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Effect of low temperature on the ascorbic acid content and quality characteristics of frozen strawberry

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Abstract

The effect of low storage temperature and freezing methods on ascorbic acid content and other qualitative characteristics of Iranian strawberries (Kordestan variety) were investigated. With two different types of freezing methods (slow at −20 °C and quick at −50 to −100 °C), three different temperatures and, following three months of storage, changes in colour, anthocyanin and ascorbic acid content, pH, acidity and sensory evaluation were tested. The major losses of ascorbic acid occurred during the first 15 days of storage and the percentage were 64.5, 10.7 and 8.9 at −12, −18 and −24 °C, respectively. No statistically significant differences were observed between the −18 and −24 °C and freezing methods in ascorbic acid losses, pH level on acidity content. In the slow freezing method, there was a statistically significant difference only in pH level, at all three temperatures. Therefore, the storage temperatures of −18 and −24 °C were best for preserving the qualitative characteristics (colour, texture, flavour and wholeness) of the strawberries.

Keywords: Strawberry; Ascorbic acid; Freezing; Storage; Quality characteristics

1. Introduction

Freezing of fruits and vegetable is one of the most common ways for maintaining the quality of these products. Recently, the consumption of fruits and vegetable have increased very much, because consumer's knowledge of their advantages has increased. On the other hand, today, the demand for storing raw material, using industrial freezing, has increased (Macrae, Robinson, & Sadler, 1993; Somogyi, Ramaswamy, & Hui, 1996). It has been specified, in recent studies, that the most important nutritional changes in frozen foods are due to the storage time. Researchers have used ascorbic acid (or vitamin C) as a quality indicator (Erikson & Hung, 1997; Rosen & Kader, 1989; Ulrich, 1978).

At different storage temperature (−5, −12 and −20 °C), frozen broccoli, spinach, lemon juice and strawberries showed marked decrease in vitamin C, so that after one month at −5 °C, a huge reduction was achieved, with levels approaching 0% retention (Mallett, 1993). A comprehensive study on frozen storage of fruits and vegetables at −18 and −30 °C revealed that vitamin C was markedly affected (Urbany & Horti, 1992). Storage of blanched Brussels sporuts at −12 °C led to rapid decrease of nutritional value, taste and odour (Klimezka & Irzyniec, 1997).

Anthocyanin resistance in frozen strawberry juice was studied and the results showed that, at −10 °C, anthocyanin content decreased by 68.8% and 69.7% after three and eight months, respectively (Torreggiani, 1999). Frozen storage of strawberry, at −18 °C after seven months, had a specific effect on colour but no significant different in total anthocyanin was observed (Sistrunk & Morris, 1978). Decrease of anthocyanin content in frozen storage strawberry, at −20 °C after six months, depending on variety was 11–27.5% (Polesello & Rampilli, 1972). Temperature is one of the effective factors for anthocyanin resistance (Urbany & Horti, 1992; Withy, Nguyen, & Wrolstad, 1993). The colour of food can be changed in quick freezing due to pigment replacement and discolouration (Urbany & Horti, 1992).

The main objective of this research programme is to assess the changing of ascorbic acid in frozen storage of

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the Iranian strawberry, at different times and temperatures, and to study its quality characteristics. This study has been was undertaken at Tarbiat Modarres University.

2. Materials and methods

2.1. Sample preparation

Samples of strawberry were used from the Kordestan area in the west of Iran. This kind of strawberry was selected by its popularity and vast area of cultivation. Samples were directly harvested from Chenareh farm of Sanandaj and were transferred and cold-stored in the university laboratory in suitable panniers. To prepare samples for freezing, they were initially washed in cold water of 5 °C and medium-sized strawberries, with clear red colour, suitable degree of ripeness and lack of any apparent damage, were selected. Then, their sepals were separated manually and after straining were packed in 450 g of 70 μm polyethylene packing (Mallett, 1993). All chemical reagents were of analytical grade and obtained from Merck Company.

