

## RESEARCH ARTICLE

## PRODUCTION AND CHARACTERIZATION OF SUGARCANE JUICE POWDER

K. Hari<sup>1\*</sup>, S. Reginold Jebitta<sup>2</sup> and K. Sivaraman<sup>1</sup>

### Abstract

Experiments were carried out to produce a powder product of sugarcane juice by employing a laboratory scale spray dryer. Sugarcane juice powder (SJP) was prepared from juice obtained from a 12 month old crop of the sugarcane genotype Co 99006. Initial attempts of spray drying raw sugarcane juice resulted in poor powder yield as most of the sprayed juice adhered to the dryer chamber wall. In optimization experiments carried out, inlet temperature of 160°C, aspirator level - 70 mm Hg, spray pressure 1.0 kg cm<sup>-1</sup> and feed rate 100 ml h<sup>-1</sup> emerged as optimum conditions producing higher SJP yield with lower moisture content (<5.0%). Further improvement in the process was carried out by adding bulking agents, viz. lactose mono hydrate, maltodextrin DE 20, soluble starch and sucrose which significantly improved the powder yield. All the powders with bulking agents recorded low moisture content (<4%), water activity (<0.34), high bulk density (>0.5 g cm<sup>-3</sup>) and better flowability (<47°) compared to the raw juice powder. Also, all powders recorded low total bacteria (<10 cfu g<sup>-1</sup>) and absence of mould, yeast and coliforms. Differential scanning calorimeter (DSC) analysis clearly indicated that addition of lactose monohydrate, maltodextrin DE 20 and soluble starch increased the glass transition temperature (T<sub>g</sub>) and decomposition temperature while addition of sucrose had negative effect. Scanning electron microscope images revealed variations in particle size, shape and surface characteristics. Addition of maltodextrin and soluble starch formed spherical particles. Composition of SJPs did not indicate significant variation among powders prepared either with or without bulking agents. Powders retained substantial quantities of nutritional substances. Powders packed and stored in different grades of moisture proof plastic pouches for three months did not show significant changes in moisture content, bulk density, colour and microbial parameters.

**Key words:** Sugarcane juice powder, spray drying, bulking agents, physicochemical properties, SEM, glass transition temperature

### Introduction

India is the second largest producer of sugarcane and cane sugar, after Brazil. Presently, India produces about 358 million tonnes of sugarcane in an area of about 5 million hectares. Of this, about 72% goes for the manufacture of white crystal sugar and the rest goes for *Gur* or *Khandsari* production (16%) and as planting material (12%) (Anonymous 2013).

Juice extracted from commercial varieties contains about 18% Brix when harvested at the age of about 12 months. The juice extracted from cane is an opaque liquid and its colour varies from light grey to dark green, depending on the cane variety crushed. It is a naturally flavoured drink on its own containing sucrose, fine particles of bagasse, wax, colouring matter and minerals. The juice is viscous due to the

---

K. Hari<sup>1\*</sup>, S. Reginold Jebitta<sup>2</sup> and K. Sivaraman<sup>1</sup>

<sup>1</sup>Division of Crop Production, Sugarcane Breeding Institute, ICAR, Coimbatore 641007, Tamil Nadu, India

<sup>2</sup>Department of Food Processing and Engineering, School of Food Science and Technology, Karunya University, Coimbatore 641114, Tamil Nadu, India

\*email : sbi\_hari@yahoo.com

presence of colloidal substances, wax, protein, pentosans, pectic substances, natural gums, starch and silica. The cane juice has an acidic pH ranging from 4.5 to 5.7.

As a well known natural thirst-quenching drink, hygienic handling of sugarcane juice undoubtedly needs attention (Reddy 1999; Nagalakshmi and Reddy 1999; Lopes et al. 2006; Oliveira et al. 2006; Subbannyya et al. 2006; Oliveira et al. 2008). Sugarcane juice as such is highly nutritious and prone to microbial contamination and spoilage. Fermentation sets in within a few hours of extraction and the juice loses its natural refreshing properties. It is very difficult to maintain sugarcane juice in the liquid state without adding a high amount of preservatives which would affect the organoleptic qualities of the juice. The difficulty in preserving sugarcane juice originates from the nature of the juice itself as the pH above 5.0, high sugar and nutrient content favour microbial growth (Yusof et al. 2000). In addition, the high sugar content of the juice is prone to degradation when heated to high temperatures during pasteurization, evaporation or drying bringing a negative effect on the sensory attributes of the juice. Therefore, most of the attempts to preserve the sugarcane juice have been focusing on the use of refrigeration, freezing and preservatives (Bhupinder et al. 1991; Yusof et al. 2000).

Attempts made to preserve the sugarcane juice involved blanching of stems, juice extraction, pasteurization followed by addition of ascorbic or citric acid and preservatives such as potassium metabisulphite, sulphur dioxide and bromo nitro propanediol. Ginger or lemon extract were added to improve the taste. The juice thus prepared was bottled in sterilized glass bottles to be used as an acceptable beverage with a low shelf life under room temperature or at refrigerated condition (Anonymous 1991; Mann and Singh 1988). Changes in the physical, chemical, microbiological and taste qualities of the juice were also reported. Significant changes with respect to pH, total soluble solids, total sugars

and reducing sugars, titrable acidity, total microbial count and sensory qualities on storage of preserved juice were reported (Kapur et al. 1978; Mann and Singh 1988; Rao 1990; Anonymous 1991; Bhupinder et al. 1991; Alvarez et al. 1997; Chauhan et al. 2002; Campo et al. 2004; Mao et al. 2007). Chun et al. (2007) has reported improvement on sugarcane juice preservation by blanching and ascorbic acid addition. Overall, these studies indicated that preserving raw sugarcane juice is a risky affair, posing food related hazards.

To preserve the flavor, nutritional and nutraceutical qualities of sugarcane juice, water in the juice needs to be removed as quickly as possible. Dehydration by spray drying is used extensively in food related industries for a wide range of products to be stored in dry particulate form as powders and agglomerates (Sagar and Kumar, 2010). In spray drying, exposure of juice to heat is minimum and the product obtained is in powder or granular form without substantial loss in nutritional and nutraceutical substances essential for human health (Adhikari et al. 2004). However, powders produced from fruit juices had problems, such as stickiness and high hygroscopicity, due to the presence of low molecular weight sugars and organic acids with low glass transition temperature (T<sub>g</sub>) (Bhandari et al. 1993; Tonan et al. 2011). Sugarcane juice contains about 18 per cent (w/v) sucrose which has low T<sub>g</sub>. Apart from sucrose many low T<sub>g</sub> substances like glucose, fructose and organic acids such as citric, malic, aconitic, tartaric and other acids are also present. Efficient spray drying needs temperatures higher than 100°C. At this temperature low T<sub>g</sub> substances melt and stick to the dryer chamber wall leading to a poor powder yield. The addition of high molecular weight additives such as maltodextrins, gum arabic, waxy starch and microcrystalline cellulose has been suggested as an alternative to tackle T<sub>g</sub> related problems and improve the final powder recovery (Bhandari and Howes 1999; Truong et al. 2005; Shrestha et al. 2007).

