Efficacy of ascorbic acid treatments in the production of green raisins

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The quality of raisins is mainly perceived by their colour. Green-coloured raisins are considered as the best quality raisins whereas brown/dark-coloured raisins possess poor quality. Raisin colour is affected by different factors like grape variety, pre-treatments to grape berries, drying method, drying conditions, etc. The present study was conducted to produce green-coloured raisins through two different treatments of ascorbic acid – dipping and spraying. These treatments were applied to Thompson Seedless grapes independently with different doses (100–500 ppm) of ascorbic acid. Results indicated that lesser darkening of raisins was observed when ascorbic acid was sprayed on bunches during drying than the dipping treatment. In all the samples, polyphenol oxidase (PPO) activity decreased with drying duration. Lower PPO content was noted in dipped and sprayed grapes than control. However, application of ascorbic acid influenced the other parameters. The present study revealed that ascorbic acid spray is suitable for retaining green colour in raisins with faster drying. Overall, 200 ppm ascorbic acid spray was found appropriate in the production of green raisins.

Keywords: Ascorbic acid, dipping and spraying, green raisins, polyphenol oxidase.

RAISINS are dried grapes, commonly known as kishmish, bedana, manuka or dry fruit. They are sweet in taste and their sweet flavour is similar to the grapes from which they are made; however, not all grapes varieties are suitable for making raisins[1]. Raisins are a potential source of various health elements like carbohydrates, folic acid, pantothenic acid, vitamin B6 and minerals (calcium, magnesium, phosphorus, iron, copper, zinc, etc.) which makes them a healthy snack[1,2]. Raisins have a good shelf life of around six months if stored properly. Concentrated sugars, low moisture levels and lower pH make them a shelf stable food. For prolonged storage, they are refrigerated in tightly sealed plastic bags. Apart from use as a dry fruit item, raisins are also used in large quantities in many sweet preparations, bakery items, farsan (snacks) and desserts (ice-cream and shakes). Raisins are commonly produced by drying grapes. The grapes are either sun-dried or dehydrated mechanically[3]. In India, different varieties of grapes are sun dried to produce raisins. They are usually small, dark and wrinkled in appearance.

Colour is the first notable characteristic of a food and a way to judge its quality. The quality of raisins is also decided on the basis of their colour. Raisins are available in various colours ranging from yellow/golden to black depending upon the method of drying, grape variety, harvesting stage and type of processing. Demand for light-coloured raisins or green raisins is more compared to darker ones[4]. Consequently, green-coloured raisins fetch higher price in the market and thus provides more profit margin to the producers. Also, the organoleptic quality and nutritional composition of green raisins are on the higher side compared to other commercially available raisins of different colours. The raisin colour is mainly influenced by the type of processing followed during its production.

Raisin production is a major business where grapes are grown. Raisin-producing regions in India are mainly Sangli, Solapur and Nasik districts of Maharashtra, and Bijapur district of Karnataka[5]. However, these raisins are mostly golden or brown in colour. Green-coloured raisins are mainly imported in India and other Asian countries from Afghanistan, where they are produced in traditional mud houses commonly called kishmish khanas. The climatic conditions prevailing in Afghanistan are suitable for retaining green colour in the raisins. The drying conditions during green raisin production include shade-drying, low relative humidity and moderate air temperature (below 40°C). Raisin quality depends on size of the berry, berry colour uniformity, brilliance of berry colour, berry surface condition, skin texture, pulp chemical composition and presence of any foreign matter. However, for retention of green colour in the grape berries during drying there are some basic requirements which include air temperature 25–35°C, relative humidity 25–35%, mean, moderate air velocity and no direct exposure to sunlight[5]. Besides, green-coloured raisins can also be obtained by employing suitable treatments during grape drying. Sharma *et al.*[6] reported the significance of pre-treatments on grape berries for producing lighter-coloured raisins.

One of the major factors influencing raisin colour is the discolouration or browning during drying. Grapes lose their natural green colour and turn brown due to a combi-

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nation of browning reactions during drying, which may be enzymatic and non-enzymatic. Polyphenol oxidase (PPO) is the major causative enzyme for browning in raisins[7]. The reaction is a consequence of the oxidation of phenolic compounds by PPO, which triggers the generation of dark pigments[8]. Also, drying at high temperatures (>40°C) results in the formation of brown polymers called melanoidins. Studies also indicate that non-enzymatic browning (NEB) is a common reaction observed in products with high sugar content, which further affects the quality of foods by colour changes, loss of sugars and formation of 5-hydroxymethylfurfural[9]. Reducing sugars and ascorbic acid also contribute to browning reactions.

