Reduction of non-enzymatic browning of orange juice and semi-concentrates by removal of reaction substrate

Satish K. Sharma · Shashibala Juyal · V. K. Rao ·
V. K. Yadav · A. K. Dixit

Revised: 1 January 2012 / Accepted: 24 January 2012 / Published online: 16 February 2012
© Association of Food Scientists & Technologists (India) 2012

Abstract A study was conducted to standardize the technology for the removal of amino acids (one of the browning reaction substrates) from sweet orange cv. Malta Common juice to reduce colour and quality deterioration in single strength juice and during subsequent concentration. Juice of sweet orange (*Citrus sinensis*) cv. Malta Common fruits was extracted by screw type juice extractor, preserved in 500 ppm SO₂ and clarified by using “Pectinase CCM” enzyme (0.2% for 2 h at 50±2 °C). For removal of amino acids juice was passed under gravity through a glass column packed with an acidic cation exchange resin (CER), Dowex-50 W and quantity to be treated in one lot was standardized. The CER treated and untreated juices were concentrated to 15 and 30°Brix in a rotary vacuum evaporator. Results indicate that 121 ml of orange juice when passed through a glass column (5 cm internal diameter) packed with cation exchange resin (Dowex-50 W) upto a height of 8 cm, could remove about 98.4% of the amino acids with minimum losses in other juice constituents. With cation exchange resin treatment, the

non-enzymatic browning and colour deterioration of orange juice semi-concentrates was reduced to about 3 folds in comparison to untreated counterparts. The retention of vitamin C and sugars was also better in semi-concentrates prepared from cation exchange resin treated juice. Thus, cation exchange resin treatment of orange juice prior to concentration and storage is highly beneficial in reduction of non-enzymatic browning, colour deterioration and retention of nutritional, sensory quality of product during preparation and storage.

Keywords Sweet orange · Malta · Non-enzymatic browning · Cation exchange resin · Juice · Semi-concentrates

Introduction

Sweet orange, the second largest citrus fruit cultivated in India after mandarin, belongs to genus *Citrus*, sub family Aurantioideae, family Rutaceae and is believed to have been originated in India. It is mainly grown in Andhra Pradesh, Maharashtra, Punjab, Haryana and Rajasthan. The total sweet orange production in India is 35.67 lakh MT from an area of 3.18 lakh ha (NHB 2009). Main varieties of sweet orange in India being cultivated on commercial scale are Blood Red, Mosambi and Satgudi (Chadha 2006). Sweet orange cv. ‘Malta Common’ has its origin in Punjab and is also very popular in Haryana and Uttarakhand. Malta fruits are sub-globular to oval in shape, orange coloured and tight skinned with solid central core. Fruit is firm and leathery to medium soft, having 10–13 segments, rind is medium thick with thickness 4–7 mm. Malta fruit juice is abundant in pleasant aroma and good flavour. Fruit is sour–sweet and its flesh is usually orange coloured (Tanushree and Singh 2009).

Juice is the most important product obtained from sweet orange cv. ‘Malta Common’ fruit and may be canned,

S. K. Sharma (✉) · A. K. Dixit
Central Institute of Postharvest Engineering and Technology,
PAU Campus,
Ludhiana, Punjab, 141 004, India
e-mail: drsatish10@yahoo.com

S. Juyal · V. K. Rao
Department of Horticulture,
GB Pant University of Agriculture and Technology,
Hill Campus,
Ranichauri, Uttarakhand, 249 199, India

V. K. Yadav
Department of Crop Improvement,
GB Pant University of Agriculture and Technology,
Hill Campus,
Ranichauri, Uttarakhand, 249 199, India

frozen, converted into beverages or chemically preserved either as natural single strength juice or after concentration. Malta juice is one of the most delicious fruit juices that enjoy a wide popularity in view of its pleasing taste, refreshing tingle and wide availability during greater part of the year throughout the country (Tanushree and Singh 2009). Sharma and Nautiyal (2007) have given the complete technology for postharvest management for Malta fruits and reported that good quality beverages including squash and RTS beverages can be prepared from the fruits. But browning of citrus juices and beverages during preparation as well as storage has been recognized as a big problem for the fruit processing industry (Sharma et al. 2006).