The present study investigates the optimization of conditions for sugarcane juice spray drying and the

influence of different bulking agents on the production of sugarcane juice powder (SJP).

## Materials and methods

### Experimental site

The experiments were conducted at Sugarcane Breeding Institute, Coimbatore 641007, Tamil Nadu, India.

### Raw material

Twelve months old canes of the sugarcane clone Co 99006 obtained from Sugarcane Breeding Institute farm were used in this study. After removing the dry leaves, green tops, and insect infested and damaged portions, the canes were washed and scrubbed mildly under clean water to remove the adhering soil and other dirt. Cleaned canes were then stored at 4°C.

### Sample preparation

Juice was extracted from canes using a table top power crusher having two stage stainless rollers (Savvy, Coimbatore, India) and filtered through layers of fine sieves. The juice was blended with different bulking agents like gum arabic, lactose monohydrate, maltodextrin DE 20, sucrose and soluble starch.

### Spray drying of sugarcane juice

A laboratory model glass spray dryer (Spraymate, JISL, Mumbai, India) was used in the experiments. The spray drying was carried out using the co-current system with 1.0 mm atomizer nozzle. Optimization of spray drying conditions was carried out with different combinations of spray dryer parameters viz., inlet and outlet temperature, feed volume, nozzle diameter, spray pressure and aspirator level, and feeding rate. During spray drying the juice was mixed continuously using a magnetic stirrer to avoid settling of bulking agents. The powder accumulated in glass cyclone collector and collection bottle was collected and taken as powder yield. The powder collected was stored in airtight containers and stored at 4°C.

## Physical and rheological analysis

Physical and rheological characteristics such as bulk density, colour, flowability, hygroscopicity, particle distribution, powder particle morphology, solubility, thermal properties and viscosity were analysed as described below.

**Bulk density:** Bulk density was determined from the ratio between the weight of powder and the volume occupied after tapping the powder in a measuring cylinder for 20 times (Goula and Adamopoulos 2004; Phoungchandang and Sertwasana 2010) and was expressed as  $\text{g cm}^{-3}$ .

**Colour measurement:** About 2.0 g powder sample was filled in spectrophotometric cuvette and tapped twenty times for compaction. The approximate colour of the powder sample in terms of  $L^*a^*b^*$  was determined by visually comparing the sample with a simple colour image generated using computer in a TFT flat monitor. The  $L^*a^*b^*$  value of the image was taken as colour. Multiple samples were taken and the nearest  $L^*a^*b^*$  value was expressed as powder colour.

**Flowability:** Flowability was analyzed by the static angle of repose method (Teunou et. al. 1999). About a 50.0 g of the powder was dropped from a height of 25 cm using a funnel fitted on top of a glass box. The radius of the conical pile formed was measured. The angle of repose values were calculated by using the formula  $\tan \alpha = H/R$  where  $\alpha$  = angle of repose in degrees ( $^\circ$ ), H = height from which the powder is dropped and R = radius of the conical pile.

**Particle morphology:** Particles were imaged using a scanning electron microscope (SEM) (JEOL-6390, JEOL USA, Inc., USA). For imaging, powders attached to a double-sided adhesive tape mounted on SEM stubs were coated with gold/palladium under vacuum and scanned.

**Solubility:** The dissolution test was carried out by placing 1.0 g of the samples in a 25 ml beaker. The beaker was placed on a magnetic stirrer, 10 ml of distilled water was added to the powder and stirrer

was set at 100 rpm. The time taken in seconds for full reconstitution of the powder was recorded using a timer (Eastman and Moore 1984).

**Thermal Analysis:** Thermogram of SJP was obtained using a differential scanning calorimeter (Q-200, TA Instruments, USA) with an integrated software for calculating T<sub>g</sub>, melting point and decomposition temperature. A sample of 5.0 mg was taken in a sealed Aluminium pan and the analysis was carried out under the flow of nitrogen gas @ 50 ml min<sup>-1</sup> with a scanning rate of 10°C min<sup>-1</sup> from 0 to 200 °C.

**Viscosity:** Viscosity was determined using the Vibro-viscometer (SV-10, A & D, Japan). About 35 ml of juice was placed in the sample cups and the viscosity value was recorded at 20°C.

### Chemical analysis

**Moisture content:** Powder moisture content was determined using automatic moisture analyzer (MX-50, A & D, Japan) with halogen lamp heating. About 5.0 g of spray dried SJP was used at 80°C to determine moisture content.

**pH:** The pH of the sugarcane juice was measured using a digital pH meter (Cyber scan 500, Eutech Instruments, Netherlands).

**Water activity:** Measurement of water activity was carried out by placing 50 g of spray dried SJP in an air tight 100 ml glass bottle with an electronic humidity sensor. The bottle was incubated at 30°C and the relative humidity inside the bottle was recorded after 12 h. Water activity (aw) was calculated using the relationship  $RH = aw \times 100\%$ .

**Total solid content (TS):** About 2 ml of sugarcane juice was taken and moisture content determined using automatic moisture analyzer (MX-50, A & D, Japan) set at 103°C and the TS content was calculated from the moisture percent.

**Total soluble solid content (TSS):** TSS content of the fresh juice was measured using the Hand-Held refractometer (PAL-1, ATAGO, USA).

**Ash:** Ash content was determined by taking 1.0 g sample in a pre-weighed crucible and heating in a muffle furnace at 550°C for 2 hours. Weight of the crucible with ash was taken and the ash percent was determined (AOAC, 1995).

**Carbohydrate, protein, phenols, chlorophyll and flavonoids:** Carbohydrate was estimated by the anthrone method (Hodge and Hofreiter 1962), total protein by Lowry's method (Lowry et al. 1951), total phenols by Folin-Ciocalteu method (Tsao et al. 2005), chlorophyll by ether extraction and spectroscopic determination (Arnon 1949) and flavonoids by the method described by Ali and Chang (2008).

### Microbiological analysis

Total bacteria, fungi, yeast and coliforms were enumerated by serial dilution and plating method using Nutrient Broth 1% peptone (Himedia, India), Rose Bengal Agar Base high medium (M842, Himedia, India), Potato Dextrose Broth with 10% glucose (M403, Himedia, India) and Brilliant Green Bile Broth 2% (M121S, Himedia, India) respectively. Samples of 1.0 g were serially diluted, 1.0 ml of different dilutions (10<sup>-1</sup> to 10<sup>-5</sup>) were plated and incubated for 5 days at 30°C. For coliforms, brilliant green bile plates were incubated at 37°C. Colonies formed were enumerated and the population expressed as colony forming units (cfu) g<sup>-1</sup>.