Different chemical treatments for reducing browning reactions in foods have been documented, including application of ascorbic acid in fresh cut fruits and vegetables[10–14]. Ascorbic acid is an antioxidant and also a GRAS (generally recognized as safe) chemical. Use of ascorbic acid and its derivatives as anti-browning agents has been documented in several studies in concentrations ranging from 0.5% to 4% (ref. 15).

Efficacy of antioxidants such as benzyl adenine and ascorbic acid in reducing the browning of raisins has been studied earlier[16,17]. Raisins produced from Thompson Seedless grapes after treatment with ethyl oleate and ascorbic acid (1000 ppm) solutions showed the lowest browning and increased percentage of green-coloured raisins[17].

However, limited information is available on use of ascorbic acid for retaining the green colour of raisins. Considering the importance of green raisins in terms of economic gains as well as nutritional value, the present study was carried out to evaluate the effect of ascorbic acid application in retaining green colour of raisins.

Materials and methods

Mature fruits of *Vitis vinifera* L., commonly known as grapes var. Thompson Seedless (moisture content 82.6% (wb), total soluble solids 22–23%, pH 3.82, titrable acidity 4.8 g/l) at the green ripe stage grown in a grape vineyard at Dindori, Nasik, were selected for experiments. Fruits with average diameter at the thickest point in the range 17.5–18.5 mm were selected for the study. Grapes after harvesting were packed in corrugated boxes lined with a sulphur sheet. They were then brought to ICAR-Central Institute of Post-Harvest Engineering and Technology (CIPHET), Abohar within 36 h of harvesting and stored at a temperature below 4°C and used within 24 h. Grapes were taken out of cold storage at least 1 h prior to experiments, washed and dried with a paper towel.

Grapes were washed with chlorine water followed by separating the damaged and shrivelled berries from the bunches. Each bunch weighing between 100 g and 150 g was selected as the sample size. Samples were pretreated by dipping in a beaker containing 500 ml of ethyl oleate (15 ml/l) and potassium carbonate (25 g/l) for 2 min (based on preliminary trials). The purpose of dipping in this solution is to enhance the rate of drying. Ethyl oleate disturbs the waxy cuticle of grape berries and potassium carbonate acts as an emulsifier. Grapes after pretreatment were rinsed with cold water for approximately 30 s and used for further study.

Two ascorbic acid treatments applied independently

Dipping in ascorbic acid solution before drying: Subsequently after ethyl oleate and potassium carbonate treatment, the grapes were dipped in ascorbic acid solution of different concentrations (100, 200, 300, 400 and 500 ppm) for a fixed time of 2 min (based on preliminary studies). After dipping treatment, the samples were shade-dried. Grapes that were not pretreated with dipping solution served as control.

Spraying of ascorbic acid solution during drying: Samples treated with ethyl oleate and potassium carbonate were shade-dried. Ascorbic acid solution of different strengths (100, 200, 300, 400 and 500 ppm) was sprayed on each sample at an interval of 24 h. The spray was applied for 30 s to each sample from an angle of 45° at a distance of 1 m, so that all the berries were uniformly coated with ascorbic acid solution. Spraying was done using a sprayer with a nozzle. Spraying treatment was continued till the desired level of moisture content was obtained. Grapes that were not subjected to spraying treatment served as control.

A total of ten treatments of ascorbic acid dip and spray were done independently to the samples. Table 1 gives the treatment codes used in the study.

Samples of grape were shade-dried in a closed ventilated room. During drying, day temperature ranged from 25°C to 27°C and night temperature from 20°C to 22°C, while relative humidity ranged between 25% and 35%. Ceiling fan was operated for 8 h in a day for drying of the samples. The grapes were tied with the help of a string in air for proper air circulation. The dried samples were collected each day to evaluate the changes occurring in colour attributes, moisture content, total phenolic content and PPO activity.

The moisture content of samples was measured using an infrared moisture balance (LCGC Moisture Balance, MAC 50/NH, M/s The Bharat Instruments and Chemicals, Ludhiana) following the standard procedure using AACC[18] methods.

Colour attributes of raisin samples were determined using Hunter lab colour scale (model no. LX16244, Hunter Associates Laboratory, Virginia, USA) in terms of CIE (Commission Internationale de L'Eclairage) L^*

Table 1. Treatment codes used in the study

	Concentration of ascorbic acid solution (ppm)					
Ascorbic acid treatment	Nil	100	200	300	400	500
Dipping	D0	D100	D200	D300	D400	D500
Spraying	S0	S100	S200	S300	S400	S500

D, Dipping; S, Spraying.