Biochemically, browning predominantly results from the reaction of sugars and amino acids leading to the formation of melanoidins (brown polymers). Browning reactions are supposed to slow down in the absence of any of these two substrates (Handwerk and Coleman 1988; Sharma et al. 2004, 2009). Several authors have reported that quality of fruit products is generally reduced during storage because of change in colour, aroma and taste of the products (Giese 1992; Sharma et al. 2006). Maintaining the product at low temperature is the common mean to avoid colour and flavour deterioration of processed citrus fruit juices, concentrates and dehydrated products in long term storage (Handwerk and Coleman 1988). But when subjected to non-refrigerated storage, citrus juice rapidly develop objectionable colour and flavour making the product unacceptable. Sharma et al. (2006) and Sharma et al. (2011) have reported about 96% reduction in amino acid (one of the browning reaction substrates) by use of Dowex-50 W cation exchange resin and subsequent four-fold reduction in browning of lemon juice, concentrates and powder. But, the work on reduction of browning specifically in sweet orange juice and concentrates is scanty in literature.

Keeping the above facts in view, the present investigation was designed to standardize the technology for the removal of amino acids (one of the browning reaction substrates) from sweet orange cv. Malta Common juice to reduce colour and quality deterioration in single strength juice and during subsequent concentration.

Materials and methods

Fruits of sweet orange (*Citrus sinensis*) cv. Malta Common, devoid of blemishes, any visible signs of microbial infection, insect infestation and physical injury were procured from malta growing areas of district Tehri Garhwal, Uttarakhand, India during January 2009. Juice was extracted by using semi-automatic motor operated Screw type juice extractor (Bajaj Maschinen, Pvt. Ltd., New Delhi). The extracted juice was then strained through muslin cloth and pasteurized at 90°C for

10 s followed by quick cooling to room temperature and preservation with 500 ppm SO₂. The juice was clarified by using “Pectinase CCM” enzyme (Advanced Enzyme Technologies Ltd. Thane, Maharashtra, India) at 0.2% for 2 h at 50±2 °C (Sharma et al. 2001).

For removal of amino acids (one of the browning reaction substrates), an acidic cation exchange resin, Dowex-50 W, (Hi Media Laboratories Pvt. Ltd., Mumbai, India) was packed in a glass column (5 cm internal diameter) upto a height of 8 cm. 500 ml of clarified juice was put into the column and allowed to flow under gravity through the cation exchange resin. 15 samples of treated juice were withdrawn at 5 min interval. The level of juice inside the column was maintained at 500 ml level throughout the run by continuously adding juice from the top of the glass column. All the samples were evaluated separately for any changes in chemical quality. The column, after use, was washed with 0.2 N HCl solution (3–4 times the volume of resin) and regenerated with 0.2 N NaOH solution (2–3 times

Fig. 1 Enzymatic clarification and cation exchange resin treatment of malta juice

the volume of resin) with EDTA (AOAC 1995; Sharma et al. 2004). Excess of alkali was removed by washing the CER with 3–4 volumes of distilled water and dried under suction at room temperature. Properly washed and regenerated column was repeatedly used for separation of amino acids from malta juice without any practical loss in its activity (Figs. 1 and 2)

Both types of juices i.e. one from which browning reaction substrates had been removed (treated) and untreated one were used for the preparation of semi-concentrates of 15, 30°Brix using a rotary type vacuum evaporator (Rotating Evaporator RE 2000A, Associated Scientific Technologies, Delhi) at 50 ± 2 °C under 28 ± 2 ” Hg vacuum. In order to achieve fast condensation of vapours, the temperature of water circulating through the condenser was maintained between -15 and -5 °C by using a circulatory water bath. The freezing point of water was lowered by addition of 20%

salt. All the semi-concentrates were packed in glass bottles (200 ml capacity) and analyzed for their chemical quality.

