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Studies on Commercially Canned Juices Produced Locally in Saudi Arabia: Part 2—Physicochemical, Organoleptic and Microbiological Assessment

E. H. Ewaidah

Food Science Department, College of Agriculture, King Saud University, PO Box 2460, Riyadh 11451, Saudi Arabia

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ABSTRACT

Single-strength canned orange and tomato juices (SSOJ and SSTJ) were obtained from a commercial canning plant in Saudi Arabia and were stored at controlled temperatures of 5, 24 and 42°C and under ambient warehouse conditions (average 33°C) for a 12-month period. Changes during storage in physicochemical (ascorbic acid, sucrose, reducing sugars, acidity, pH and vacuum), microbial, and sensory characteristics were studied to determine the effect of storage time and storage temperatures on the quality. Losses in vitamin C content of orange and tomato juices stored for 12 months in the warehouse under Saudi Arabian conditions were 37·7% and 34·0%, respectively. The decrease in ascorbic acid, sucrose and vacuum and increase in reducing sugars were linearly related to the storage time. The increase in the reducing sugars was due to the hydrolysis of the sucrose under these conditions. Based on the results of sensory evaluation on month 12 of storage, panellists were able to detect significant changes in quality attributes among samples stored at different temperatures. The overall acceptability of the orange juice stored at the warehouse temperature was rated as 'dislike slightly' and tomato juice stored under the same conditions was rated as 'neither like nor dislike', on a 9-point hedonic scale. Microbial analysis of the two types of juices revealed the absence of aerobic plate counts, coliforms, sporeformers and yeasts and moulds either on the initial analysis (month 1) or on month 12 of storage at the four different temperatures.

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INTRODUCTION

This work complements a previous study of tin and iron contents during one year of storage of canned single-strength orange and tomato juices produced in the largest commercial plant in Saudi Arabia (Ewaidah, 1987).

In recent years the local manufacturing of canned juices in Saudi Arabia has increased steadily. Juices are stored in warehouses and groceries for extended periods of several months, and yet no study has been conducted regarding the effect of the storage conditions (temperature–time) on the quality characteristics of canned juices under Saudi Arabian climate conditions. The quality of the canned juices is a function of the physicochemical properties (acidity, pH, total soluble solids (TSS), sugars, colour, viscosity, vacuum, vitamin C), microbiological and organoleptic characteristics. Many studies have shown that quality characteristics of canned fruit juices can be affected during the storage period; for example, developing of off-flavour in orange juice (Aharoni & Houck, 1982; Tatum *et al.*, 1975), browning and loss in vitamin C of single-strength orange juice (Trammell *et al.*, 1986), decrease in vitamin C, Hunter colour value and taste panel scores of orange juice (Marcy *et al.*, 1984), loss in total free amino acids of apple juice (Babsky *et al.*, 1986) and degradation in the colour of grape juice (Montgomery *et al.*, 1982).

The aim of this study was to evaluate the effect of storage temperature and storage time on the chemical, physical, microbial and sensory characteristics of canned orange and tomato juices produced in the largest commercial plant in Saudi Arabia in order to make recommendations with regard to the most suitable storage conditions for canned juices.

MATERIALS AND METHODS

Sampling

This study was conducted during September 1985–September 1986. Canned single-strength orange and tomato juices from concentrates packed in tin cans, were obtained from the largest commercial plant in Saudi Arabia. Samples were collected in three different production periods and were coded accordingly. Three different code lots for each type of canned juice were collected with a total of 12 cartons for each type of juice. Thus 24 cartons (each containing forty-eight 6 oz cans) were obtained from two types of juice. Samples were kept in one of the three temperature-controlled rooms for one year: $5 \pm 1°C$; $24 \pm 1°C$ and $42 \pm 1°C$. In addition, a fourth storage treatment was undertaken where juices were kept under fluctuating ambient temperature—warehousing conditions, where temperatures ranged between

20 and 43°C during one year's storage (average warehouse temperature was 33°C).

For analysis, six cans were drawn randomly from each of the three different code lots at monthly intervals for one year; the 18 cans for each temperature condition were thoroughly mixed to form a composite sample for each juice.

Chemical and physical analyses

Sugars were determined by the Lane and Eynon Volumetric method described in the AOAC (1980). The acidity was determined by titrating the samples with 0·1N NaOH and was expressed as per cent citric acid according to AOAC (1980) procedures. Also, AOAC (1980) procedures were used for the determination of vitamin C.

pH was measured using a pH digital meter (Jenwey, Model PHM 10) standardised with pH 2 buffer and pH 7 buffer. Vacuum measurements were made with a Flip Vacuum Gauge graduated from 0–30 in Hg.

