramchandran *et al.*, (2016) [51] studied that extract of moringa seed and leaf (*Moringa oleifera*); lemon (*Citrus limon*) and ginger (*Zinziber officinale*) were added to fresh sugarcane juice in different combination and evaluated on storage at 2,4 and 30 °C. Combinations of moringa seed extract with lemon and ginger showed high antimicrobial activity when compared with sodium benzoate (as chemical preservative), at the permitted level. Lemon lowered the pH of sugarcane juice to 3.01 and inhibited the growth of microorganism during storage. Further, phytochemical analysis of methanol extract of moringa seeds and leaves revealed polyphenols, flavonoids, tannins and terpenoids compounds. It was revealed that good quality sugarcane juice (100 ml) with satisfactory storage stability at refrigeration could be prepared from heat-treated juice (72 °C for 15 sec) before addition of lemon (3 ml) as a combination of flavour, color enhancer and

sources of citric acid (antioxidant); moringa (10 ml); ginger (0.6 ml) as flavour enhancer.

Use of chemical antimicrobials for preservation

Karmakar *et al.*, (2010) [20] observed the effect of temperature on the rates of decomposition of Vitamin-C and destruction of microorganisms in sugarcane juice during pasteurization, followed by packaging in flexible packs. Pasteurization of 30 conical flasks which contained 100 ml of sugarcane juice per flask at different temperatures, 80 °C, 85 °C and 90 °C for different time intervals; 30 seconds, 1 minute, 2 minutes and 5 minutes for the estimation of Vitamin-C and microbial count while keeping the flasks under two different conditions such as refrigerated temperature (4 °C) and room temperature (30 °C). Another set of experiments were carried out by adding sodium metabisulphite (preservative) at two concentrations; 500 ppm and 1000 ppm. Initially the quality of sugarcane juice with respect to Vitamin-C and microbial count were evaluated. Similarly, the quality of the processed sugarcane juice was also evaluated. Proximate analyses such as taste, smell and colour were also undertaken. The best result with respect to Vitamin-C retention and reduction of microbial load was obtained from the juice which was pasteurized at 90 °C for 5 minutes and stored at refrigerated temperature (4 °C). After 25 days the Vitamin-C content was found to be 4.7 mg/ml and microbial count was found to be 50/1ml in comparison to the values of the original sample.

Use of Thermal treatment for preservation

Verma *et al.*, (2016) [60] subjected the Sugarcane juice to heat treatment at 85 °C for 10 minutes followed by the addition of fresh lemon juice. After this the juice was subjected to the following treatments: in the first treatment the juice was immediately bottled, in the second treatment, ascorbic acid (40 ppm), potassium sorbate (120 ppm) and sodium benzoate (120 ppm) were added. In the third treatment cinnamon oil (0.4 ml) was added. The treated juices were bottled and pasteurized in hot water at 85 °C for 10 minutes and stored under ambient conditions (30±5 °C). Physico-chemical and microbiological observations were taken along with sensory evaluation. The chemical preservatives enhanced the shelf-life for up to 45 days. However, the pasteurized juice with no preservatives also showed acceptable sensory and microbial properties for up to 20 days of storage.

The CSIR - Central Food Technological Research Institute (CFTRI), Mysore, filed a patent for preservation and bottling of flavoured sugarcane juice. The processing steps involved were soaking the canes in water (0.1% potassium metabisulphite and 0.01% citric acid for 2–4 h), washing, crushing using the twin roller crusher, filtration using muslin cloth, reducing the TSS to 15°Brix by adding soft beverage water, acidification (0.1–0.3% citric acid and 0.01–0.03% sodium citrate), addition of flavouring agents (0.05–0.20% ginger oleoresin and/or 0.01–0.05% essential oils of lime and lemon), homogenization at 140 bar through deaerator, pasteurization (90–110 °C for 30–180 s), and filling in 250-ml aseptic unit packs (Raghavan *et al.* 2010) [48].

Damane *et al.* (2015) [9] prepared the milk whey blended sugarcane juice using chemical preservatives. Milk whey, ginger juice and lemon juice were added at different proportion ranges 15-60, 0.5-0.7 and 2.5-3.0 respectively in the 100ml of sugarcane juice. Raw sugarcane juice was prepared by pasteurizing at 70 °C for 10 minutes and adding KMS 225 ppm as preservatives. Blended sugar cane juice was optimised on the basis of sensory analysis. It was found that

sample T5 (35:2.75:0.6) was best as compared to other samples. Physico-chemical analysis of sample T5 was carried out and it was found that the nutritional value was more as compared to the control sample T0. Microbial analysis (Total Plate Count and Yeast mould count) of sample T5, T7 and T9 was carried out from 0 days to 55 days, and shows the growth of microbial activity was increased. Sample T5 shows satisfactory storage life. The lemon and ginger were able to lower the pH of sugarcane juice to 4.1 which gave a preservative action and inhibit the growth of microorganisms during storage.