Standard analytical procedures were followed for estimation of TSS, titratable acidity, colour and non-enzymatic browning of samples (Ranganna 1997; Sharma and Nautiyal 2009). Sugars were estimated by rapid colorimetric method of simultaneous determination of total reducing sugars and fructose (Ting 1956), ascorbic acid by direct colorimetric method (Ranganna 1997), total amino acids were determined by ninhydrin colorimetric method (Ting and Deszyck 1960). The data on chemical characteristics was analysed statistically by CRD (Cochran and Cox 1967) with the factors $3 \times 2 \times 3$, where 3 indicates the number of semi-concentrates (Juice, 15, 30°Brix), 2 the levels of CER treatment (untreated and treated) 3 number of replications.

Results and discussion

Physico-chemical quality

The fruits of sweet orange cv. Malta Common used in the present investigation had average weight of 123.0 g with 6.9 cm and 6.7 cm of length and diameter respectively (Table 1). Fruits were medium in size and may be categorized in grade “A” to grade “Good” (Sharma 2010). As far as the physico-chemical quality is concerned, the TSS and titratable acidity were quite high i.e. 11°Brix and 1.3%

Fig. 2 Regeneration of cation exchange resin (Dowex-50W) packed in glass column

Table 1 Physico-chemical characteristics of malta fruits

Parameters	Mean $\pm$ S. E. ^a
Length (cm)	6.9 $\pm$ 0.14
Diameter (cm)	6.7 $\pm$ 0.22
Weight (g)	123.0 $\pm$ 3.39
Volume (cc)	170.8 $\pm$ 6.66
Firmness (Kg/cm ²)	12.1 $\pm$ 0.39
Seed (%)	2.2 $\pm$ 0.28
Number of segment	10.6 $\pm$ 0.16
Flavedo (%)	11.4 $\pm$ 0.51
Albedo (%)	19.4 $\pm$ 1.63
Rags (%)	1.2 $\pm$ 0.21
Juice (%)	31.9 $\pm$ 2.38
Residue (%)	32.1 $\pm$ 3.43
Total solids (%)	14.0 $\pm$ 0.47
TSS (°Brix)	11.0 $\pm$ 0.23
Titratable Acidity (%)	1.3 $\pm$ 0.029
Reducing sugars (%)	3.6 $\pm$ 0.073
Total sugars (%)	8.6 $\pm$ 0.40
Ascorbic acid (mg/100 g)	74.3 $\pm$ 2.26
Amino acid (mg/100 g)	260.0 $\pm$ 1.89

^aEach value is mean $\pm$ S. E. of $n=21$ replications

Table 2 Effect of enzymatic clarification and cation exchange resin treatment on physico-chemical characteristics of malta juice

Parameters	Unclarified Juice	Enzymatically Clarified Juice	CER Treated Juice	CD _{0.05}	S.E.
Total solids (%)	14.0	11.2	9.6	0.62	0.30
TSS (°Brix)	11.0	10.5	8.8	0.58	0.28
Titrateable Acidity (%)	1.3	1.3	1.2	0.13 (NS)	0.06
Reducing sugar (%)	3.6	3.5	3.2	0.11	0.05
Total sugar (%)	8.6	8.5	7.4	0.30	0.15
Ascorbic acid (mg/100 g)	74.3	74.0	70.2	0.35	0.17
Amino acid (mg/100 g)	260.0	256.3	4.3	1.30	0.62
NEB (OD ₄₄₀ nm)	0.024	0.024	0.010	0.002	0.001
Colour (OD ₄₂₀ nm)	0.023	0.023	0.010	0.002	0.001

Each value is mean of $n=7$ replications

CER Cation exchange resin (Dowex - 50 W), S.E. Standard error, NS Non - significant

respectively, indicating good possibilities for using the fruit juice in preparation of various beverages. The percentage of flavedo and albedo were 11.38 and 19.40 respectively, which were very well comparable with available report (Cohen et al. 1990). The acidity (1.3%) and total sugars (8.6%) of Malta juice used in present study were in conformity with the information available in literature (Pruthi et al. 1984; Soule and Grierson 1986; Premi et al. 1995, Chopra et al. 2004). The ascorbic acid content of fruits recorded in this investigation was 74.3 mg/100 g which was within the range reported by Ghosh et al. (2002). Pruthi et al. (1984) reported juice recovery of 48.70–51.20% respectively in malta fruits. Lower extractable juice content (31.9%) of malta fruits as observed in the present study might be due to smaller size of fruits and comparatively higher proportion of peel and residue.