(lightness and darkness), a^* (redness and greenness) and b^* (yellowness and blueness). The sensor was standardized with a white tile and a black tile to assess the colour. From each sample, five berries were chosen and the colour values were recorded at two different points. From the L^*, a^* and b^* values, total colour difference (ΔE) was calculated using eq. (1)

$$\Delta E = \sqrt{(L^*_{\text{sample}} - L^*_{\text{ref}})^2 + (a^*_{\text{sample}} - a^*_{\text{ref}})^2 + (b^*_{\text{sample}} - b^*_{\text{ref}})^2}, \quad (1)$$

where 'sample' indicates raisin sample and 'ref' indicates control sample. The ΔE values obtained were used to determine whether the total colour difference of the raisins was visually obvious from the control samples[19] as follows

$\Delta E^* < 1$; Colour difference is not obvious for human eye.

$1 < \Delta E^* < 3$; Minor colour difference that could be appreciated by the human eye depending on the hue.

$\Delta E^* > 3$; Colour difference is obvious for human eye.

PPO activity in the samples was measured according to the method described by Nath *et al.*[20]. For this activity, 2 g of sample was homogenized at 0°C in 20 ml of 0.1 M sodium phosphate buffer (pH 7). The extract was filtered using a muslin cloth and centrifuged at 0°C for 20 min at 13,109 *g*. The supernatant was suitably diluted with a known volume of 0.02 M sodium phosphate buffer (pH 2). Next, 4 ml of 0.1 M phosphate buffer and 0.8 ml of catechol (0.055 g dissolved in 100 ml distilled water) were dispensed in four test tubes. One millilitre of distilled water was added in a test tube as sample blank and in the others 1 ml of sample extract was added. The absorbance was measured after 1, 2 and 3 min at 410 nm using UV–Vis spectrophotometer (UV-2550, SHIMADZU, Chandigarh). Three replicates were taken for each sample per treatment.

Browning index in raisins was measured according to the method described by Meydav *et al.*[21], with slight modifications, to determine the extent of non-enzymatic browning. The sample extract was centrifuged at 760 *g* (Eltek Refrigerated, Mumbai) for 15 min at room temperature. The supernatant was mixed with ethanol in 1 : 1 dilution (i.e. 10 ml supernatant was mixed with 10 ml ethanol). The mixture was again centrifuged at 760 *g* for 10 min. Centrifugation followed absorbance measurement at 420 nm using UV–Vis spectrophotometer (UV-2550, SHIMADZU, Chandigarh). The results were expressed in terms of absorbance value; higher the absorbance value, higher was the browning in the sample.

All the quality attributes of raisins were measured in triplicate and mean values were determined. Duncan's multiple range test (DMRT) was performed to test the statistical differences in these attributes as affected by different ascorbic acid treatments. SPSS software (version 16.0) was used for DMRT. The significance was accepted at 5% levels of significance ($P < 0.05$).

Principal component analysis (PCA) was performed to determine the relationships between various quality attributes as well as their association with ascorbic acid treatment. Addin software XLSTAT (version 2014.5.03) was used to perform PCA.

Results and discussion

Raisin production in India involves dipping the freshly harvested grapes in 2.4% potassium carbonate and 1.5% ethyl oleate solution, and subsequent drying under open tier system. However, the resulting raisins have poor colour quality. The colour of raisins is generally yellow, golden-yellow, brown or dark brown. In the present study, known concentrations of ascorbic acid solutions were sprayed on grape berries after dipping in ethyl oleate and potassium carbonate. Ascorbic acid was utilized because of its ability to function as an anti-browning agent. The effect of ascorbic acid treatments on selected quality attributes of raisins evaluated during this study is presented below.

Moisture content

Results revealed that on the basis of optimum storage moisture content of raisins (20–22%, wb), drying duration of grapes with different ascorbic acid treatments was 6 days (Table 2). Ascorbic acid treatments significantly

Table 2. Effect of ascorbic acid dipping and spraying treatments on moisture content (%, wet basis (wb)) of raisins