Karmakar *et al.* (2010) [20] reported that sugarcane juice beverage samples were prepared by pasteurizing the juice at different temperatures. Pasteurization was done in eight conical flasks which contain 100 ml of sugarcane juice per flask at different temperatures *viz.*, 80, 85, 90, 95 °C for 2 min. Samples of sugarcane juice were stored at 25 and 4 °C in pasteurized glass bottles and analysed vitamin C and microbiological attributes at every 2 days interval for 25 days. sample heated at 90 °C for 5 min and stored at 4 °C, the desired properties remain intact for a longer time. After studying all the parameters of the sugarcane juice in each of the above mentioned conditions this juice is biologically safe after pasteurization and the food value is more or less same. An acceptable quality beverage of sugarcane juice with satisfactory storage stability for 25 days at 4 °C could be prepared.

Microwave Treatment

Pradhan *et al.* (2019) [44] made an attempt to preserve sugarcane juice with the help of microwave processing. Sugarcane variety CoLk 94184 were harvested from the farms of Indian Council of Agriculture Research-Indian Institute of Sugarcane Research, Lucknow (Uttar Pradesh). Peeled sugarcane sticks was subjected to heat treatment at 10 psi for 5 minutes and then sticks was immediately cooled in a deep freezer and juice was extracted through sugarcane juice extraction machine followed by the addition of lemon juice to maintain the pH 4.2-4.3. After this the juice was subjected to microwave treatments for time period of 1-4 minutes. Fresh sugarcane juice was taken as control. All the treated juices were bottled and pasteurized in hot water at 80 °C for 25 minutes. All the lots were stored under refrigerated condition. The prepared juices were observed for physico-chemical and microbiological aspects like pH, total soluble solids, colour (L^* , a^* , b^* values), total plate count, yeast and mould count along with sensory evaluation (overall acceptability). Changes in the above characteristics were observed and analyzed. From the results obtained it was clear that the overall performance of the above characteristics was found best when the juice was preserved by using microwave treatment for time period of 3 minutes (T3) which enhanced the shelf-life of sugarcane juice for upto 56 days.

Use of Nonthermal Treatment for preservation

A non-thermal technology for microbial inactivation in food products extends their shelf life and enables retention of their nutritional, physical, and sensory qualities. Thenon-thermal technologies are promising, and it includes high hydrostatic pressure (HHP), pulsed electric fields (PEF), and gamma irradiation (Mohd and Benchamaporn, 2007) [36]. Non-thermal treatment results in minimum loss of the organoleptic properties of food products (Oms-Oliu *et al.* 2012) [40].

Pulse Electric Field Treatment

Application of PEF technology has been successfully demonstrated for the pasteurization of foods such as juices, milk, yogurt, soups, and liquid eggs (Qin *et al.* 1995) [45]. When a plant tissue is treated with high pulsed electric field, the cell membranes are ruptured leading to an increase in permeability of the cell walls and subsequent increase in juice yield (Eshtiaghi and Knorr, 1999) [12]. Increased yield of sugarcane juice by PEF treatment during extraction has been observed (Kuldiloke *et al.* 2010; Eshtiaghi and Yoswathana 2012) [26, 13].

PEF treatment of sugarcane juice using static treatment chamber. The Marx's generator circuit was used to produce impulse voltages of 1.3/45 μ sec. (Kayalvizhi *et al.*, 2016) [22]. Sugarcane juice with and without lemon and ginger was treated with optimized test voltages and pulse rate. For all PEF experiments 300 mL of sugar cane juice was added inside the static treatment chamber under sterile condition. After PEF treatment the sample was collected in a sterilized, wide mouthed, screw-capped glass bottle and stored at 4 °C (refrigeration temperature) for 14 days storage period.