2.2. Methods

Slow freezing in a domestic freezer (Bush model) at −20 °C for 24 h and quick freezing with liquid nitrogen at −50 to −100 °C for 11 min, were done. For both freezing methods, packed strawberries, in polyethylene packing, were directly used. Temperature of the strawberry centre was measured by digital thermometer. Samples were stored in a domestic freezer (calibrated with ±1 °C) at −12, −18 and −24 °C and tested after 1, 15, 30, 60 and 90 days. The ascorbic acid was measured by classical titration method using 2,6-dichlorophenol indophenol solution in mg/100 g sample (Charalambous, 1984; Miller, 1998). Dehydroascorbic acid plus ascorbic acid make up vitamin C (Tannenbaum, Archer, & Young, 1985). The anthocyanin was measured with a spectrophotometer (Unicam, model 8620) on the basis of maximum absorption at 500 nm wavelength and was calculated as absorbance/1 g of sample (Miller, 1998; Morris, Sistrunk, Sims, & Main, 1985; Sistrunk, Wang, & Morris, 1983). The pH was measured with a pH meter and acidity was measured by titration with 0.1 N NaOH, based on citric acid (Rosen & Kader, 1989; Sistrunk et al., 1983). For sensory evaluation, after thawing the frozen samples at 35 °C for 30 min, acceptability of fruit was evaluated by 18 trained taste panels (10 for excellent, 5 for acceptable and 1 for non-acceptance) the sensory evaluation was conducted using the Hedonic test (Main, Morris, & Wehunt, 1986; Morris et al., 1985; Sistrunk et al., 1983). All sensory evaluation tests were done under fluorescent light.

2.3. Statistical analysis

The data were analyzed by analysis of variance in randomized complete blocks using the SPSS statistical programme (Dixon & Massey, 1983; Hicks & Turmer, 1999; Steel, Torrie, & Dickey, 1997; Yandell, 1997).

3. Results and discussion

3.1. Ascorbic acid

The effect of storage time on ascorbic acid content is presented in the Fig. 1. Comparison of average ascorbic acid contents at a storage temperature showed significant decreases of 64.5%, 10.7% and 8.9% in ascorbic acid at −12, −18 and −24 °C, respectively (Table 1). The major loss of ascorbic acid occurred during the first 15 days of storage at −12 °C (31.4%). This result confirms those of Ibanez, Foin, Cornillon, and Reid (1996), that showed that the sharpest decrease of ascorbic acid occurred in the first 15 days of storage. The most likely cause for this behaviour is freeze-concentration, i.e., the increase in concentration of solutes that occurs in the unfrozen phase during freezing (Thomson & Fennema, 1971).

3.2. Anthocyanin

The effect of storage time on anthocyanin content is presented in Fig. 2. Comparison of average anthocyanin contents at −12 °C did not show significant difference during the first 15 days of storage but, in total period of storage, the decrease rate was 40.2%. This amount is less than with the results of Torreggiani (1999) which showed a decrease of 65% in anthocyanin of strawberry juice at −10 °C. It seems that the difference is rooted in

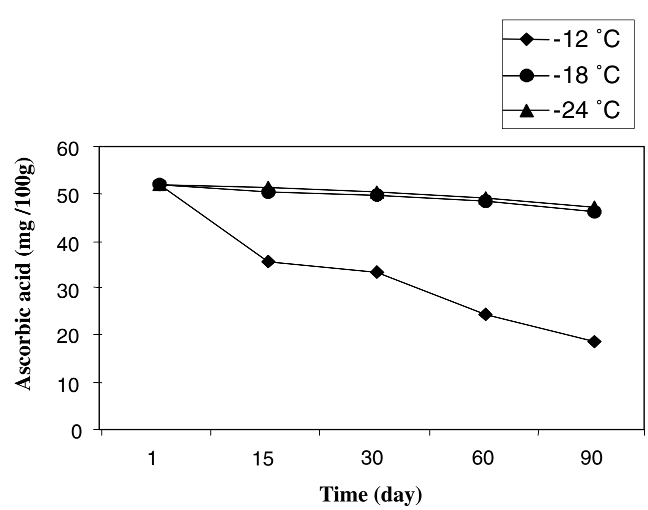

Fig. 1. The effect of storage time on ascorbic acid content.