Sensory evaluation

Sensory evaluation was carried out on the orange and tomato juices after 12 months of storage at 5, 24, 33 and 42°C. The colour, flavour and overall acceptability of the samples were rated on a 9 point hedonic scale in which 9 = like extremely and 1 = dislike extremely (Larmond, 1970). Assessments were carried out by nineteen experienced panellists selected from the Food Science Department Staff. Juice samples were placed in individual white plastic containers, coded with a three-digit randomised number and served in a randomised order for evaluation. The panellists were provided with water (20°C) for mouth rinsing between samples and judged the samples in a room under diffusion of light at room temperature. Judges were asked to evaluate four samples in each session.

Microbial analyses

The initial microbial analysis was conducted on the first month of the manufacturing date and the second analysis on the last month of the expiry date. All four types of juice were subjected to the following microbial analysis according to the procedures described in the Compendium of Methods for the Microbiological Examination of Foods (APHA, 1987).

(1) Total Plate Count	(TGEA, 32 C/48 h)
(2) Total Coliforms	(VRB, 37 C/24 h)
(3) Yeasts and Molds	(APDA, 25 C/5 days)
(4) Sporeformers	(TGEA, 32 C/48 h)

Statistical analysis

Statistical analysis was performed for the two-factor experiment as outlined by Steel & Torrie (1980). Both factors (temperature, time) were considered fixed and the interaction between the two factors was used as the error term.

As the objective of the present investigation was to study the response of the different quality characteristics (Y) to storage periods under different temperatures, the following quadratic regression model was used.

$$Y = a + b_1X_1 + b_{11}X_1^2$$

where Y = quality characteristics; a = intercept; b_1 = linear regression coefficient; b_{11} = quadratic regression coefficient and X_1 = storage period in months (time).

The significance of the regression coefficient was tested using the remainder mean square. As the quadratic coefficient was not significant for all the characteristics under test, only the linear regression model was considered (Steel & Torrie, 1980).

Sensory data were subjected to analysis of variance (Steel & Torrie, 1980) and significant differences among the means were determined using Duncan's New Multiple Range Test (DMRT). The analysis was carried out using SAS computer programs.

RESULTS AND DISCUSSION

Physical and chemical characteristics

Figure 1 shows the level of vitamin C in canned orange juices as a function of storage temperature and storage time.

Results show that, as the storage time proceeded, the vitamin C contents of juices stored at 5°C, 24°C, 33°C and 42°C were gradually decreased. Also, the loss in vitamin C content increased with increasing storage temperature. For example, after 12 months of storage at 5°C, 24°C, 33°C and 42°C, the losses in vitamin C were 10·4% 15·8%, 37·7% and 71·6%, respectively. Marcy *et al.* (1984) reported that a significant ($P < 0{\cdot}01$) decrease was found in ascorbic acid (7 mg/100 ml) of orange concentrate after 12 months of storage at 4·4°C. Statistical analysis indicated that storage of juice at 42°C caused a significant decrease ($P < 0{\cdot}05$) in vitamin C level compared with other storage temperatures. Statistical analysis using regression also showed that there was a significant decrease in vitamin C content during one year of storage at the four different temperatures. The rates of decreases were 0·59, 0·87, 2·22 and 3·98 mg/month/100 g juice (Table 1) for juices stored at 5, 24, 33 and 42°C, respectively, up to 12 months. Kanner *et al.* (1982) reported that

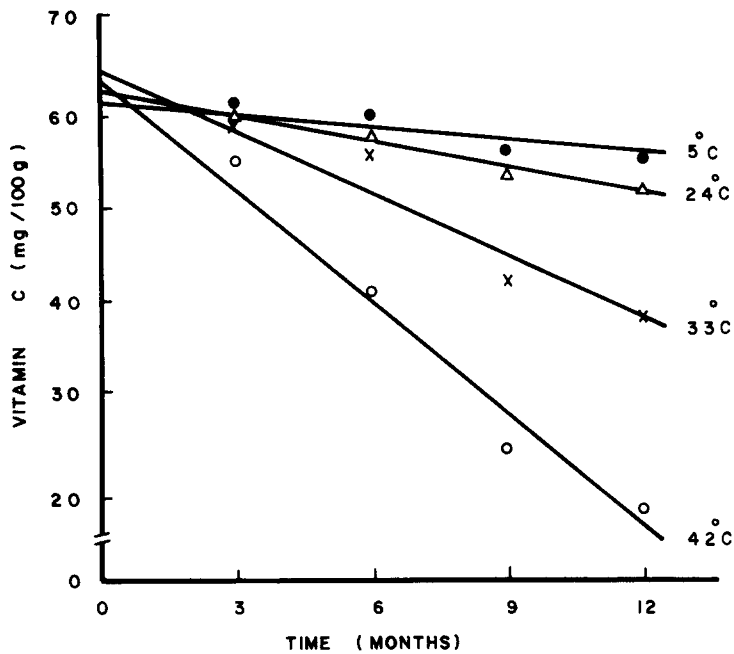

Fig. 1. Effect of storage temperature and time on vitamin C concentration of orange juice.