High-Pressure Processing (HPP)

HPP is an innovative and novel technique with a number of commercial processing applications that are reaching consumers all over the world. High-pressure processing is considered to be an effective technology for inactivation of Huang POD and PPO in fruit juices (Terefe *et al.*, 2014) [59]. Huang *et al.* (2015) [18] studied the effect of HPP (600 MPa for 6 min) on quality parameters (antioxidant capacity, physicochemical properties, sucrose neutral invertase activity, and sensory attributes) of sugarcane juice. The microbiological safety of the juice has been ensured for 28 days at 4 °C. Based on the physicochemical properties of the sugarcane, sugarcane juice treated with HPP resulted in significant difference in the color. However, changes in color caused by HPP treatment was relatively lower than pasteurized juice. Further, the juice reserved a greater amount of antioxidants. High-pressure processing does not affect the covalent and hydrogen bonding. Therefore, the pH remained constant before and after the treatment. And the sucrose neutral invertase activity was inhibited; thereby, degradation of reducing sucrose during storage becomes stable. The HPP-treated juice retained the sensory attributes; especially the flavour remained similar to that of the fresh sugarcane juice. The sugarcane juice treated at 600 MPa pressure at 60 °C in 6 min inactivated total plate count, yeast count, mould count, and also coliform, whereas complete inactivation of enzymes (polyphenol oxidase (PPO) and peroxidase) was found at 600 MPa at 60 °C in 8 min (Chauhan *et al.* 2017) [6]. Another study by Sreedevi *et al.* (2017) [57] revealed that maximum inactivation of PPO at 57% and maximum reduction of microbial activity obtained at 400 MPa pressure for 25 min. Hence, enzymatic and microbial activities were dependent on the pressure, temperature, and time. The inactivation of PPO found to be increased with pressure level or dwell time.

Ozone Treatment

Ozone applications in the sugarcane industry are mostly related to color reduction and preservation of the sugarcane juice. Ozone is attractive to the food industry due to its strong oxidative agents (Pandiselvam *et al.* 2015) [41], quick decomposition and that it doesn't leave any residues during food preservation (Pandiselvam *et al.* 2017) [42]. It is generally

recognized as safe (GRAS) to use as an antimicrobial agent on processed food (Loeb 2011) [33].

Garud *et al.* (2017) [15] employed a combination of ozone (1.2 g/h for 10 min), lactic acid (0.5%), and pasteurization (85 °C for 15 min) which resulted in 4.3 log reduction in total bacterial count and arrested 60 and 72% activity of polyphenol oxidase and peroxidase activity of sugarcane juice. The above-said treatment maintained the microbial and sensory quality of the sugarcane juice for a period of 1 month under refrigerated condition.

Effect of some Indian herbs and chemical

Kumar and Singh, (2016) [27] subjected the sugarcane juice to heat treatment at 75 °C for 15 minutes (T1). Heat treatment after addition of lemon juice + ginger + Pudina extracts + black salt (T2), heat treatment after addition of lemon juice + ginger + Tulsi extracts + black salt (T3), heat treatment after addition of 0.04 per cent propyl parabens (T4) and heat treatment after addition of 0.06 per cent propyl parabens (T5). Fresh sugarcane juice was taken as control (T0). All the treated juices were bottled and were pasteurized in hot water at 75 °C for 15 minutes. All the lots were stored for 30 days at room temperature (30 ± 5 °C). The prepared juice was observed for physico-chemical and microbiological aspects like T.S.S, pH, colour, total plate counts, yeast and mould growth along with sensory evaluation. The experiment was laid down using Completely Randomized Design. From the experiment it was clear that the overall performance of the above characteristics was found best when the juice was preserved by using heat treatment after addition of 0.04 per cent propyl parabens (T4). However, the use of Pudina in the treatment (T3) and Tulsi in the treatment (T4) have shown the maximum values of sensory attributes upto the interval of 5 days as compared to others.

Preservation of Sugarcane Juice Using Herbal Clarificant

Preparation of Ladies Finger Extract and Mixing into Juice: First we collected the ladies finger plant. We cut the stem into pieces. Then we collect the outer layer of the stem and put into water for 30 minutes. Mucilage substances came out from stem and mixed with water. 250-300 gm extracts are used as clarificant for 180 litre sugarcane juice. Juices were then boiled at 100 °C for 10 minutes. During boiling mucilage substances which were collected from ladies finger was mixed with juice. After mixing the extract all the dirty substances and fiber became clod together. Then we removed them completely. Thus we got a clear and transparent juice. Then the juices were bottled after cooling in germfree airtight bottles using laminar flow chamber and preserved for four months in room temperature (25°C). (Begum *et al.* 1995) [4]

Recent Advances in the preservation of sugarcane juice

Preservation of Sugarcane Juice Using Hurdle Technology

Traditional and novel food is based on a combination of several preservative factors which microorganisms present in the food are unable to overcome. This is known as hurdle effect. The hurdle effect is of fundamental importance for the preservation of foods. From an understanding of the hurdle effect, hurdle technology was derived, which allows improvements in the safety and quality of foods using deliberate and intelligent combinations of hurdles (Leistner 1999). Potential hurdles used in the preservation of foods can be divided into physical, physicochemical, microbially derived and miscellaneous hurdle. Among these hurdles, the most important ones are high temperature, low temperature,

water activity, acidity, redox potential (Eh), competitive microorganism (e.g. lactic acid bacteria) and preservatives (e.g. nitrite, sorbate, sulphite) (Leistner and Gorris 1995) [30].