Table 1
Comparison of storage time effects on acidity, anthocyanin and ascorbic acid contents in frozen strawberry at 5% statistical level

Storage time (day)	Storage temperature (°C)								
	−12			−18			−24		
	Acidity (%)	Anthocyanin (abs/gfw[a])	Ascorbic acid (mg/100 g)	Acidity (%)	Anthocyanin (abs/gfw[a])	Ascorbic acid (mg/100 g)	Acidity (%)	Anthocyanin (abs/gfw[a])	Ascorbic acid (mg/100 g)
1	1.22a	7.75a	52a	1.22a	7.73a	52.0a	1.22a	7.67a	52.0a
15	1.19b	7.21a	35.7b	1.20b	7.56b	50.6b	1.22a	7.34b	51.5b
30	1.18c	6.62b	33.3c	1.18c	6.87b	49.8c	1.18b	7.1b	50.5c
60	1.16d	5.87b	24.1d	1.15d	6.63b	48.5d	1.15b	6.72b	49.0d
90	1.08e	4.63c	18.5e	1.15d	5.08c	46.4e	1.14b	6.32b	47.4e

Different letters in one column (a–e) show significant differences by statistical programme.
[a] Absorbance/gramme fruit weight.

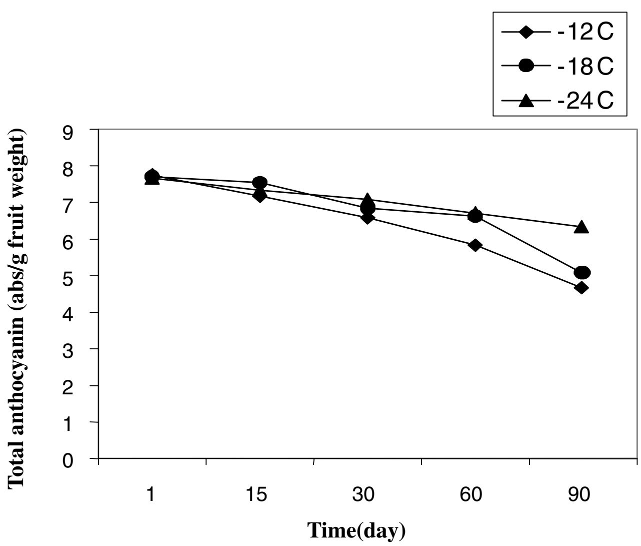

Fig. 2. The effect of storage time on anthocyanin content.

Table 2
Comparison of storage temperature effects and freezing method on total anthocyanin content (abs/gfw[a]) in frozen strawberry at 5% statistical level

Storage temperature (°C)	Slow freezing method	Quick freezing method
−12	7.09a	5.73a
−18	7.30a	6.26b
−24	7.69a	6.36b

Different letters in one column(a, b) show significant differences by statistical programme.
[a] Absorbance/gramme fruit weight.

the different storage temperatures of the tests. At −18 °C, there was a significant difference of anthocyanin content (34.3%) between the first and 15th days of storage. This result was not in line with that of Sistrunk and Morris (1978), because the variety, degree of strawberry ripeness and method of freezing were different. Also, at −24 °C, significant difference was found only in the first 15 days of storage and decrease of anthocyanin was 17.6% (Table 2) which corresponds with results of Polesello and Rampilli (1972).

3.3. Acidity and pH

The effects of storage time on the acidity and pH are presented in Figs. 3 and 4. Results for acidity showed significant differences at all levels (Table 3). At −12 °C, at any time, acidity of samples showed a significant difference (5%) and at 24 °C, acidity was fixed at the first and last storage period. Study of acidity changes

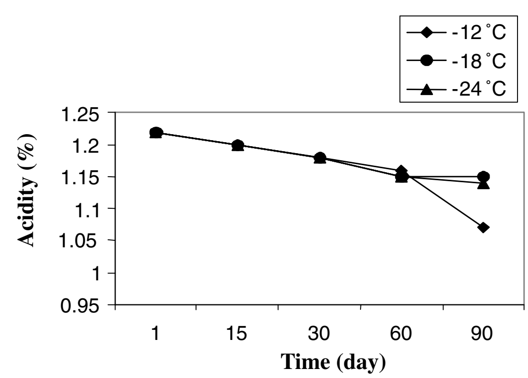

Fig. 3. The effect of storage time on acidity.