### Shelf life study

SJPs were packed in different food grade pouches viz. low density polyethylene (100µ), polypropylene (100µ) and aluminum lined polypropylene (50µ) and were stored for 180 days at 4°C and 30°C. The SJPs were analysed for physical, rheological, chemical and microbiological properties at 90 and 180 days of storage.

### Statistical analysis

The data obtained from various tests were subjected to analysis of variance (ANOVA) and means compared using least significant difference (LSD).

## Results and discussion

The difficulty in preserving sugarcane juice is due to its pH and nutrient content (Yusof et al. 2000) which favor microbial growth leading to spoilage. In addition, the high sugar content of the juice makes it vulnerable to sugar degradation if heated to high temperatures during the processes of pasteurization, evaporation and drying. Therefore, most of the attempts to preserve the sugarcane juice have been on the use of refrigeration, filtration, heat treatment and addition of preservatives. Use of low temperatures or chilling has been the most preferred method in maintaining the quality of sugarcane juice (Yusof et al. 2000; Bhupinder et al. 1991). Dehydration by spray drying is used extensively in food related industries for a wide range of products in dry particulate form as powders and agglomerates (Sagar and Kumar 2010).

In the present study, attempts were made to produce SJP by spray drying. The juice used for different experiments was extracted from a sugarcane clone Co 99006, which gave about 60% v/w juice yield. The characteristics of sugarcane juice obtained and used in this study are given in Table 1.

### Optimizing spray drying parameters

Different combinations of inlet temperature, feed rate, vacuum and spray pressure were experimented to identify optimum spray drying conditions required for raw sugarcane juice. An initial attempt to optimize

spray drying parameters for raw sugarcane juice has resulted in operational problems. Most juice sprayed from the nozzle stuck to the dryer chamber wall and resulted in poor powder yield. Similar observations were reported by Bhandari et al. (1997). This necessitated the addition of 20 % w/v maltodextrin to the sugarcane juice in optimization experiments. The results indicated a powder yield range of 0.0 - 69.8 g. The highest powder yield of 69.8 g was obtained when spray drying was carried out with inlet temperature of 160°C, aspirator level -70 mm Hg, spray pressure 2.0 kg cm<sup>-2</sup> and feed rate 100 ml h<sup>-1</sup> (Fig. 1) The powder thus obtained recorded a moisture content of 1.78%, bulk density 0.79 g cm<sup>-3</sup>, water activity 0.32, flowability 47.0 and colour L\*95 a\*-1 b\*30.

Higher inlet temperature and lower feed volume significantly affected the moisture content of the powder. The highest moisture content of 2.7 % was obtained when the inlet temperature was at 140 °C and the feed volume at 120 ml h<sup>-1</sup>. The lowest moisture content of 1% was obtained at 220 °C and 40 ml h<sup>-1</sup> (Fig. 2).

Experiments were carried out to find the effect of spray pressure, nozzle size and suction level on powder production keeping the inlet temperature at 160 °C and feed volume at 100 ml h<sup>-1</sup>. Spray pressure from 1.0 to 4.0 kg cm<sup>-2</sup>, nozzle size from 0.5 to 3.0 mm and aspiration levels from -50 to -100 mm Hg did not show significant effect on powder yield, moisture content and bulk density. However, a minimum of -50 mm Hg suction level may be required to operate the spray dryer to collect the juice powder in the collection chamber. Similar results were reported by Goula et al. (2004) in spray drying of tomato pulp. According to the authors, the plastic layer droplet surface characteristics exhibited by the feed at higher temperatures resulted in lower bulk density of the dried product.

### Effect of bulking agents on SJP

Major constituent of sugarcane juice is sucrose that has low Tg. Apart from this, many low Tg substances

**Table 1. Characteristics of sugarcane juice used in the study**

Sl. No.	Character	Value/grade
1	Brix (TSS)	19.40
2	Total Solids (TS)	22.2% w/v
3	pH	4.7
4	Electrical conductivity	2.4 mS cm <sup>2</sup>
5	Viscosity @ 20 °C	4.2 cp
6	Colour	L*92 a*1 b*30

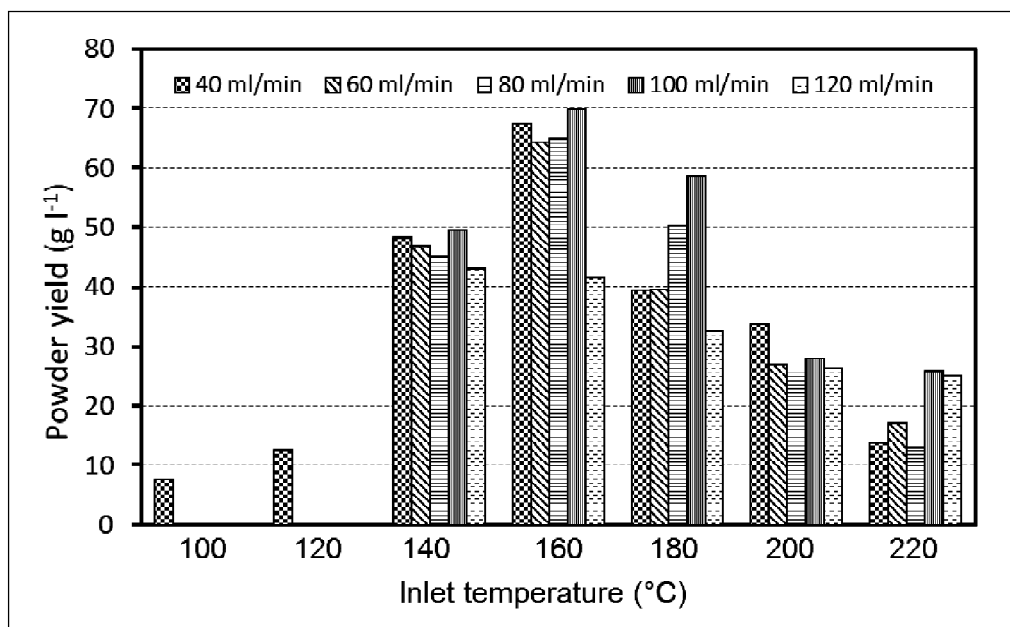


Fig 1. Effect of temperature and spray volume on sugarcane juice powder yield

like glucose and fructose and organic acids such as citric, malic, aconitic, tartaric and other acids are present in the sugarcane juice thus making a powdered product from sugarcane juice by spray drying difficult. Theoretically, efficient spray drying can happen at temperatures above 100°C. Our attempts with spray drying raw juice at temperatures

above 100°C resulted in the juice attaching to the dryer chamber wall leading to poor powder yield. Similar problems of stickiness and high hygroscopicity were reported in fruit juice powder production due to the presence of low molecular weight sugars and acids with low T<sub>g</sub> (Bhandari et al. 1993; Bhandari et al. 1997; Tonon et al. 2011).