TABLE 1
Linear Regression Coefficient per Month and Mean of Quality Factors of Orange and Tomato Juices During One Year of Storage at Different Temperatures

Quality factor	*Statistics*	*Storage temperature*			
		5°C	*24°C*	*33°C*	*42°C*
Vitamin C	L	−0·590*	−0·876**	−2·220*	−3·980**
	M	58·55[a]	56·86[a]	51·45[a]	39·53[b]
Sucrose	L	−0·050*	−0·130*	−0·373*	−0·384[LND]
	M	4·105[a]	3·465[ab]	2·093[bc]	1·153[c]
Reducing sugars	L	0·082[ns]	0·231[ns]	0·428[ns]	0·468*
	M	4·370[b]	5·175[b]	6·478[ab]	7·698[a]
Acidity	L	−0·045[ns]	−0·043[ns]	−0·041[ns]	−0·041[ns]
	M	0·803[b]	0·813[ab]	0·823[a]	0·825[a]
pH	L	−0·007[ns]	−0·003[ns]	−0·004[ns]	−0·003[ns]
	M	3·568[a]	3·585[a]	3·593[a]	3·593[a]
Vacuum	L	0·067[ns]	−0·091[ns]	−0·336*	0·695*
	M	18·44[a]	17·79[a]	16·52[ab]	14·27[b]

L = Linear regression, M = Mean.
* and ** = Significant effect at 0·05 and 0·01 levels of probability, respectively.
ns = No significant effect. LND = Linear regression is not adequate to describe the relation.
Means followed by the same letter are not significantly different at the 0·05 level of probability.

the rates of degradation of vitamin C for the first 100 days were 0·24 and 0·70 mg/week/kg in orange juice of 11° Brix, stored at 17 and 25°C, respectively.

Figure 2 shows the sucrose content of canned orange juice during storage up to 12 months at various temperatures. There was a marked decrease in the sucrose level during storage time. This decrease in the sucrose content was due to conversion to reducing sugars. Also, on month 12 of storage at 33°C and 42°C, no sucrose was detected in any of the juice samples, while the juices stored at 5°C and 24°C still contained a marked quantity of the sucrose. That means the high storage temperatures (42°C and 33°C) facilitated the conversion rate of sucrose to reducing sugars. Glasstone (1946) reported that the rate of sucrose hydrolysis is a function of reactants, temperature and acid-catalyst concentration. Results obtained in this study are in agreement with those obtained by Babsky *et al.* (1986) who reported hydrolysis of sucrose in apple juice concentrate after 111 days of storage at 37°C. Statistical analysis, using regression, revealed that, during one year

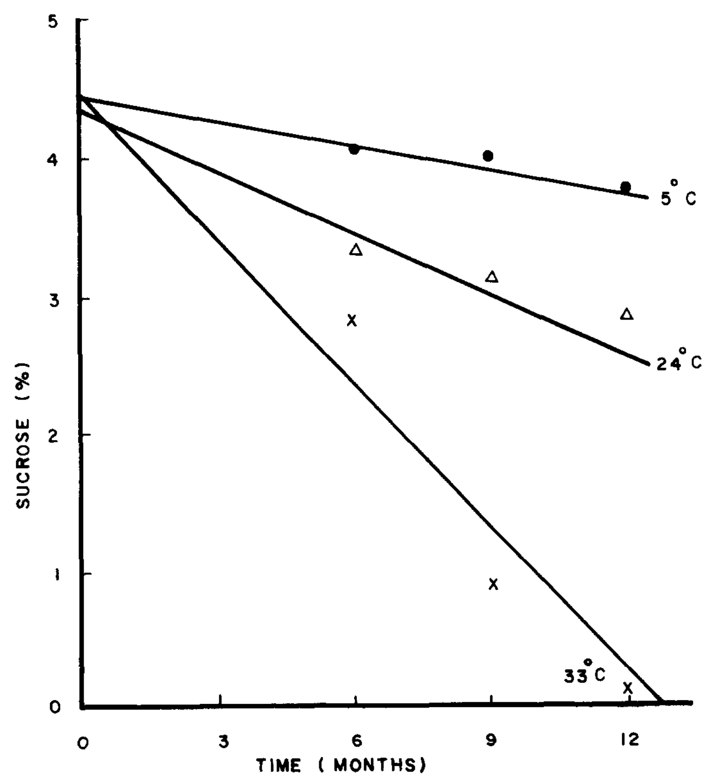

Fig. 2. Effect of storage temperature and time on sucrose concentration of orange juice (at 42°C linear regression is not adequate to describe the relationship).