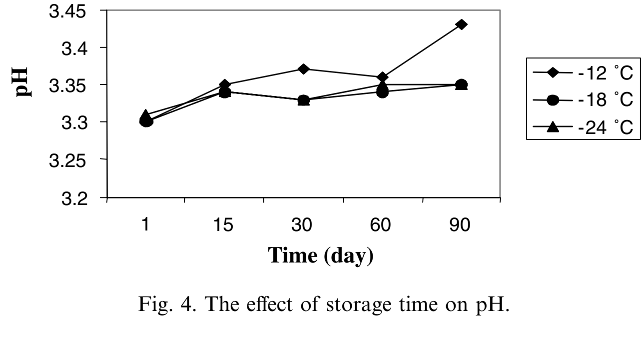

Fig. 4. The effect of storage time on pH.

Table 3
Analysis of variance for storage temperature and time, freezing method and their mutual effects on strawberry characteristics

	Degree of freedom	Ascorbic acid (mg/100 g)	Total anthocyanin (abs/gfw[a])	Acidity(%)	pH	*F* (5%)	*F* (1%)
Temperature	2	29048**	82**	1.41^{ns}	25.0**	3.15	4.98
Storage time	4	5563**	439**	236**	25.6**	2.53	3.56
Freezing method	1	62.4**	993**	0.533^{ns}	2.5^{ns}	4	7.08
Storage temperature × freezing method	2	1.72^{ns}	9.26**	2.3^{ns}	4.05*	3.15	4.98
Storage time × freezing method	4	2.89**	158**	1.54^{ns}	0.58^{ns}	2.53	3.65
Storage temperature × storage time	8	609.3**	24.3**	30.9**	2.34*	2.1	2.82
Storage temperature × storage time × freezing method	8	4.25**	4.25**	0.97^{ns}	0.89^{ns}	2.1	2.82
Error	60	0.099	0.035	0.0015	0.0006		

[a] Absorption/gramme fruit weight.
[ns] No significant difference.
[*] Significant difference(at 5% level).
[**] Significant difference (at 1% level).

against storage time is important; in this study, acidity, volatile and aromatic acids are computed on the basis of the dominant acid (i.e. citric acid). Average pH showed, significant differences (5%) between 15 days, second and third months (Fig. 4). At −12 °C, in the final storage period, pH was above 3.4 and this could be one of the reasons for anthocyanin decrease at this temperature. At pH above 3.4, anthocyanin is destroyed (Sistrunk et al., 1983). Storage time, enzymatic and microbial changes have many effects on hydrogen ion concentration; therefore, pH is important in assessing the efficiency and quality of performing processing methods.

3.4. Freezing method

The effects of freezing method and storage temperature on ascorbic acid, anthocyanin content, and pH are presented in Figs. 5–7. Ascorbic acid showed no significant differences, at any temperature, between the two methods of freezing; at −12 °C, however, decrease of ascorbic acid was significant (Fig. 5). These results were similar with those of Ibanez et al. (1996); Klimezka and Irzyniec (1997); Ulrich (1978), who reported a quick decreasing trend of ascorbic acid at temperatures above −18 °C. The results are, however, in contrast to those of Ibanez et al. (1996), who reported, in the slow freezing