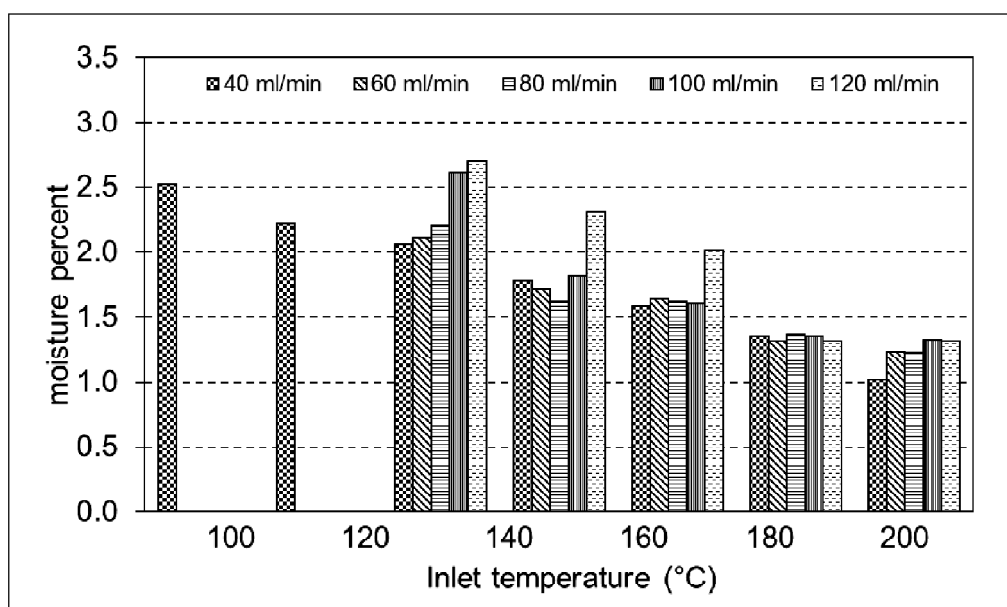


Fig. 2. Effect of temperature and spray volume on moisture content of sugarcane juice powder

Addition of high molecular weight additives such as maltodextrins, lactose, gum arabic, starch, microcrystalline cellulose, etc. is widely adopted in food industry as a means to increase Tg (Bhandari and Howes 1999; Truong et al. 2005; Shrestha et al. 2007). Different grade maltodextrins (modified starches) are available having Tg above 100°C. Apart from this, these maltodextrins have high solubility in water and provide good stability for the powder product at low cost (Beristain et al. 2002; Bhandari and Hartel 2005). Insoluble and soluble starches and cellulose substances, though have high Tg and are less costly, they are not readily water soluble as maltodextrins and, hence, are not suitable for powders necessitating reconstitution into a clear solution. Gum arabic is a natural plant exudate of *Acacia* trees, which consists of a complex heteropolysaccharide with highly ramified structure. It is the only gum extensively used in food products that has high water solubility and low viscosity in aqueous solution, making it easier in the spray-drying process (Rosenberg et al. 1990). Extensive reports are

available on significant improvement in powder yield due to addition of bulking agents in fruit juices (Jaya and Das 2004; Chegini and Ghobadian 2007; Oliveira 2009; Quek 2010; Sagar and Kumar 2010; Tonon et al. 2010).

Results of the present experiment also clearly showed that SJP yield was significantly higher when added with bulking agents such as lactose monohydrate, maltodextrin DE 20, soluble starch and sucrose (Table 2). The highest powder yield of 86.21 g l<sup>-1</sup> was obtained with 20% maltodextrin and the lowest of 33.12 g l<sup>-1</sup> with raw sugarcane juice. Addition of bulking agents significantly affected the moisture content of SJP. The highest moisture content of 2.24% was recorded with SJP from raw juice. Different bulking agents at varying levels had no influence on moisture content except 20% maltodextrin DE 20. The highest bulk density of 0.71 g cm<sup>-3</sup> was recorded with 20% maltodextrin DE 20 which was significantly different from all the other bulking agents used at different levels. Addition

**Table 2. Influence of bulking agents on physical properties of sugarcane juice powder**

S.No.	Bulking agent	Powder yield (g l <sup>-1</sup> )	Moisture content (%)	Bulk density (gcm <sup>-3</sup> )	Water activity	Flow-ability (°%)	Colour		
							L*	a*	b*
1	Raw juice (control)	33.12	3.24	0.79	0.32	47	95	-1	30
2	Maltodextrin 5%	71.34	2.81	0.65	0.31	32	95	-2	29
3	Maltodextrin 10%	81.11	2.96	0.61	0.31	30	94	-2	30
4	Maltodextrin 15%	85.33	3.01	0.67	0.33	29	95	-1	29
5	Maltodextrin 20%	86.21	3.24	0.71	0.31	28	95	-1	30
6	Sucrose 5%	56.51	3.87	0.72	0.34	35	95	-1	30
7	Sucrose 10%	61.11	3.93	0.67	0.32	35	95	-1	29
8	Sucrose 15%	59.32	3.82	0.71	0.32	37	95	-2	29
9	Lactose 5%	76.34	2.79	0.61	0.31	30	95	-1	30
10	Lactose 10%	81.61	2.85	0.57	0.30	29	94	-1	29
11	Lactose 15%	86.32	2.93	0.61	0.30	28	94	-2	30
12	Soluble starch 3%	76.22	2.88	0.62	0.30	33	95	-1	30
13	Soluble starch 6%	81.27	2.88	0.61	0.31	32	95	-2	28
14	Soluble starch 9%	86.22	2.96	0.61	0.31	34	95	-1	29
	CD (0.05)	6.21	0.63	0.14	NS	2.36	-	-	-

of different levels of maltodextrin DE 20 and sucrose resulted in significant increase in the bulk density of SJP. While addition of lactose mono hydrate and soluble starch did not affect the bulk density of SJP, addition of maltodextrin DE 20 at 15 and 20% significantly increased the bulk density compared to control SJP which was also on par with addition of different levels of lactose monohydrate, sucrose and soluble starch. Goula et al. (2004) reported similar observations in spray dried tomato pulp powder. Particles with higher moisture content tended to form dry agglomerates or larger particles leading to a lower bulk density.