Time (days)	D0	D100	D200	D300	D400	D500
0	81.14 ± 6.21g	80.12 ± 4.52g	81.52 ± 4.62g	81.28 ± 7.45g	81.24 ± 3.21g	80.14 ± 5.25g
1	71.85 ± 2.32f	72.14 ± 4.21f	70.14 ± 3.21f	75.58 ± 2.36f	73.62 ± 2.32f	71.28 ± 3.33f
2	55.52 ± 1.32e	60.21 ± 1.25e	65.12 ± 1.36e	62.14 ± 6.32e	66.29 ± 2.21e	59.85 ± 2.31e
3	42.69 ± 5.62d	51.23 ± 3.21d	57.18 ± 5.62d	53.25 ± 1.25d	56.54 ± 5.32d	45.21 ± 2.31d
4	35.25 ± 5.21c	45.14 ± 5.21c	46.54 ± 2.62c	42.14 ± 5.26c	40.41 ± 4.23c	37.48 ± 1.25c
5	28.15 ± 4.21b	29.25 ± 5.32b	28.74 ± 1.25b	30.95 ± 6.25b	32.14 ± 5.14b	26.58 ± 1.26b
6	23.25 ± 5.21a	21.86 ± 1.62a	21.51 ± 2.36a	22.14 ± 2.35a	21.11 ± 2.31a	20.21 ± 3.21a
	S0	S100	S200	S300	S400	S500
0	81.23 ± 3.21g	80.12 ± 4.21g	80.25 ± 2.36g	81.65 ± 1.25g	81.11 ± 9.62g	81.14 ± 4.21g
1	72.21 ± 5.84f	70.58 ± 4.32f	71.10 ± 2.12f	71.24 ± 3.26f	70.14 ± 1.21f	71.14 ± 4.91f
2	59.25 ± 1.54e	60.20 ± 3.21e	61.16 ± 1.35e	60.58 ± 5.32e	61.62 ± 5.23e	62.29 ± 5.34e
3	41.10 ± 2.45d	40.35 ± 2.35d	42.45 ± 4.62d	45.20 ± 4.26d	40.17 ± 2.32d	51.56 ± 2.36d
4	32.15 ± 6.20c	31.11 ± 2.36c	31.26 ± 1.54c	30.85 ± 5.20c	32.51 ± 3.14c	43.26 ± 2.15c
5	29.28 ± 2.21b	26.84 ± 1.36b	27.45 ± 2.25b	27.74 ± 4.36b	27.20 ± 2.36b	32.26 ± 2.32b
6	25.45 ± 3.21a	22.15 ± 5.62a	21.45 ± 4.35a	20.81 ± 1.32a	19.69 ± 1.22a	19.86 ± 2.31a

Values are mean of triplicate determinations ± standard deviation. Different letters within the same column are statistically different ($P < 0.05$).

($P < 0.05$) affected the moisture content of grape berries. Among dipping treatments, minimum moisture content was observed in treatment D500. The moisture content in control (D0) berries after 6 days of drying was higher, (23.25%) in comparison to ascorbic acid-treated berries where moisture content ranged from 21.86% to 20.21%. This implies that dipping in ascorbic acid solution helped in faster removal of moisture during drying.

Similarly, in spraying treatments, significant ($P < 0.05$) decrease in moisture content of berries was observed. The moisture content values decreased from 81.23% to 25.45% in S0 treatment after 6 days. Similar trends were observed in other treated samples (S100–S500) also. However, the decrease in moisture content during drying was more for higher concentration levels. The final moisture content of samples sprayed with S100, S200, S300, S400 and S500 ppm concentrations of ascorbic acid was 22.14%, 21.45%, 20.81%, 19.60% and 19.86% respectively. On comparing the final moisture content of berries treated with corresponding concentrations of dipping and spraying treatments, it was found that ascorbic acid spray during drying was more effective than the dipping treatments in removing moisture from grape berries.

Colour attributes

Colour is one of the most important sensory attributes of foods due to its direct influence on consumer acceptability. Studies show that consumers prefer light-coloured raisins due to their associated sensory and nutritional quality[4]. In the present study, the effect of ascorbic acid dipping and spraying treatments on colour attributes of raisin samples was determined (Table 3). Ascorbic acid application as a dip or spray was found suitable in maintaining the green colour of raisins. Both dipping and spraying treatments had significant ($P < 0.05$) impact on final colour values. On the basis of visual observations, it was observed that spraying treatment was superior to the dipping treatment in terms of retaining the raisin colour.