Enzymatic clarification

There was a large reduction in total solids and TSS from initial levels of 14 to 11.2% and 11 to 10.5°Brix respectively after clarification of malta juice (Table 2). Titrateable acidity did not experience any change. However, reducing sugars and total sugars underwent slight but statistically non-significant changes from an initial level of 3.6 to 3.5% and 8.6 to 8.5% respectively. The ascorbic acid and amino acids also showed the similar trend, registering a small reduction from an initial mean value of 74.3 to 74.0 mg/100 g and 260.0 to 256.3 mg/100 g respectively. Further, the non-enzymatic browning and colour recorded no change after enzymatic clarification. Enzymatic clarification had a remarkable effect on removal of suspended and insoluble

Table 3 Effect of cation exchange resin (Dowex -50 W) treatment on physico – chemical characteristics of malta juice

Sample No.	Flow rate (ml/5 min)	TSS (°Brix)	Titrateable acidity (%)	Ascorbic acid (mg/100 g)	Amino acid (mg/100 g)
1	19	8.2	1.1	68.0	3.4
2	21	8.6	1.2	70.0	3.7
3	20	8.7	1.2	70.0	4.3
4	21	8.7	1.2	70.6	4.4
5	20	9.3	1.2	70.9	4.8
6	20	9.3	1.2	72.0	4.9
7	20	9.5	1.2	73.9	13.1
8	19	9.5	1.2	74.0	41.4
9	20	9.6	1.2	74.0	69.0
10	20	9.6	1.2	74.0	89.0
11	20	9.9	1.2	74.0	102.0
12	21	10.0	1.3	74.0	107.0
13	22	10.1	1.3	74.0	110.1
14	20	10.2	1.3	74.0	114.3
15	20	10.4	1.3	74.0	125.4
Juice	–	10.5	1.3	74.0	256.3
CD _{0.05}		0.09	0.01	0.06	0.24
S.E.		0.04	0.002	0.03	0.12

Each value is mean of $n=3$ replications

Table 4 Effect of cation exchange resin treatment on folds of concentration and total solids of malta juice during concentration

Semi-concentrates (°Brix)	Folds of concentration			Total solids (%)		
	Untreated	Treated	Mean (T)	Untreated	Treated	Mean (T)
Juice	SS	SS	–	11.2	9.6	10.4
15	1.46	1.94	1.70	17.0	16.2	16.6
30	3.13	4.15	3.64	34.0	32.4	33.2
Mean (C)	2.30	3.05		20.7	19.4	
					CD _{0.05}	S.E.
CER Treatment (T)					1.10	0.51
Concentration (C)					1.35	0.62
T x C					NS	0.94

Each value is mean of $n=3$ replications

CER Cation exchange resin (Dowex – 50 W), SS Single strength juice

solids of malta juice. Although, the effect of enzymatic clarification on other soluble juice solids i.e. acidity, sugars, vitamin-C and amino acids was very small to negligible. Clarification of juice reduce the particulate matter in the juice, which improve the flux and allow higher concentration levels to be attained without causing much nutritional loss. Similar, results have been obtained by Singh and Gupta (2003) and Rai and De (2009).