Water activity is one of the most critical factors in determining quality and safety of food. Water activity affects the shelf life, safety, texture, flavor and smell of foods and is the most important factor in controlling spoilage, besides temperature, pH and several other factors. Most bacteria do not grow below 0.91, so also most molds cease to grow below 0.80. In addition,  $a_w$  plays a significant role in determining the activity of enzymes and vitamins in foods (Roos, 1993). All the SJPs produced in this study had less than 0.34 (Table 2), indicating that these powders are safe for long term storage without microbial spoilage and biochemical deterioration.

Physical properties such as particle size, size distribution, shape, surface area and density also play a role in the flowability of powders. Powder flow properties are directly related to the physical properties of the material itself and it is important for further handling, packaging and storage. In the present study, addition of bulking agents significantly improved the flowability of SJP compared to SJP with juice alone (Table 2). Addition of lactose monohydrate and maltodextrin has resulted in better flowability followed by soluble starch and sucrose. The results indicate that lactose monohydrate and maltodextrin added powders are suitable for packaging and storage.

The colour of the different SJPs was similar and it was around  $L^*95 a^*-1 b^*30$ . Colour mainly comes from the rind pigments and phenols in the juice. In

this study, it was unlikely to observe differences in terms of juice colour as the study employed only one variety Co 99006 (Table 2).

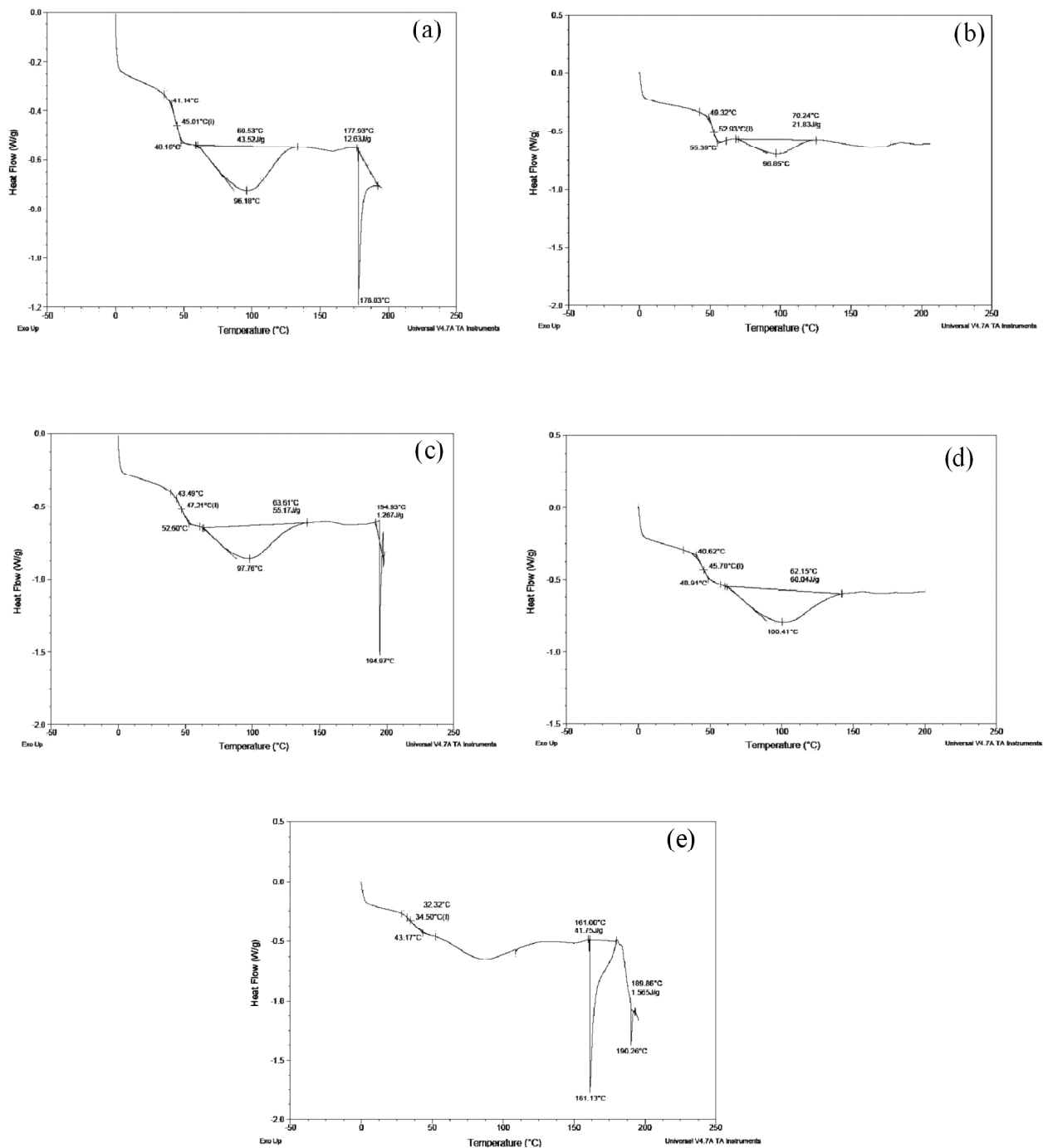
### Thermal properties of SJP

Thermograms obtained by DSC analysis clearly showed T<sub>g</sub>, melting point and the decomposition point of SJPs. While SJP without additives recorded a T<sub>g</sub> value of 45.01°C and melting point of 96.18°C, decomposition was found to set in at 177.93°C. Addition of bulking agents clearly improved the thermal properties of SJP (Fig. 3). Highest improvement in T<sub>g</sub> was obtained with the addition of lactose monohydrate (52.93°C) followed by maltodextrin (47.21°C) and soluble starch. But sucrose addition decreased T<sub>g</sub>, melting point and decomposition temperature which recorded the lowest values of 34.50, 85.00 and 161.13°C respectively. Addition of soluble starch increased the melting point, while lactose and maltodextrin recorded a lesser effect. Addition of lactose, maltodextrin and soluble starch had significant effect on decomposition temperature while lactose and soluble starch did not show decomposition even up to 200°C. Similar observations were made in fruit juice powders (Shrestha, et al., 2007).

### Particle morphology

SEM images revealed the surface characteristics of the different SJPs (Fig. 4). Maltodextrin added SJP gave clear spherical particles with smooth surface, but starch gave rough surfaced spherical particles. Since maltodextrins are lower molecular weight substances with high water solubility compared to starch, they formed smooth spherical particles. Overall, observations clearly indicated that the particle distribution was not uniform. The particles formed by lactose, sucrose and raw sugarcane juice were not clear and appeared as agglomerates. Physical appearance of SJP from lactose added juice was as a smooth fine powder but SJP of raw juice showed tendency to form clumps.