Lightness (L^*), redness (a^*) and yellowness (b^*) values of samples subjected to dipping treatment ranged from 45.36 to 41.86, 20.2 to 38.02 and 18.98 to 31.72 respectively. Lightness value was highest (44.1) in D500 treatment and lowest in D0 treatment (41.86) on the sixth day of drying. Initially, during drying, no significant ($P < 0.05$) difference was observed between the treatments. Amongst various samples, as the concentration of ascorbic acid increased, simultaneous increase in L^* values was also observed; however, the change was non-significant ($P < 0.05$). Redness value (a^*) of raisins was also significantly ($P < 0.05$) affected by ascorbic acid treatments. Grncarevic and Lewis[22] noted that Hunter Lab's L^* and b^* are the best correlating colour parameters compared to a^* for colour quality of raisins. However, in the present study, a^* value was given more importance as we were looking for green colour of raisins. In case of dipping treatments, a^* values increased during the drying period from day zero to the sixth day. The values were 27.51, 23.95, 22.14, 22.14, 23.56 and 23.14 on the second day of drying in D0, D100, D200, D300, D400 and D500 ppm respectively. Yellowness (b^*) showed a trend similar to lightness, and the values decreased during the drying period amongst all the six treatments. The values in D0 sample were lowest (18.98) initially on day zero and highest (31.72) on the sixth day during drying. Moreover, results also indicated that ascorbic acid concentration of ≥200 ppm in dipping treatments was sufficient in maintaining green colour of raisins.

Almost similar trends in observations were recorded in case of spraying treatments, where different concentrations of ascorbic acid were sprayed on grape berries at definite intervals of time. Table 3 shows that L^*, a^* and

Table 3. Effect of ascorbic acid dipping and spraying treatments on the colour attributes of raisins

	D0			D100			D200			D300			D400			D500		
Time (days)	*L*	*a*	*b*	*L*	*a*	*b*	*L*	*a*	*b*	*L*	*a*	*b*	*L*	*a*	*b*	*L*	*a*	*b*
0	45.36	20.2	18.98	45.36	20.2	18.98	45.36	20.2	18.98	45.36	20.2	18.98	45.36	20.2	18.98	45.36	20.2	18.98
1	44.82	24.14	21.15	44.51	22.12	19.61	44.92	21.62	20.11	45.11	21.09	19.45	44.91	21.11	19.17	45.21	21.14	20.11
2	44.12	27.51	23.91	44.06	23.95	20.18	44.61	22.14	22.32	44.89	22.14	20.17	44.67	23.56	21.91	44.92	23.14	21.65
3	43.51	30.61	26.14	43.72	25.23	23.12	44.27	24.12	24.32	44.56	26.54	22.95	44.35	25.32	23.51	44.72	25.16	23.51
4	42.92	32.56	27.15	43.21	27.16	26.85	43.81	28.15	26.45	44.12	30.56	25.44	44.12	28.21	24.32	44.62	27.15	24.36
5	42.21	35.91	29.83	42.82	31.21	28.21	43.08	31.14	27.32	43.85	31.21	26.55	43.91	30.21	25.93	44.32	29.54	25.78
6	41.86	38.02	31.72	42.32	35.17	30.29	42.82	34.12	28.27	43.21	32.16	27.12	43.78	31.2	26.31	44.1	30.79	26.03
	S0			S100			S200			S300			S400			S500		
0	45.36	20.2	18.98	45.36	20.2	18.98	45.36	20.2	18.98	45.36	20.2	18.98	45.36	20.2	18.98	45.36	20.2	18.98
1	44.82	24.14	21.15	44.91	21.89	20.17	45.02	21.11	20.63	45.11	21.42	20.33	45.39	20.71	19.81	45.14	20.34	19.81
2	44.12	27.51	23.91	44.72	22.14	22.81	44.81	23.19	22.12	44.91	22.81	21.07	45.21	21.17	21.14	45.47	21.42	20.89
3	43.51	30.61	26.14	44.21	26.17	23.61	44.17	25.61	23.32	44.78	24.31	21.53	45.18	23.42	21.68	45.21	23.12	21.56
4	42.92	32.56	27.15	43.87	28.14	24.51	44.12	27.14	24.41	44.52	26.18	23.36	45.12	24.56	22.16	45.17	24.21	21.96
5	42.21	35.91	29.83	43.17	30.14	26.14	43.86	29.14	25.12	44.29	27.21	24.18	44.89	25.62	22.92	44.91	25.72	22.72
6	41.86	38.02	31.72	42.15	32.12	28.17	43.25	30.17	26.52	44.16	29.17	25.84	44.95	26.15	23.12	44.89	26.41	23.32

L, *a*, *b*, are colour values; *L*, lightness; *a*, redness; *b*, yellowness.