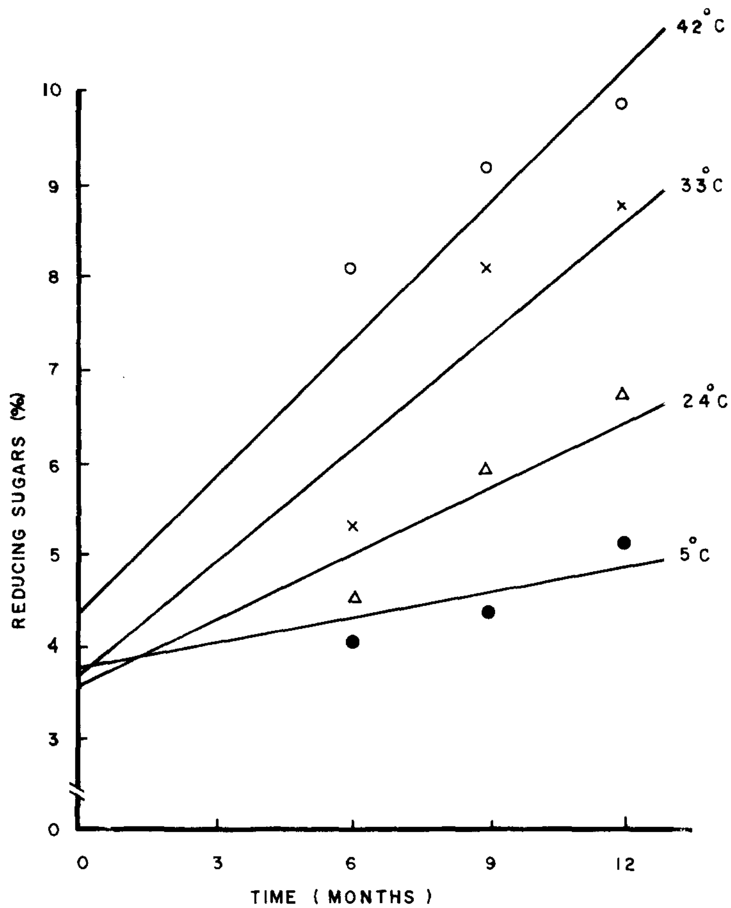

Fig. 3. Effect of storage temperature and time on reducing sugars concentration of orange juice.

storage at 5, 24, 33 and 42°C, the rates of the sucrose decreases were 0·05%, 0·13%, 0·37% and 0·38% for each month, respectively (Table 1).

Figure 3 shows the reducing sugars of canned orange juice over 12 months of storage at various temperatures. There is a marked increase in the reducing sugar levels of all the samples stored at 5°C, 24°C, 33°C and 42°C. The reducing sugar levels of the juices stored at 5°C and 24°C were lower than those of the juices stored at 33°C and 42°C on month 12 of storage. For example, the reducing sugar levels of juices on month 12 of treatment were 5·12% and 6·78% for juices stored at 5°C and 24°C, respectively, but the reducing sugar contents of juices stored at 33°C and 42°C were 8·74% and 9·39%, respectively. The increase in the reducing sugar contents was due to the conversion of sucrose to reducing sugars. These results reveal that the rate of conversion of sucrose to reducing sugar was affected by both storage temperature and storage time. Statistical analysis (regression) showed that the increase in reducing sugars during 12 months of storage at 42°C was significant ($P < 0{\cdot}05$) and the rate of this increase was 0·47% for each month (Table 1).

Figure 4 shows the effect of storage time and storage temperatures on the vacuum inside the orange juice cans. When juices were stored at 5°C and 25°C, the vacuum values decreased slightly during the storage period up to 12 months. However, significant ($P < 0{\cdot}05$) gradual decreases in the vacuums were observed during 12 months' storage of the orange juices at 33°C and 42°C. The rates of decrease in the vacuums were 0·34 and 0·70 in Hg/month during the one year storage period for juices stored at 33°C and those stored at 42°C, respectively, as shown from the regression statistical analysis in Table 1.