Cation Exchange Resin (CER) treatment

By passing the juice through cation exchange resin Dowex-50 W, a remarkable reduction (98.7 and 98.5%) in the amino acid content of juice was observed in sample No.1 and 2 respectively with amino acid content reduced to 3.4 and 3.7 mg/100 g respectively from initial level of 256.3 mg/100 g (Table 3). The cumulative reduction in amino acid content of orange juice till the 6th sample was 98.4%. Further, there was a drastic decrease in the efficiency of cation exchange resin for the removal of amino acids from the juice beyond 6th sample which might be attributed to the

reduced availability of free sites on the cation exchange resin for bonding with amino acid molecules. The reduction of amino acid content of lemon juice upto 96.79% have been reported earlier (Sharma et al. 2006). Cornwell and Wrolstad (1981) also found Dowex-50 W to be very effective for removal of amino acids from pear juice. The total solids declined from an initial value of 11.2% in enzymatically clarified juice to 9.6% after cation exchange resin treatment. The TSS of orange juice ranged between 8.2 and 9.3°Brix till the 6th sample and increased consistently till the end. However, an overall cumulative TSS of juice till 6th sample was recorded to be 8.8°Brix.

The greater availability of free sites in the cation exchange resin during initial few samples caused higher reduction in the juice constituents. However, during subsequent samplings the number of free sites on the resin, for bonding with juice constituents became lesser, resulting in reduced removal of amino acids and other soluble solids. Further, there was only 7.7, 5.1 and 12.9% loss in the acidity, ascorbic acid and total sugar of orange juice respectively, when 121 ml of juice was passed through the column in one lot. Since, the efficiency of

Table 5 Effect of cation exchange resin treatment on amino acid and ascorbic acid content of malta juice during concentration

Semi-concentrates (°Brix)	Amino acids (mg/100 g)			Ascorbic acid (mg/100 g)		
	Untreated	Treated	Mean (T)	Untreated	Treated	Mean (T)
Juice	256.3 (2288.4)	4.3 (44.4)	130.3 (1166.4)	74.0 (660.7)	70.2 (731.6)	72.1 (696.1)
15	361.7 (2127.7)	7.0 (43.2)	184.3 (1085.4)	102.0 (600.0)	116.0 (716.0)	109.0 (658.0)
30	707.3 (2080.3)	13.7 (42.3)	360.5 (1061.3)	196.3 (577.3)	225.0 (694.4)	210.6 (635.9)
Mean (C)	441.8 (2165.4)	8.3 (43.3)		124.1 (612.7)	137.1 (714.0)	
		CD _{0.05}	S.E.		CD _{0.05}	S.E.
CER Treatment (T)		18.83	8.64		19.71	9.05
Concentration (C)		23.07	10.59		24.14	11.08
T x C		32.62	14.97		NS	15.13

Each value is mean of $n=3$ replications

CER Cation exchange resin (Dowex – 50 W), S. E. Standard Error

Statistical analysis was done for the data on dry weight basis which is presented inside parentheses

Table 6 Effect of cation exchange resin treatment on reducing sugars and total sugars content of malta juice during concentration

Semi-concentrates (°Brix)	Reducing sugars (%)			Total sugars (%)		
	Untreated	Treated	Mean (T)	Untreated	Treated	Mean (T)
Juice	3.5 (31.6)	3.2 (33.5)	3.4 (32.6)	8.5 (76.0)	7.3 (76.6)	7.9 (76.3)
15	5.4 (31.8)	5.5 (33.6)	5.4 (32.7)	12.2 (71.8)	12.4 (76.2)	12.3 (74.0)
30	10.9 (32.1)	10.9 (33.8)	10.9 (33.0)	24.0 (70.6)	24.5 (75.6)	24.3 (73.1)
Mean (C)	6.6 (31.8)	6.5 (33.7)		14.9 (72.8)	14.7 (76.1)	
		CD _{0.05}	S.E		CD _{0.05}	S.E
CER Treatment (T)		1.78	0.82		1.50	0.64
Concentration (C)		NS	1.02		1.84	0.89
T x C		NS	1.36		2.60	1.14

Each value is mean of $n=3$ replications

CER Cation exchange resin (Dowex – 50 W), S. E. Standard Error

Statistical analysis was done for the data on dry weight basis which is presented inside parentheses

cation exchange resin (Dowex-50 W) was maximum upto 6th sample, beyond which it decreased drastically, it was concluded that 121 ml of orange juice when passed through a glass column (5 cm internal diameter) packed with cation exchange resin (Dowex-50 W) upto a height of 8 cm could remove about 98.4% of the amino acids with minimum losses in other juice constituents. The same column can be washed and regenerated again and again without any practical loss in efficiency if the CER (Figs. 1 and 2). These findings are in close conformity with the earlier findings (Sharma et al. 2004, 2006).