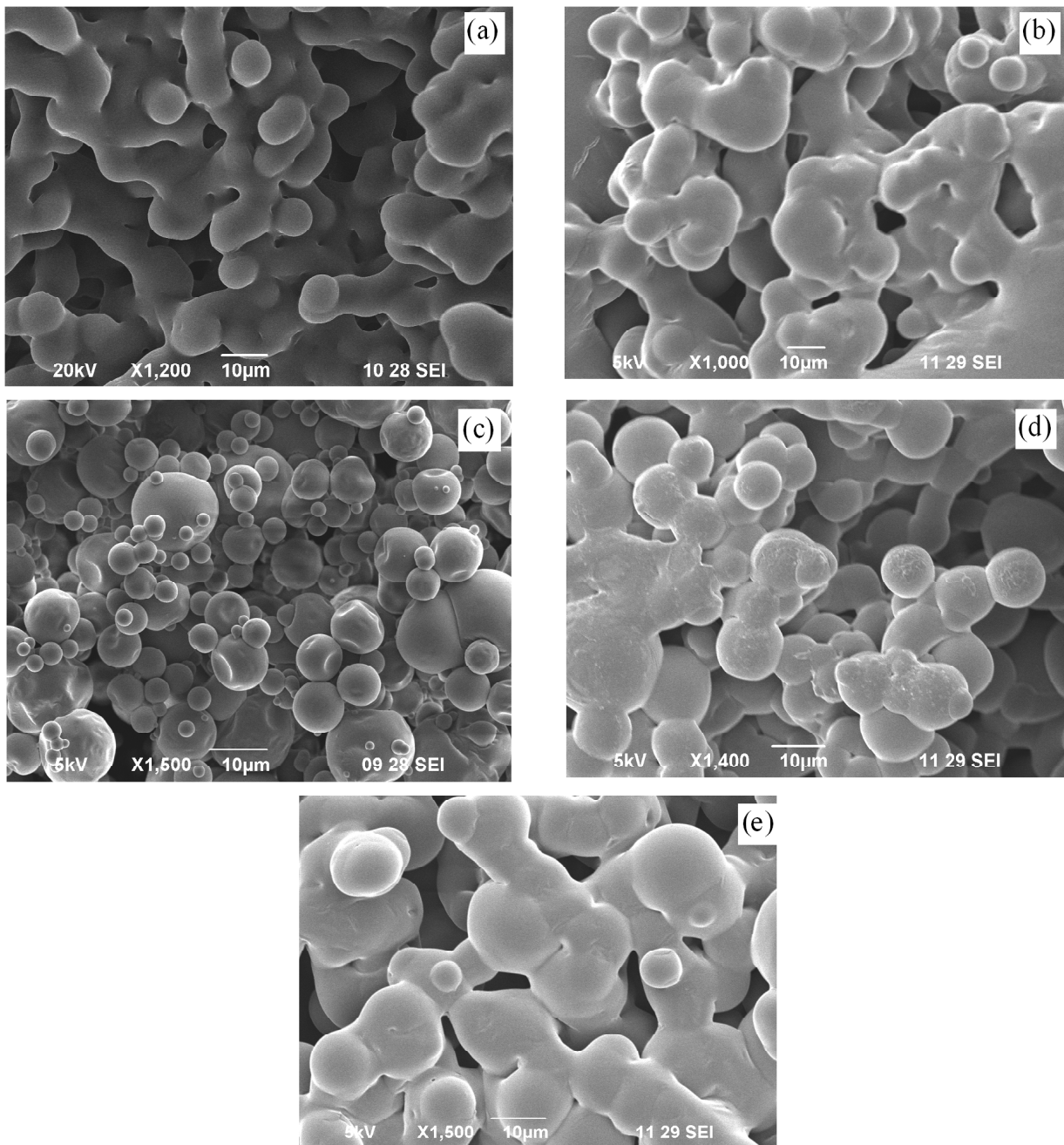


**Fig.3. DSC thermograms of SJPs with different bulking agents :**  
**(a) no bulking agents (b) 10% w/v lactose monohydrate (c) 10% w/v maltodextrin DE 20**  
**(d) 10% w/v soluble starch (e) SJP with 10% w/v sucrose**

### Chemical composition

Sugarcane juice contains plant pigments, phenolic acids, flavonoids and other phenolic compounds (Paton and Duong, 1992) which account for certain

antioxidant activity. In this regard a direct relationship between antioxidant activity and phenolics content in vegetable extracts has been demonstrated (Rice-Evans et al., 1996). Chemical composition of SJPs



**Fig. 4. SEM images of SJP with different bulking agents:**  
 (a) no bulking agents (b) 10% w/v lactose monohydrate (c) 10% w/v maltodextrin DE 20  
 (d) 10% w/v soluble starch (e) SJP with 10% w/v sucrose

did not indicate significant variation among powders prepared either with or without bulking agents. Loss of nutrient and active substances is common in spray drying process due to higher inlet temperature (Goula and Adamopoulos 2004; Goula and Adamopoulos

2005; Grabowska et al. 2008; Nadeem et al. 2011; Solvala et al. 2012). In the present study, though SJPs were not compared with raw sugarcane juice, the results clearly indicated the presence of these substances in the spray dried SJP indicating that these

**Table 3. Nutritional composition of SJP**

Sl.No.	Bulking agent	Total calorific value (kcal 100g <sup>-1</sup> )	CHO (%)	Protein (%)	Ash (%)	Insoluble matter (%)	Total phenols (µg g <sup>-1</sup> )	Chloro-phyll (mg g <sup>-1</sup> )	Total flavonoids (µg g <sup>-1</sup> )
1	Raw juice only	349	92	2.82	1.62	1.71	136	98.5	328
2	Maltodextrin 10%	357	94	2.91	1.54	1.74	142	110.4	352
3	Lactose 10%	360	94	2.91	1.43	1.73	139	100.9	312
4	Sucrose 10%	362	95	2.83	1.51	1.66	112	95.2	205
5	Starch 6%	358	93	3.11	1.51	1.70	138	102.5	321
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS

powders retained substantial quantities of nutritional substances such as carbohydrates, proteins, minerals, phenols, chlorophyll and flavonoids (Table 3). These substances in the sugarcane juice have been attributed to antioxidant activity (Hudson et al., 2000; Hollman, 2001; Duarte-Almeida et al. 2006).