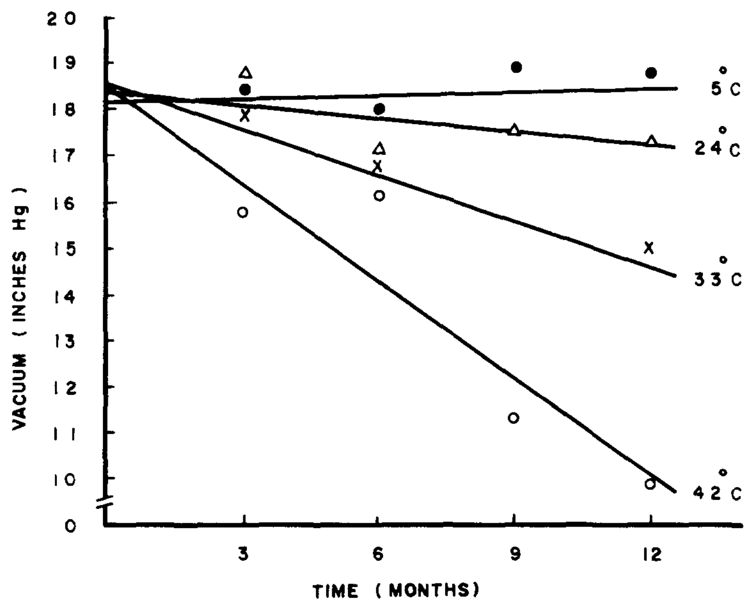

Fig. 4. Effect of storage temperature and time on can vacuum in orange juice.

Similar results were reported by Mahadeviah *et al.* (1976) who found a gradual decrease in vacuum of canned orange juice during storage at 37°C up to 12 months.

The acidity of orange juice as a function of storage temperature and storage time is shown in Table 1. In spite of no significant changes ($P < 0{\cdot}05$) in acidity during a one year storage period for all the juices stored at the various temperatures, slight decreases were observed. This decrease could be partly due to the copolymerisation of organic acids with products of the browning reactions (Babsky *et al.*, 1986). In addition, the organic acids can react with reducing sugars to form brown pigments (Lewis *et al.*, 1949). Montgomery *et al.* (1982) reported that there was a slight decrease in titratable acidity of grape juice during storage at $-1°C$ for 261 days. With respect to the effect of storage temperature, a significant difference ($P < 0{\cdot}05$) was found between the juices stored at 5°C and those stored at 42°C in their acid contents.

Table 1 shows the pH values of canned orange juice stored at different temperatures for a one year period. The pH values of orange juices did not vary during storage at 5°C, 24°C, 33°C and 42°C during a one year period. Also, statistical analysis showed that storage temperatures did not cause any significant differences ($P < 0{\cdot}05$) in the pH value.

Figure 5 shows that the vitamin C content of tomato juices decreased as the storage time and storage temperature increased. For example, the vitamin C losses of tomato juices were 15·2, 17·5, 34·0 and 52·1 mg/100 g juice in month 12 of storage at 5, 24, 33 and 42°C, respectively. A significant difference ($P < 0{\cdot}05$) in vitamin C level of juice stored at 24°C and that stored at 33 or 42°C was found (Table 2). Statistical analysis using regression indicated that the rates of vitamin C decrease per month were 0·73, 0·75, 1·75 and 2·53 mg/100 g juice stored at 5, 24, 33 and 42°C, respectively (Table 2). Lee *et al.* (1977) reported that the rate of ascorbic acid destruction in tomato juice increased with increasing storage temperature, and the activation energy (E_a) for anaerobic destruction was 3·3 kcal/mole at pH 4·06.

Figure 6 indicates that, as the storage period of canned tomato juices proceeds, sucrose content decreases. This result was due to the hydrolysis of

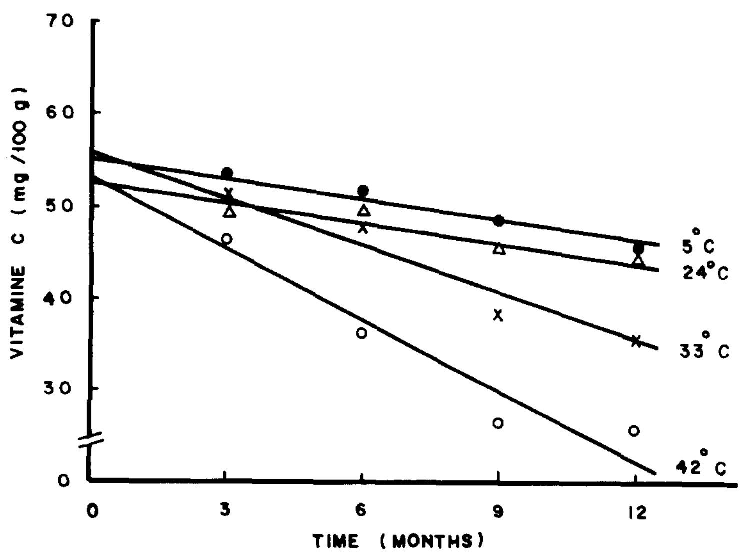

Fig. 5. Effect of storage temperature and time on vitamin C concentration of tomato juice.