Semi-concentrates

Folds of concentration were observed to be higher in concentrates prepared from treated juice as compared to that of those prepared from untreated juice (Table 4). The higher folds of concentration in the semi-concentrates prepared from treated juice were probably due to the lower initial TSS of treated juice. Similar results have been obtained by

Sharma et al. (2004) and Sharma et al. (2006). The mean value of total solids was found higher in semi-concentrates prepared from untreated juice in comparison to semi-concentrates prepared from treated juice. The treatment of juice by passing through glass column packed with cation exchange resin, brought about removal of suspended material along with some juice solids thereby reducing the TSS and total solids of the treated juice.

There was continuous reduction in amino acid content with the advancement of levels of concentration, which was visualized on conversion of data to dry weight basis (values in parentheses) as depicted in Table 5. The loss of amino acid was only 4.73% (dwb) when the treated juice was concentrated to 30°Brix as compared to about 9.09% (dwb) loss occurring in untreated juice concentrated to the same TSS. These losses may be due to involvement of amino acids in various browning reactions. The reason for very small changes in the amino acids of treated juice during concentration than that of untreated juice was that very low concentration of amino acids, render them ineffective to participate in browning reactions as has also been reported

Table 7 Effect of cation exchange resin treatment on non - enzymatic browning and colour of malta juice during concentration

Semi-concentrates (°Brix)	NEB (OD _{440 nm})			Colour (OD _{420 nm})		
	Untreated	Treated	Mean (T)	Untreated	Treated	Mean (T)
Juice	0.0235	0.0103	0.0169	0.0230	0.0102	0.0166
15	0.0348	0.0139	0.0244	0.0345	0.0137	0.0241
30	0.0528	0.0178	0.0353	0.0533	0.0176	0.0355
Mean (C)	0.0370	0.0140		0.0369	0.0138	
		CD _{0.05}	S.E.		CD _{0.05}	S.E.
CER Treatment (T)		0.002	0.001		0.002	0.001
Concentration (C)		0.003	0.001		0.003	0.001
T x C		0.004	0.002		0.004	0.002

Each value is mean of $n=3$ replications

CER Cation exchange resin (Dowex – 50 W), S. E. Standard Error, OD Optical density

earlier in lemon juice concentrates earlier (Sharma et al. 2004, 2006).

In similarity to the trend for amino acids, there was a decreasing trend of ascorbic acid content (on dry weight basis) in Malta Common juice upon concentration upto 30° Brix (Table 5). These losses may be due to involvement of ascorbic acid in various browning reactions. The loss in ascorbic acid (on moisture free basis) was only 5.08% in treated juice as compared to about 12.62% loss occurring when the untreated juice was concentrated upto the same TSS. The better retention of ascorbic acid in treated juice, during concentration, might be attributed to the non-availability of sufficient amino acids to react with ascorbic acid molecules to cause browning.

As depicted in Table 6 there was a slight increasing trend in reducing sugar content from an initial mean value of 32.6% to 33.0% on dry weight basis, when the Malta Common juice in the present study was concentrated to 30°Brix, which might be due to inversion of non-reducing sugars into reducing sugars. Also, the changes in the sugar contents were lesser during concentration of treated juice as compared to those of untreated juice, which was probably due to non-availability of sufficient amino acids to react with sugars of treated juice. The total sugar contents were observed to be higher at all degrees of concentration, in the concentrates prepared from treated juice as compared to the untreated counterparts, which might be attributed to their corresponding higher folds of concentration (Table 6). There was continuous reduction in total sugar content of the product on concentration of Malta juice upto various levels of TSS. These losses might be attributed to the involvement of sugars in the browning reactions and formation of hydroxymethyl furfural. However, the loss in total sugars was only 1.30% when treated juice was concentrated to 30°Brix as compared to about 7.10% loss occurring when the untreated juice was concentrated to the same TSS, which might be due to non-availability sufficient amino acids to react with sugars in treated juice, as has also been reported earlier in lemon juice concentrates (Sharma et al. 2004, 2006).