Table 4. Effect of ascorbic acid dipping and spraying treatments on polyphenol oxidase activity (EU ml^{-1} min^{-1}) of raisins

Time (days)	D0	D100	D200	D300	D400	D500
0	86.24 ± 2.32g	86.24 ± 2.32g	86.24 ± 2.32g	86.24 ± 2.32g	86.24 ± 2.32g	86.24 ± 2.32g
1	68.13 ± 3.21f	63.68 ± 4.32f	60.12 ± 2.36f	62.15 ± 2.52f	63.40 ± 2.11f	62.32 ± 5.32f
2	51.20 ± 2.32e	51.14 ± 2.21e	48.58 ± 3.17e	51.25 ± 1.32e	52.29 ± 2.56e	50.52 ± 4.21e
3	40.52 ± 1.21d	39.75 ± 6.32d	35.51 ± 2.58d	35.56 ± 6.21d	34.15 ± 4.21d	43.15 ± 2.32d
4	31.54 ± 3.25c	25.24 ± 1.25c	22.02 ± 2.46c	25.25 ± 5.21c	23.22 ± 1.32c	32.85 ± 4.21c
5	22.55 ± 2.22b	18.87 ± 4.21b	16.25 ± 1.96b	15.14 ± 1.22b	17.28 ± 1.42b	26.58 ± 1.23b
6	15.21 ± 1.32a	13.81 ± 4.36a	10.20 ± 1.59a	10.25 ± 2.12a	11.14 ± 1.22a	13.54 ± 2.51a
	S0	S100	S200	S300	S400	S500
0	86.24 ± 2.32g	86.24 ± 2.32g	86.24 ± 2.32g	86.24 ± 2.32g	86.24 ± 2.32g	86.24 ± 2.32g
1	62.12 ± 5.32f	53.68 ± 2.35f	50.14 ± 2.36f	52.15 ± 2.11f	53.40 ± 5.62f	52.14 ± 2.32f
2	45.22 ± 4.32e	40.14 ± 6.33e	38.58 ± 5.22e	41.25 ± 2.36e	42.19 ± 4.32e	40.15 ± 1.23e
3	30.52 ± 2.36d	29.85 ± 1.22d	25.51 ± 3.61d	26.56 ± 1.33d	24.89 ± 2.15d	23.54 ± 2.51d
4	23.54 ± 1.36c	15.24 ± 1.52c	12.02 ± 2.36c	13.25 ± 5.21c	13.22 ± 2.13c	12.56 ± 1.42c
5	19.55 ± 2.31b	8.87 ± 1.33b	6.25 ± 1.25b	8.45 ± 1.22b	7.87 ± 1.36b	6.56 ± 1.51b
6	14.21 ± 1.55a	3.80 ± 0.62a	3.20 ± 0.95a	4.25 ± 1.63a	4.50 ± 1.85a	3.05 ± 1.06a

Values are mean of triplicate determinations ± standard deviation. Different letters within the same column are statistically different ($P < 0.05$).

b^* values are significantly ($P < 0.05$) affected by spraying treatment. The visual colour showed slight change from green to light green, but the colour quality was appreciable. The colour values in terms of lightness, redness and yellowness ranged from 45.36 to 41.86, 38.02 to 20.2 and 31.72 to 18.98 respectively. On comparing with dipping treatments, it was seen that raisin samples treated with spraying treatment retained more green colour. Lightness in S0 samples decreased significantly ($P < 0.05$) from 45.36 on day zero to 41.86 on the sixth day of drying. Decrease in L^* value implies darker coloured sample; however, ascorbic acid spray resulted in brighter samples. Per cent decrease in lightness was less in case of spraying-treated samples. Also, increase in ascorbic acid concentration resulted in significant ($P < 0.05$) decrease in L^* values of all the samples. L^* value on the sixth day of drying in decreasing order was observed as 41.86 > 42.15 > 43.25 > 44.16 > 44.95 > 44.89 in S0, S100, S200, S300, S400 and S500 ppm respectively.

Generally, a^* value is related to the degree of redness in the samples or the level of browning due to drying or processing. With an increase in ascorbic acid concentration in spraying treatments, the level of redness in the samples decreased significantly ($P < 0.05$) from S0 to S500 treatments. However, a^* value increased significantly ($P > 0.05$) in the respective treatments. The results were found to be similar to the b^* values. Lower b^* value was observed in ascorbic acid-sprayed samples than in S0 sample. The b^* value in S0 sample was 18.98 on day zero and increased to 31.72 on the sixth day of drying. Whereas with subsequent drying duration, the per cent increase in b^* values was less in ascorbic acid-sprayed samples than S0 sample; however, the difference observed in both the cases was significant ($P > 0.05$). With increase in ascorbic acid concentration from S100 to S500, significant decrease ($P < 0.05$) in b^* values was recorded.