TABLE 2
Linear Regression Coefficient per Month and Mean of Quality Factors of Tomato Juices During One Year of Storage at Different Temperatures

Quality factor	*Statistics*	*Storage temperature*			
		5°C	*24°C*	*33°C*	*42°C*
Vitamin C	L	−0727^{ns}	−0·752**	−1·670*	−2·533**
	M	50·74^{a}	58·42^{a}	45·77^{a}	37·79^{b}
Sucrose	L	−0·055^{ns}	−0·061*	−0·084**	−0·089^{LND}
	M	0·630^{a}	0·539^{ab}	0·338^{ab}	0·233^{b}
Reducing sugars	L	0·087^{ns}	0·102*	0·112**	0·125**
	M	1·745^{b}	1·908^{b}	2·038^{ab}	2·253^{a}
Acidity	L	−0·043*	−0·043*	−0·041*	−0·041*
	M	0·465^{b}	0·468^{b}	0·475^{ab}	0·483^{a}
pH	L	−0·003^{ns}	−0·022^{ns}	−0·022^{ns}	−0·020^{ns}
	M	3·728^{a}	3·635^{a}	3·635^{a}	3·623^{a}
Vacuum	L	−0·025^{ns}	−0·125^{ns}	−0·261*	−0·521**
	M	17·95^{a}	17·53^{a}	17·00^{a}	15·30^{b}

L = Linear regression, M = Mean.
* and ** = Significant effect at 0·05 and 0·01 levels of probability, respectively.
ns = No significant effect. LND = Linear regression is not adequate to describe the relation.
Means followed by the same letter are not significantly different at the 0·05 level of probability.

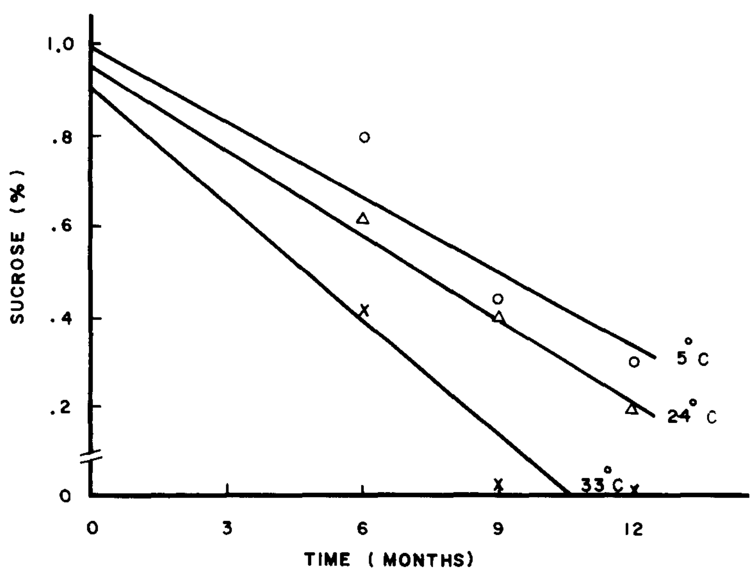

Fig. 6. Effect of storage temperature and time on sucrose concentration of tomato juice (at 42°C linear regression is not adequate to describe the relationship).

sucrose. Also, the rate of hydrolysis increases with increasing storage temperature. For example, no sucrose was found in juices stored at 33 or 42°C after 6 and 9 months, respectively, while the juices stored at 5 and 24°C still contained sucrose until month 12 of the storage. Statistical analysis, using regression, showed that the rates of sucrose decrease per month were 0·055, 0·061, 0·084 and 0·089% for tomato juices stored at 5, 24, 33, 42°C, respectively (Table 2).