Rawat and Pokhriyal (2014) [54] observed that the moisture content, ascorbic acid, viable bacterial count and viable yeast and mould count were decreased significantly ($P>0.05$) by irradiating the juice with 0.25, 0.5 and 1.0 kGy whereas no significant effect was observed on reducing and total sugars in cane juice. On storage, ascorbic acid and total sugars were decreased significantly ($P>0.05$). All the samples were packed in glass bottles, polyethylene Tetrathelate (PET) bottles and low density polyethylene pouches (LDPE) and then stored for 90 days at room and low temperature. Among the three packaging material used, glass and PET was found to be at par in increasing the shelf life of sugarcane juice in comparison to LDPE pouches.

Mishra *et al.* (2011) [35] analysed that a combination of gamma radiation (5 kGy) with permitted preservatives and low temperature storage (10 °C) could preserve raw sugarcane juice for more than a month. The preservatives used were citric acid (0.3%), sodium benzoate (0.015%), potassium sorbate (0.025%), and sucrose (10%). The treatment helped in extending the shelf life to 15 days at ambient temperature (26± 2 °C) and 35 days at 10 °C. The microbial load was found to be below detectable limit within this period. The biochemically phenolics and flavonoids were not found to be affected by addition of these preservatives. The antioxidant activities including free radical scavenging activity, nitrite scavenging activity, and reducing power were also not significantly affected. The sensory evaluation scores showed that the juice with this combination treatment was highly acceptable.

Jittanit *et al.* (2010) [19] observed that, the Ultra Heat Treatment (UHT) sterilization at 140°C and holding for 4 seconds could maintain the sugarcane flavours and provide the more favourable juice than those at 135°C for 10 seconds.

Clarification process of sugarcane Juice

Clarification aims to remove impurities, namely soluble, insoluble, and colloids in suspension, from the juice to preserve sucrose, main product of interest, preventing the decomposition of reducing sugars (Copersucar, 1987) [8].

The clarification of sugar cane juice occurs by coagulation, flocculation, and precipitation of the colloids and pigmented substances, which are later eliminated by decanting and filtration, i.e., an insoluble precipitate which absorbs and drags such compounds from the juice is formed. Flocculation can be carried out by changing the pH, using chemical reagents, or through heating (Koblitz and Moretti, 1999; Stupello, 1987) [23, 58].

Clarification by Ultrafiltration

Gaschi *et al.*, (2014) [16] observed that the sugar cane juice from COCAFE Mill, was clarified using tubular ceramic membranes (α -Al₂O₃/TiO₂) with pore size of 0.1 and 0.3 μ m, and membrane area of 0.005 m². Experiments were performed in batch with sugar cane juice, in a pilot unit of micro and ultra-filtration using the principle of tangential filtration. The sugar cane juice was settled for one hour and the supernatant was treated by microfiltration. After that, the MF permeate was ultra-filtered. The experiments of micro and ultrafiltration were carried out at 65°C and 1 bar. The ceramic membranes were able to remove the colloidal particles, producing a limpid permeated juice with color reduction. The clarification process with micro- followed by ultrafiltration produced a

good result with an average purity rise of 2.74 units, 99.4% lower turbidity and 44.8% lighter color in the permeate.

One disadvantage of conventional clarification of the sugar cane is the high amount of inputs used a sulphur and lime. Besides, the conventional production of white sugar features inefficient removal of substances like starch, silica, ash, colloids, during the clarification, which in turn affect the colour of the final product (Bhattacharya *et al.*, 2001) [5].

Future Research Need

Sugarcane juice is a very popular drink in India but still it is rarely available commercially in packaged form. The researches should focus on hurdle approach and a combination of novel processing technologies. They can cause minimum damage to the delicate flavour of the sugarcane-juice and also preserve the juice for longer duration.

Conclusion

This review states that the juice was stabilized by using herbal clarificant, and the presence of lemon and ginger paves the way for natural preservation, while thermal and chemical treatments have also been highly effective to improve the shelf-life of the sugarcane juice. Non-thermal treatments such as high pressure processing (HPP), gamma irradiation, Ohmic heating and Pulse Electric Field have been used to treat sugarcane juice and meet consumer requirements. However, temperature and holding time optimization still remains the most effective way to design efficient and energy-saving methods. However, they effect the delicate flavours and colour of the sugarcane juice and thereby reducing the consumer acceptability of the product.

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