Polyphenol oxidase activity

PPO is a group of enzymes that catalyse the oxidation of phenolic compounds to produce a brown colour in exposed and disrupted tissues of plants. Application of ascorbic acid had an impact on PPO activity. Lower PPO activity was noted in ascorbic acid-treated grape berries than D0 and S0 treatments (Table 4). Decrease in PPO activity was observed with increasing drying time in each treatment. Initial PPO activity under dipping treatments was recorded as 86.241 EU ml^{-1} min^{-1}; it decreased with the drying period. PPO activity in dipped samples ranged from 86.210 to 10.2 EU ml^{-1} min^{-1}. Lower PPO activity was recorded in D200, D300 and D400 with values of 10.2, 10.25 and 11.145 EU ml^{-1} min^{-1} respectively, whereas higher activity was observed in D500 (13.545 EU ml^{-1} min^{-1}) on the sixth day of drying. Minimum activity, i.e. 10.200 EU ml^{-1} min^{-1} was also observed on the sixth day of drying in grapes treated with D200 of ascorbic acid (Table 3), whereas maximum activity (15.210 EU ml^{-1} min^{-1}) was recorded for D0.

Similar observations were made in grape berries treated with ascorbic acid spray during drying. The enzyme activity ranged from 86.241 to 3.050 EU ml^{-1} min^{-1}. Lowest activity (3.050 EU ml^{-1} min^{-1}) was observed in S500 treatment and maximum activity (14.210 EU ml^{-1} min^{-1}) was noticed in S0 treatment. The decrease in PPO activity with drying time might be due to increasing sugar content with subsequent moisture loss. Our results are in agreement with those of Zheng *et al.*[23] and Yaar *et al.*[24]; who found that ascorbic acid was the most

Table 5. Effect of ascorbic acid dipping and spraying treatments on browning index of raisins

Time (days)	D0	D100	D200	D300	D400	D500
0	0.21 ± 0.2a	0.21 ± 0.2a	0.20 ± 0.2a	0.20 ± 0.2a	0.20 ± 0.2a	0.20 ± 0.2a
1	0.35 ± 0.3b	0.30 ± 0.1b	0.39 ± 0.2b	0.39 ± 0.3b	0.36 ± 0.1b	0.33 ± 0.6b
2	0.56 ± 0.1c	0.41 ± 0.3c	0.45 ± 0.3c	0.45 ± 0.2c	0.51 ± 0.2c	0.45 ± 0.2c
3	0.67 ± 0.2d	0.51 ± 0.3d	0.56 ± 0.2d	0.59 ± 0.1d	0.63 ± 0.3d	0.63 ± 0.5d
4	0.81 ± 0.1e	0.60 ± 0.1e	0.63 ± 0.1e	0.74 ± 0.6e	0.79 ± 0.3e	0.80 ± 0.3e
5	0.91 ± 0.3f	0.73 ± 0.2f	0.74 ± 0.6f	0.81 ± 0.2f	0.96 ± 0.6f	0.95 ± 0.6f
6	2.13 ± 0.2g	1.14 ± 0.1g	1.13 ± 0.6g	1.21 ± 0.7g	1.21 ± 0.3g	1.24 ± 0.7g
	S0	S100	S200	S300	S400	S500
0	0.20 ± 0.2a	0.21 ± 0.2a	0.20 ± 0.1a	0.20 ± 0.2a	0.20 ± 0.2a	0.20 ± 0.1a
1	0.32 ± 0.2b	0.28 ± 0.3b	0.37 ± 0.2b	0.36 ± 0.1b	0.37 ± 0.1b	0.32 ± 0.2b
2	0.51 ± 0.1c	0.38 ± 0.1c	0.48 ± 0.3c	0.45 ± 0.3c	0.47 ± 0.3c	0.43 ± 0.3c
3	0.62 ± 0.3d	0.41 ± 0.2d	0.52 ± 0.5d	0.56 ± 0.4d	0.60 ± 0.5d	0.61 ± 0.4d
4	0.75 ± 0.2e	0.65 ± 0.3e	0.67 ± 0.6e	0.70 ± 0.5e	0.78 ± 0.6e	0.79 ± 0.6e
5	0.98 ± 0.1f	0.85 ± 0.1f	0.87 ± 0.6f	0.82 ± 0.8f	0.93 ± 0.4f	0.92 ± 0.7f
6	1.98 ± 0.3g	0.98 ± 0.6g	0.96 ± 0.8g	0.99 ± 0.8g	1.12 ± 0.8g	1.21 ± 0.8g

*Values are mean of triplicate determinations ± standard deviation.