Per cent reducing sugars of tomato juices increased by increasing the storage time and storage temperature as shown in Fig. 7. The increase in

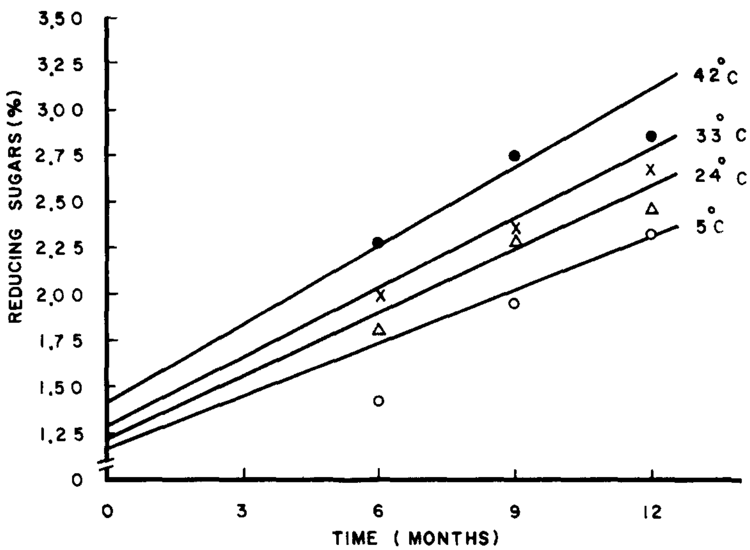

Fig. 7. Effect of storage temperature and time on reducing sugar concentration of tomato juice.

reducing sugar contents was due to the conversion of sucrose. Statistical analysis using regression (Table 2) indicated that the rates of increase in reducing sugars during 12 months of storage were 0·087, 0·102, 0·112 and 0·125% per month for juices stored at 5, 24, 33 and 42°C, respectively.

Vacuum inside the can decreased gradually during the storage period (12 months) for all the tomato juices stored at 5, 24, 33 and 42°C as shown in Fig. 8. The decrease was greater as the storage temperature increased. Statistical analysis showed that the rates of vacuum decrease were 0·025, 0·125, 0·261 and 0·521 in Hg/month during a one year storage period for juices stored at 5, 24, 33 and 42°C, respectively (Table 2).

Table 1 indicated that a significant ($P < 0·05$) decrease in acidity of tomato juices occurs during one year of storage at all temperatures. However, the steady pH (without any significant change) during the storage time could not be explained.

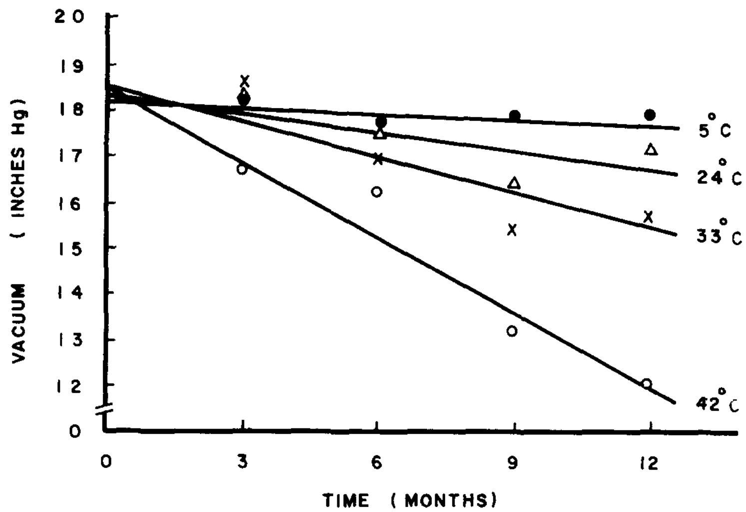

Fig. 8. Effect of storage temperature and time on can vacuum in tomato juice.

Sensory evaluation

Table 3 shows the mean hedonic rating for the colour, flavour and overall acceptability of the canned orange and tomato juices stored at 5°C, 24°C, 33°C and 42°C up to 12 months.

Colour

The mean rating for colour on month 12 of storage at various temperatures ranged from 2 (dislike very much) to 8 (like very much) for orange juice and from 6 (like slightly) to 8 (like very much) for tomato juice. At month 12, there was a significant difference ($P < 0.05$) in colour among the orange juice samples stored at the four temperature treatments. Also, data reveal that the samples stored at refrigerated temperature (5°C) rated the highest in colour, while those stored at 42°C rated the lowest.

With respect to tomato juice, there was no significant ($P < 0.05$) change in colour between the juices stored at 5°C and 24°C after 12 months. However, a significant difference existed between the juice stored at 5°C and that stored at 33°C or 42°C.

Flavour

The ratings by the judges for orange and tomato juices ranged from 2 (dislike very much) to 7 (like moderately) and 4 (dislike slightly) to 7 (like moderately), respectively.

There was a significant difference in flavour among the orange juice samples at month 12 of storage at 5°C, 24°C, 33°C and 42°C.