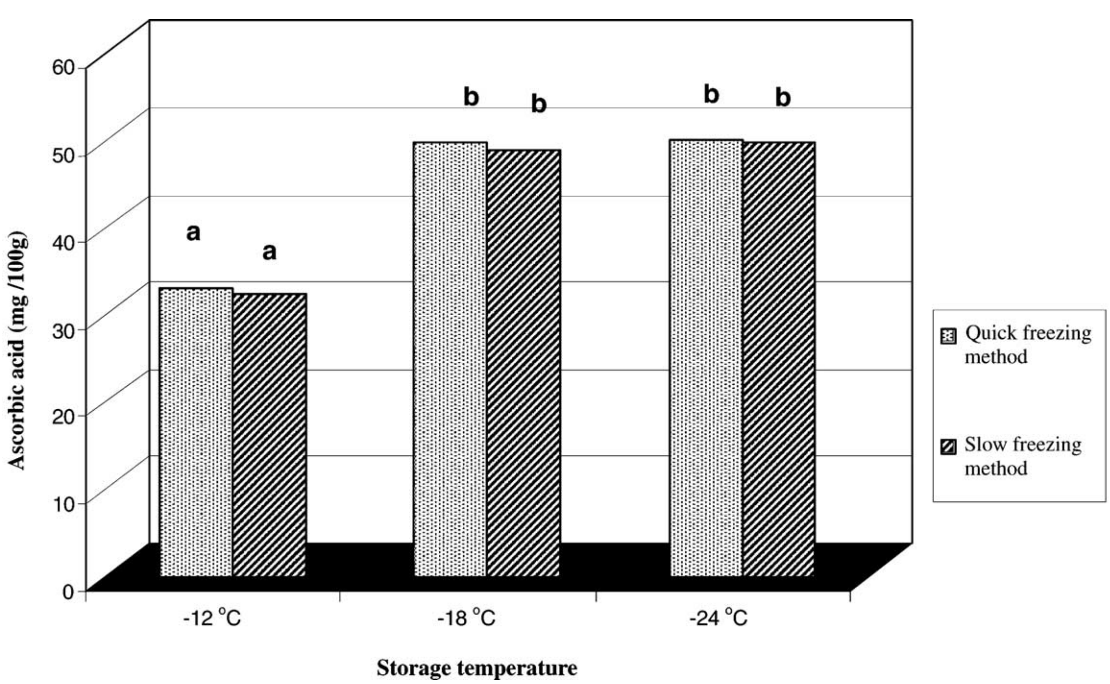

Fig. 5. The effect of freezing method and storage temperature on ascorbic acid content.

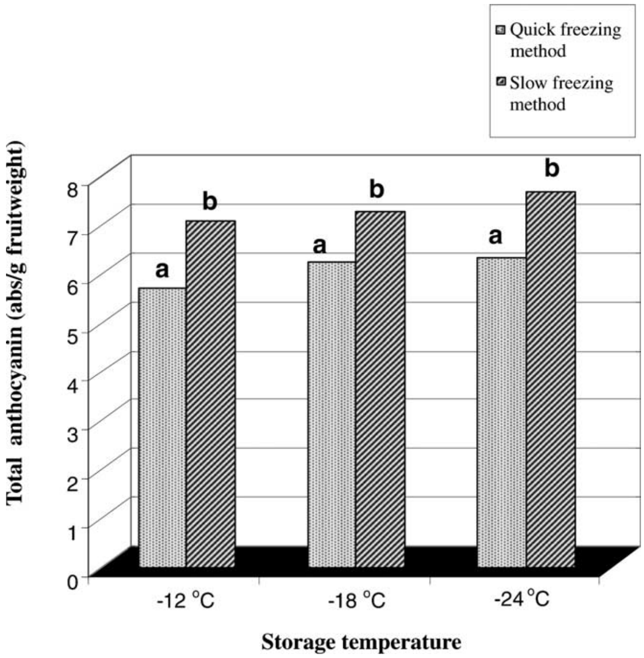

Fig. 6. The effect of freezing method and storage temperature on anthocyanin content.