### Microbiological quality

In order to adhere to food safety regulations microbial load has to be minimum and food products should not carry any pathogens. Presence of microbes is an indication of unhygienic handling of raw materials, contaminated water and unclean machinery used in the process. In spray drying process the juice is atomized and passed through hot air of 100 °C or more which easily inactivate or kill most of the microbes. Also moisture level and water activity of SJP are very low, making it unsuitable for microbial growth. Different SJPs recorded low microbial load in terms of total bacteria (10 - 100 cfu g<sup>-1</sup>) whereas mould, yeast and coliforms were not detected. The results indicated that the SJPs produced are microbiologically safe for human consumption.

### Shelf life

SJPs are hygroscopic and need proper packing. Moisture proof packing material is highly suited for this purpose. Hymavathi and Khader (2005) reported that the physico-chemical and nutrient changes were less pronounced in vacuum dehydrated ripe mango

powders packaged in metallized polyester/polyethylene than the powders in polyester poly packaging. But Liu et al. (2010) reported insignificant physico-chemical changes for tomato powder stored at 0°C, but powders stored at 37°C for 5 months showed significant changes in bulk density, colour, aggregation, sucrose, fructose, total sugar, L-ascorbic acid and free amino acids. In this study, different SJPs packed in 100µ low density polyethylene, 100µ polypropylene and aluminum lined 50µ polypropylene did not show any significant changes in moisture content, bulk density, colour, flowability and microbiological properties during 90 and 180 days of storage at 4°C as well as 30 °C (data not shown). Agglomeration was observed in SJP of raw juice after 90 days of storage both at 4°C and 30°C indicating that the bulking agents prevent agglomeration. Overall results indicated that the SJP with proper packing can have longer shelf life without significant deterioration in physico-chemical and microbial properties.

### Conclusion

The present study provides information about the production of SJP by spray drying. Problems like juice sticking to the dryer wall and poor yield encountered during spray drying of raw sugarcane juice were overcome by the use of bulking agents. Addition of bulking agents such as maltodextrin and lactose was found useful in obtaining higher powder yield and quality. Addition of maltodextrin, lactose

monohydrate and soluble starch improved the thermal properties of the powder making it suitable for long term storage. Spray dried SJPs having different colour, flavor and organoleptic properties can be prepared using juice from different cultivated varieties or by appropriate addition of permitted flavouring and colouring agents. This SJP can be reconstituted to sugarcane juice, used as a regular sweetener and added to foods to provide functional and nutritional benefits.

### Acknowledgements

The authors thank Dr N. Vijayan Nair, Director, Sugarcane Breeding Institute, Coimbatore, for providing facilities to carry out this work. The authors thank Dr K. Gowthamarajan, Department of Pharmaceutics, JSS College of Pharmacy, Ootacamund, for providing DSC analysis. The authors thank Department of Nanotechnology, Karunya University, Coimbatore, for SEMs.

### References

- Adhikari B, Howes T, Bhandari BR, Troung V (2004) Effect of addition of maltodextrin on drying kinetics and stickiness of sugar and acid-rich foods during convective drying: experiments and modeling. *J Food Engineering* 62: 53 - 68.
- Ali MA, Chang YL (2008) Optimization of phenolics and dietary fiber extraction from date seeds. *Food Chem* 108: 977- 985.
- Alvarez IL, Martí BS, Utset ZE, Hernández GM (1997) Analysis of the sensory characteristics of natural cane juice in three types of packages, *Alimentaria*, 35: 73-76.
- Anonymous (1991) Sugarcane juice preservation for beverage, Sugarcane Breeding Institute Newsletter 10: 1-2.
- Anonymous (2013) Statement showing figures of area under sugarcane, yield of sugarcane, production of sugarcane, number of factories, working capacity, cane crushed, Recovery, sugar production, duration and molasses production from 1930-31 to 2011-12. *Indian Sugar* 53:51- 52.
- AOAC (1995) Official methods of analysis, 16th edn., Association of Official Analytical Chemists, Arlington.
- Arnon DI (1949) Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiol* 24: 1- 5.
- Beristain CI, Azuara E, Vernon-Carter EJ (2002) Effect of water activity on the stability to oxidation of spray dried encapsulated orange peel oil using mesquite gum as wall material. *J Food Sci* 67: 206 - 211.
- Bhandari BR, Datta N, Howes T (1997) Problems associated with spray drying of sugar-rich foods. *Drying Technol* 15:671- 684.
- Bhandari BR, Howes H (1999) Implication of glass transition for the drying and stability of dried foods. *J Food Engineering* 40: 71 - 79.
- Bhandari BR, Hartel RW (2005) Phase transitions during food powder production and powder stability. In C. Onwulata, & R. P. Konstance (Eds.), *Encapsulated and food powder* (pp. 261–292). Marcel Dekker, New York.
- Bhandari BR, Senoussi A, Dumoulin ED, Lebert A (1993) Spray drying of concentrated fruit juices. *Drying Technol* 11:1081-1092.
- Bhupinder K, Sharma KP, Harinder K (1991) Studies on the development and storage stability of ready-to-serve bottled sugarcane juice. *Intern J Tropical Agri* 9: 128 - 134.
- Campo F, Santo Tomás JF, Bermello A (2004) Cane juice drying. A preliminary study in continuous and batch conventional dryers. *Revista ICIDCA Sobre los Derivados de la Cana de Azucar* 38: 54 - 59.