The mean levels of non-enzymatic browning of semi-concentrates prepared from treated juice was about three folds less as compared to that of those prepared from untreated juice (Table 7). Further, there was an increasing trend in non-enzymatic browning, when juice was concentrated to 30°Brix. However, the non-enzymatic browning experienced a higher change in semi-concentrates prepared from untreated juice as compared to very less changes in the products prepared from treated juice. This indicates that the cation exchange resin treatment of sweet orange cv. Malta Common juice prior to concentration was highly effective in reduction of browning during product preparation. The reaction of amino acids with sugars and the degradation of ascorbic acid were, probably responsible for the increase in non-enzymatic browning during evaporative concentration of the juice. A comparatively

lesser increase in non-enzymatic browning of treated orange juice as compared to the untreated juice, during concentration, might be attributed to the non-availability of sufficient amino acids for participation in browning reactions as has been reported earlier (Sharma et al. 2004, 2006). The browning occurring in treated juice may be due to the degradation of ascorbic acid and other juice constituents during the process of concentration. Kacem et al. (1987) also demonstrated that the amino acid content below 0.66% did not significantly affect browning of orange juice. Thus, the removal of amino acids from orange juice by cation exchange resin treatment brought about a marked reduction in the non-enzymatic browning of orange juice during the process of evaporative concentration, thereby improving its appearance and acceptability.

Colour of semi-concentrates prepared from untreated juice was about three times higher than that of their counterparts prepared from treated juice (Table 7). This indicates that the darkening of the products was about three times more during concentration of untreated juice upto 30°Brix than that of the changes occurring in the products prepared from cation exchange resin treated juice during similar heat application for concentration to correspondingly same TSS. Further, there was an increasing trend in darkening of colour, when juice was concentrated to 30°Brix. The increase in colour values may be due to non-enzymatic browning on heat application.

Conclusively, it emerges that sweet orange cv. malta had juice content of about 32%. For reduction of browning of juice and concentrates, enzymatically clarified juice should be treated with cation exchange resin (Dowex 50 W) prior to concentration and storage. 121 ml of orange juice when passed through Dowex-50 W, resulted in 98.4% reduction of the amino acids with minimum losses in other juice constituents. Cation exchange resin treated orange juice suffered about 3 folds lesser browning in comparison to untreated counterparts during concentration upto 30°Brix. Retention of vitamin C and sugars was also better in semi-concentrates prepared from cation exchange resin treated juice.

References

- AOAC (1995) Official methods of analysis of AOAC international, 16th edn. Association of Official Analytical Chemists, Arlington, p 66
- Chadha KL (2006) Handbook of horticulture. Indian Council of Agricultural Research, New Delhi, p 329
- Chopra S, Kudos SKA, Oberoi HS, Baboo B, Ahmad KUM, Kaur J (2004) Performance evaluation of evaporative cooled room for storage of Kinnow mandarin. *J Food Sci Tech* 41(5):573–577
- Cochran WG, Cox GW (1967) Experimental designs. John Wiley and Sons, Inc., New York, p 613
- Cohen E, Lurie S, Shapiro B, Yehoshub SB, Shalon Y, Rosenberger I (1990) Prolonged storage of lemons using individually seal packaging. *J Amer Soc Hortl Sci* 115(2):251–255
- Cornwell CJ, Wrolstad RE (1981) Causes of browning in pear juice concentrate during storage. *J Food Sci* 46:515–518