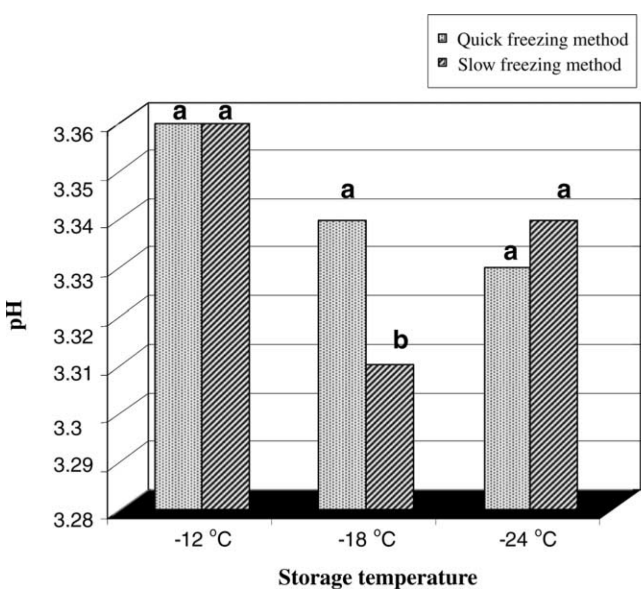

Fig. 7. The effect of freezing method and storage temperature on pH averages.

method, that the decrease of ascorbic acid was greater than with quick freezing, which may be due to the strawberry varieties used in the different experiments. Anthocyanin contents showed significant differences at all temperatures and between the two freezing methods (Fig. 6 and Table 2). This result was similar to that of Urbany and Horti (1992), who reported that, in quick freezing, the food colourant changed. This change was probably due to replacement of anthocyanin pigment in quick freezing. The effects of freezing methods on pH showed significant difference only at −18 °C and at a suitable pH level in both methods (Fig. 7).

Table 3 shows the analysis of variance for three factors: storage temperature, storage time and freezing method and their mutual effects on strawberry characteristics (ascorbic acid content, total anthocyanin, acidity and pH). The individual effects of these factors on strawberry characteristics were statistically significant and have been explained. Differences in: kind, size and surface of ice crystals, favourability of reaction in the partially frozen state and decrease of dielectric constant or increase of proton mobility, that accompanies formation of ice, may contribute to this explanation (Thomson & Fennema, 1971). The combined effects on ascorbic acid and total anthocyanin were statistically significant, but combined effects on acidity and pH were not great.

3.5. Sensory evaluation

The sensory evaluation results showed that the effect of freezing method on desirability after storage (with the exception of texture) was not important while, at −12 °C desirability and quality of frozen strawberry decreased (Fig. 8). Also, samples stored at −18 and −24 °C maintained the highest degree of quality based on colour, texture, flavour and wholeness; the sample maintained at −12 °C was not acceptable (Fig. 9).

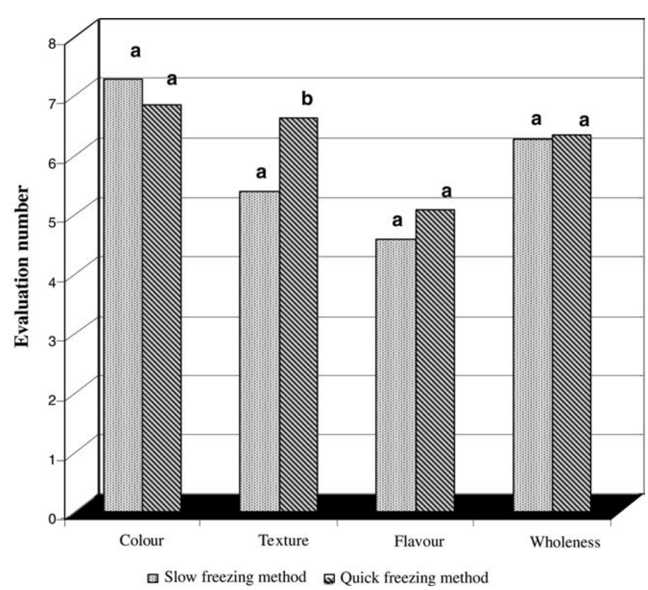

Fig. 8. The sensory evaluation results in various freezing methods after three months of storage.