TABLE 3
Sensory Evaluation Ratings for Quality Attributes of Commercial Canned Orange and Tomato Juices at Month 12 of Storage at Various Temperatures

Juice type	*Storage temperature (°C)*	*Sensory attributes*		
		Colour	*Flavour*	*Overall acceptability*
		(------Panel Mean Ratings------)*		
Orange	5	8·26*a*	7·95*a*	8·05*a*
	24	7·63*b*	6·53*b*	7·05*b*
	33	5·00*b*	4·47*c*	4·42*c*
	42	2·37*c*	2·32*d*	2·21*d*
Tomato	5	8·00*a*	7·78*a*	7·94*a*
	24	7·37*ab*	6·37*b*	6·47*b*
	33	6·79*b*	5·58*bc*	5·89*b*
	42	6·79*b*	4·95*c*	5·32*b*

* Mean ratings for nineteen panellists. Mean ratings in the same column with the same letters are not significantly different at the 5% level. Rating scale: 1 = Dislike extremely, 5 = Neither like nor dislike, 9 = like extremely.
Analysis accomplished by DMRT.

Nagy & Randall (1973) reported that the flavour differences during storage of orange juice correlated closely with furfural formation. They found that organoleptic evaluation, during storage of commercially processed orange juice, showed that, when the level of furfural exceeded 55 mg/l of juice, the panellists observed a difference in flavour compared to controls at a significance of $P < 0.001$. In addition, Kanner *et al.* (1982) mentioned that the accumulation of furfural was greater in orange juice of 11° Brix than that in juice concentrate of 58° Brix, and this accumulation of furfural increased with increasing storage temperature.

There was no significant difference in the flavour between the tomato juices stored at room temperature (24°C) and tomato juices stored at the warehouse temperature (33°C).

Acceptability

The mean ratings by panellists of the overall acceptability, on month 12 of storage at various temperatures, were between 2 (dislike very much) and 8 (like very much) for orange juice and 5 (neither like nor dislike) and 7 (like moderately) for tomato juice.

These ratings revealed that the orange samples stored at 5°C, 24°C, 33°C and 42°C were significantly different ($P < 0.05$) from one another after 12 months of storage.

With respect to the effects of the various storage temperatures on the overall acceptability of tomato juices, results indicated a significant ($P < 0{\cdot}05$) difference between the samples stored at 5°C and the samples stored at 24°, 33° or 42°C at month 12.

Visual observation of the juice after 12 months of storage at 5, 24, 33 and 42°C showed that the lower the storage temperature, the less is the browning. Samples A (stored at 5°C, control) and B (stored at 24°C) were the lightest in colour of all samples. Sample D (stored at 42°C) was relatively the darkest in colour, while C (stored at 33°C) was slightly lighter than D. Thus the higher the storage temperature, the clearer the occurrence of the browning reactions. These results are in agreement with the results obtained by the panellists during the sensory evaluation of juice colour. Kanner *et al.* (1978) reported that low concentrated orange juice could be stored at 5 and 12°C for 24 and 18 months, respectively, without significant colour deterioration. Also, Kanner *et al.* (1982) found that the rate of browning was higher in the 11° Brix orange juice than that in 34 to 58° Brix orange juice concentrate after 200 days of storage at 17°C.

Visual observation revealed that samples C (stored at 33°C) and D (stored at 42°C) were slightly darker in colour than A (stored at 5°C, control) and B (stored at 33°C). A similar result was obtained in this study by the panellists as shown in Table 2.

Microbial analysis

The microbial quality analyses were conducted on the commercially canned orange and tomato juices stored at various temperatures up to 12 months. No microbial growths (aerobic plate counts, yeasts and moulds, coliforms, sporeformers) were detected initially (month 1) or in month 12 of storage at 5, 24, 33 and 42°C. This result is mainly due to the presence of sulphur dioxide (197·7 ppm for orange and 189 ppm for tomato, Ewaidah 1989), high acidity, and the effect of heat treatment during processing of cans. All the three previous factors are known to be inhibitors of microbial growth.

CONCLUSION

In conclusion, our results showed that storage of SSOJ or SSTJ (from concentrates) produced in Saudi Arabia at refrigerated temperature (5°C) or ambient temperature (24°C) could be recommended. However, storage of these juices for the prolonged period of 12 months in the warehouses under Saudi Arabian climate conditions developed undesirable off-flavour and darkening of the colour. Therefore, to avoid these undesirable changes another study should be conducted to determine the proper shelf time under fluctuating ambient temperature–warehousing conditions. This is essential since temperature ranges between a minimum of 20°C in winter and a maximum of 43°C in summer during one year of storage. SSOJ and SSTJ produced locally are of excellent microbial quality and this finding revealed that the canning process was proper.

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