- Chauhan OP, Singh DS, Tyagi M, Balyan, DK (2002) Studies on preservation of sugarcane juice. Intern J Food Properties 5: 217 - 229.
- Chegini GR, Ghobadian B (2007) Spray Dryer Parameters for Fruit Juice Drying, World J Agri Sci 3: 230 – 236.
- Chun ML, Quan XY, Fei Q (2007) Maintaining the quality of sugarcane juice with blanching and ascorbic acid. Food Chem 104: 740-745.
- Duarte-Almeida JM, Novoa AV, Linares AF, Lajolo FM, Genovese MIE (2006) Antioxidant Activity of Phenolics Compounds From Sugar Cane (*Saccharum officinarum* L.) juice. Plant Foods for Human Nutrition 61: 187 - 192.
- Eastman JE, Moore CO (1984) Cold water soluble granular starch for gelled food composition. US Patent 4465702.
- Goula AM, Adamopoulos KG (2004) Spray drying of tomato pulp: Effect of feed concentration. Drying Technol 22: 2309–2330.
- Goula AM, Adamopoulos KG (2005) Stability of lycopene during spray drying of tomato pulp. LWT Food Sci Technol 38: 479–487.
- Goula AM, Adamopoulos KG, Kazakis NA (2004) Influence of spray drying conditions on tomato powder properties. Drying Technol 22:1129–1151.
- Grabowskia JA, Truonga VD, Daubertb CR (2008) Nutritional and rheological characterization of spray dried sweet potato powder. LWT Food Sci Technol 41: 206–216
- Hodge JE. and Hofreiter, B.T. 1962. In: Methods in Carbohydrate Chemistry, Eds. Whistler, R.L. and Be Miller, J.N., Academic Press, New York.
- Hollman PCH (2001) Evidence for health benefits of plant phenols: Local or systemic effect? J Sci Food Agri 81: 842-852.
- Hudson EA, Dinh PA, Kokubu T, Simmonds MSJ, Gescher A (2000) Characterization of potentially chemopreventive phenols in extracts of brown rice that inhibit the growth of human breast and colon cancer cells. Cancer Epidemiology, Biomarkers & Prevention, 9: 1163 - 1170.
- Hymavathi TV, Khader V (2005) Carotene, ascorbic acid and sugar content of vacuum dehydrated ripe mango powders stored in flexible packaging material. J Food Composition and Analysis, 18: 181 - 192.
- Jaya S, Das H (2004) Effect of maltodextrin, glycerol monostearate and tricalcium phosphate on vacuum dried powder properties. J Food Engineering, 63: 125-134.
- Kapur KL, Singh VP, Garg RG (1978) Preliminary studies on preservation of sugarcane juice, Indian food packer, 32: 32-33.
- Liu F, Cao X, Wang H, Liao X (2010) Changes of tomato powder qualities during storage. Powder Technology, 204: 159 - 166.
- Lopes G, Cresto R, Carraro CNM (2006) Microbiological analysis of sugarcane juice sold on the streets of Curitiba PA. Revista Higiene Alimentar, 20: 40 - 44.
- Lowry OH, Rosebrough NJ, Farr AL, Randall RJ (1951) Protein measurement with the folin phenol reagent. J Biol Chemistry, 193: 265-275.
- Mann RS, Singh S (1988) Processing, Packaging and Preservation of Sugarcane juice. Indian Farming, 37: 15 - 17.
- Mao LC, Xu YQ, Que F (2007) Maintaining the quality of sugarcane juice with blanching and ascorbic acid. Food Chemistry, 104: 740 - 745.
- Nadeem HS, Torun M, Ozdemir F (2011) Spray drying of the mountain tea (*Sideritis stricta*)

- water extract by using different hydrocolloid carriers. *LWT - Food Sci Technol* 44: 1626 - 1635.
- Nagalakshmi AVD, Reddy MU (1999) Quality analysis of selected fruit juices sold by street vendors in Hyderabad city. *Indian J Nutrition and Dietetics* 36: 78 - 83.
- Oliveira ACG, Seixas ASS, Sousa CP, Souza CWO (2006) Microbiological evaluation of sugarcane juice sold at street stands and juice handling conditions in São Carlos, São Paulo, Brazil. *Cadernos Saúde Pública* 22:1111-1114.
- Oliveira MAD (2009) Addition of cashew tree gum to maltodextrin based carriers for spray drying of cashew apple juice. *Intern J Food Science Technol* 44: 641-645.
- Oliveira TS, Ribeiro DS, Paulo EM (2008) Microbiological analysis of sugarcane juice (with or without ice) sold in the streets of Feira de Santana, BA. *Higiene Alimentar* 22: 56 - 60.
- Paton NH, Duong M (1992) Sugar cane phenolics and first expressed juice colour - Part III: Role of chlorogenic acid and flavonoids in enzymatic browning of cane juice. *Intern Sugar J*, 94:170-176.
- Phoungchandang S, Sertwasana A (2010) Spray-drying of ginger juice and physicochemical properties of ginger powders. *Science Asia*, 36: 40 – 45.
- Quek Y (2010) The physicochemical properties of spray dried watermelon powders. *Sci Asia*, 36: 40–45.
- Rao KC (1990) Bottling of sugarcane juice - a profitable venture (small scale or on large scale). In: *Proceedings of 40<sup>th</sup> Annual Convention of the Deccan Sugar Technologists' Association*, pp. A207 - A212.
- Reddy MU (1999) Quality analysis of selected fruit juices sold by street vendors in Hyderabad city. *Indian J. of Nutrition Dietetics* 36:78-83.
- Rice-Evans C, Miller NJ, Paganga G (1996) Structure-antioxidant activity relationships of flavonoids and phenolic acids. *Free Radical Biol Med*, 20: 933 - 956.
- Roos Y H (1993) Water activity and physical state effects on amorphous food stability. *J Food Processing and Preservation* 16:433- 447.
- Rosenberg M, Kopelman IJ, Talmon Y (1990) Factors affecting retention in spray-drying microencapsulation of volatile materials. *J Agri Food Chemistry*. 38: 1288–1294.
- Sagar VR, Kumar PS (2010) Recent advances in drying and dehydration of fruits and vegetables: a review. *J Food Sci Technol* 47:15-26.
- Shrestha AK, Howes T, Adhikari BP, Bhandari BR (2007) Water sorption and glass transition properties of spray dried lactose hydrolyzed skim milk powder. *LWT Food Sci Technol* 40: 1593 - 1600.
- Shrestha AK, Ua-Arak T, Adhikari BP, Howes T, Bhandari BR (2007) Glass transition behavior of spray dried orange juice powder measured by differential Scanning calorimetry and thermal Mechanical compression test. *Intern J Food Properties* 10: 661 - 673.
- Solvala KM, Sundararajan S, Alfaro L, Sathivel S (2012) Development of cantaloupe (*Cucumismelo*) juice powders using spray drying technology. *LWT Food Sci Technol* 46: 287 - 293.
- Subbannayya K, Bhat GK, Shetty S, Junu VG (2006) How safe is sugarcane juice? *Indian J Medical Microbiol*, 25:73-74.

- Teunou E, Fitzpatrick JJ, Synnott EC (1999) Characterization of food powder flowability. *J Food Engineering*, 39:31-37
- Tonon RV, Brabet C, Hubinger MD (2010) Anthocyanin stability and antioxidant activity of spray-dried açai (*Euterpe oleracea* Mart.) juice produced with different carrier agents. *Food Res Intern* 43:907- 914.
- Tonon RV, Freitas, SS, Hubinger MD (2011) Spray drying of açai (*Euterpe oleraceae* Mart.) juice: Effect of inlet air temperature and type of carrier agent. *J Food Processing Preservation*, 35: 691 - 700.
- Truong V, Bhandari BR, Howes T (2005) Part1: Moisture and glass optimization of co-current spray drying process of sugar rich foods: transition temperature profile during drying. *J Food Engineering*, 71: 55 - 65.
- Tsao R, Yang R, Xie S, Sockovie E, Khanizadeh S (2005) Which polyphenolic compounds contribute to the total antioxidant activities of apple? *J Agri Food Chem*, 53: 4989-4995.
- Yusof S, Shian LS, Osman A (2000) Changes in quality of sugar-cane juice upon delayed extraction and storage. *Food Chem* 68:395-401.