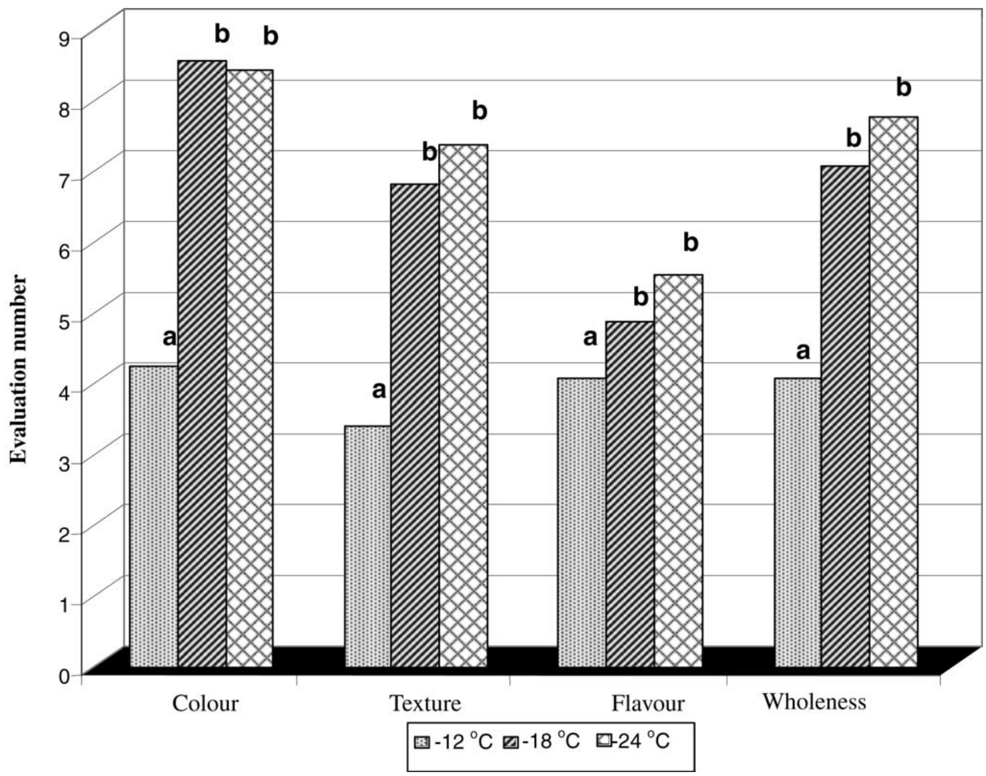

Fig. 9. The sensory evaluation results at various storage temperatures after three months of storage.

4. Conclusions

The individual effects of storage temperature, time and freezing method on strawberry characteristics and also their combined effects on ascorbic acid and total anthocyanin contents were statistically significant. But their mutual effects on acidity and pH were not great. Generally, the results of this research showed that most changes in quality of frozen strawberry during storage period centered on ascorbic acid and anthocyanin contents and their decrease at −12 °C was considerable. Frozen strawberries at other storage temperatures (−18, −24 °C) were clearly acceptable to consumers. Therefore, for short time storage of strawberry (three months), −18 °C (for lower expense of energy) was selected as the optimum storage temperature. On the other hand, the results showed that freezing was not effective for a desirable of colour, flavour and wholeness of frozen strawberry. Therefore, the temperature and freezing method for frozen strawberry production should be selected according to the consumer's interest. Finally, a comparison of some characteristics of Iranian and other strawberry varieties, without any interpretation, is presented in Table 4.

Table 4
Comparison of some characteristics of Iranian and other strawberry varieties

Variety of strawberry	Acid ascorbic (mg/100 g)	Anthocyanin (abs/gfw[a])	Acidity (%)	pH	Bx
Kordestan	2.52	9	25.1	28.3	5.8
Cardinal	8.32	4.24	81.0	41.3	9.5
Sunrise	4.32	8	82.0	37.3	5.5
A-5344 (Arkansas × Cardinal)	34	3.7	85.1	4.3	9.6
Benton (ripe)	2.40	7.32	127 (meq/100 g)	33.3	8.7
(Super ripe)	39	8.58	115	48.3	4.1
Totem (ripe)	8.43	3.50	119 (meq/100 g)	44.3	6.7
(Super ripe)	42	6.80	111	57.3	7.8

[a] Absorbance/gramme fruit weight.

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