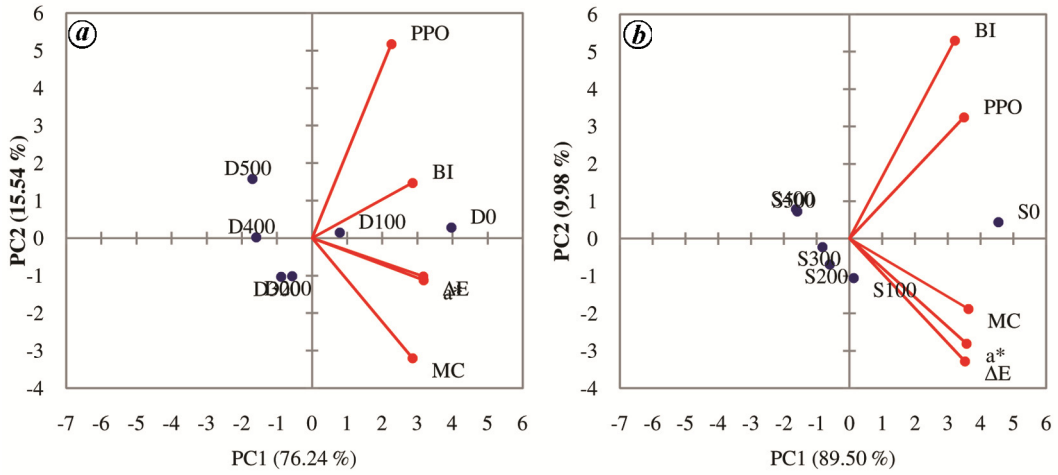

Figure 1. Principal component analysis for quality attributes of grapes subjected to (***a***) dipping and (***b***) spraying treatments.

effective PPO activity inhibitor after L-cysteine and that it acts as a direct reductant for PPO-generated ortho-quinones. Importance of ascorbic acid in the inhibition of PPO activity has also been well documented[15,25].

Browning index

Ascorbic acid dipping and spraying treatments showed significant ($P < 0.05$) effect on browning index of raisins (Table 5). During drying, it was observed that increase in browning index was exponential in all the samples; however, the rate of increase was highest in case of control samples (D0 and S0) and was lowest in grapes sprayed with 200 ppm of ascorbic acid (S200). On comparing all the treatments it was observed that on the last day of drying the values were 1.989, 0.988, 0.958, 1.123 and 1.212 for S0, S100, S200, S300, S400 and S500 samples respectively. Comparing the dipping and spraying treatments, it was observed that ascorbic acid spray samples showed lower browning index than ascorbic acid dip-treated samples. Our observations corroborate the findings in air-dried asparagus, mushrooms and apricots[26–29].

Principal component analysis of raisin quality attributes

In the present study, raisins were evaluated for moisture content, colour attributes (a^* and ΔE), PPO activity and browning index. All these attributes are undesirable for a good-quality raisin. Moreover, higher values of a^*, ΔE, PPO activity and browning index indicate the browning/darkening of raisins. Hence, their association with the samples indicates poor-quality (dark coloured) raisins.

Figure 2. Raisins produced from S0 and S200 treatments.

PCA was performed for these quality attributes; Figure 1 presents the results in the form of biplots. It is evident from Figure 1 *a* that all the quality attributes show their association with dipping treatments D0 and D100 indicating that these samples have higher moisture content, brown/dark colour, higher PPO activity and higher browning index. However, samples subjected to treatments D200 to D500 did not show any association with these quality attributes, and thus indicate the retention of green colour of the raisins. Figure 1 *a* also reveals that PPO and browning index show a grouping, indicating that the increase in one attribute is associated with a simultaneous increase in the other. Similar kind of grouping was observed among a^*, ΔE and moisture content.

Figure 1 *b* presents results of PCA performed for quality attributes of samples subjected to spraying treatments. Results indicate that treatment S0 showed association with all the quality attributes, indicating poor quality (brown/dark colour) of the samples. However, samples subjected to spraying treatments S100 to S500 were placed at considerable distance from these quality attributes and thus indicated the production of green-coloured raisins.

Thus, PCA indicated that ascorbic acid treatments (dipping and spraying) were useful in retaining the colour and producing green-coloured raisins. However, based on all the observations (Tables 2–5 and Figures 1 and 2), treatment S200 (spray of 200 ppm ascorbic acid solution) was found optimal treatment to produce green-coloured raisins.

Conclusion

The results of the present study reveal that the application of ascorbic acid is useful in retaining the colour of raisins and improving drying rate of grapes. Application of ascorbic acid on grape bunches has been proved significant. The raisin quality was improved in ascorbic-acid treated cases compared to untreated grape berries. Different doses of ascorbic acid were recorded with reduced PPO activities during grape-drying. Spraying of ascorbic acid during drying was found more effective than ascorbic acid dip. Among different concentrations of ascorbic acid, we recommend that 200 ppm is sufficient in controlling drying-induced browning and producing green raisins.

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