- Ghosh SP, Mitra SK, Singh S (2002) Citrus. In: Bose TK, Mitra SK, Sanyal D (eds) Fruits: tropical and subtropical, vol 1. Naya Udyog, Calcutta, pp 109–225
- Giese JH (1992) Hitting the spot: beverages and beverage technology. Food Tech 46(7):70–80
- Handwerk RL, Coleman RL (1988) Approaches to the citrus browning problem – a review. J Agri Food Chem 36:231–236
- Kacem B, Matthews RF, Crandall PG, Cornell JA (1987) Non-enzymatic browning in aseptically packaged orange juice and orange drinks – effect of amino acids deaeration and anaerobic storage. J Food Sci 52:1665–1667
- NHB (2009) Statewise area and production of sweet orange in India. www.hortibizindia.org website visited on 8th December 2009
- Premi BR, Lal BB, Joshi VK (1995) Efficacy of various techniques for removing bitter principles in Kinnow juice. J Food Sci Tech 32(4):332–335
- Pruthi JS, Manan JK, Teotia MS, Sethy R, Eipenson WE, Saroja S, Chikkoppaji KC (1984) Studies on the utilization of kinnow and malta oranges. J Food Sci Tech 21:123–125
- Rai P, De S (2009) Clarification of pectin containing juice using ultrafiltration. Curr Sci 96(10):1361–1371
- Ranganna S (1997) Handbook of analysis and quality control for fruit and vegetable products, 2nd edn. Tata McGraw-Hill Pub Co Ltd, New Delhi, p1112
- Sharma SK (2010) Postharvest management and processing of fruits and vegetables. New India Pub Agency, New Delhi, 390p
- Sharma SK, Nautiyal MC (2007) Postharvest management of malta - low cost technology for storage and value addition. Technical Bulletin No.FHA/17/Hort./07. Univ of Hort and Forestry, Ranichauri, Tehri Garhwal, Uttarakhand, India, 22p
- Sharma SK, Nautiyal MC (2009) Postharvest technology of horticultural crops - practical manual series – 2. New India Pub Agency, New Delhi, 229p
- Sharma PC, Sharma SK, Kaushal BBL (2001) Preparation and evaluation of some value added products from lemon (*Citrus pseudolimon* Tan.) fruits. Indian J Agri Sci 71:691–694
- Sharma SK, Kaushal BBL, Sharma PC (2004) Effect of temperature and removal of amino acids on non-enzymatic browning of lemon juice concentrates during storage. J Sci Ind Res 63:444–451
- Sharma SK, Kaushal BBL, Sharma PC (2006) Reduction of non-enzymatic browning of lemon juice concentrates by removal of reaction substrates. J Food Sci Tech 43(1):83–88
- Sharma SK, Kaushal BBL, Sharma PC (2009) Effect of cation exchange resin treatment and addition of anti-caking agent on non-enzymatic browning of lemon juice powder during storage. J Sci Ind Res 68:611–616
- Sharma SK, Kaushal BBL, Sharma PC (2011) Effect of cation exchange resin treatment and addition of sugar as anti-caking agent on retention of nutritional and sensory quality of lemon juice powder during storage. J Food Sci Tech 48(3):296–304
- Singh S, Gupta R (2003) Apple juice clarification using fungal pectinolytic enzyme and gelatin. Indian J Biotechnol 3:573–576
- Soule J, Grierson W (1986) Maturity and grade standards. In: Wardowski WF, Nagy S, Grierson W (eds) Fresh citrus fruits. Van Nostrand Reinhold Co, Melbourne, pp 23–46
- Tanushree CCS, Singh CP (2009) Studies on standardization and shelf stability of malta (*Citrus sinensis*) orange beverages. Indian Food Packer 65(5):46–53
- Ting SV (1956) Rapid colorimetric methods for simultaneous determination of total reducing sugars and fructose in citrus juices. J Agr Food Chem 4:263–266
- Ting SV, Deszyck EJ (1960) Total amino acid content of chilled orange juice and frozen concentrate. Proc Fla State Hortl Soc 73:252–257