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Kinetic modelling of vitamin C losses in fresh citrus juices under different storage conditions

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Abstract: The degradation kinetics of vitamin C in different citrus juice types (tangerine, grapefruit, orange and lime) were investigated during four hours storage at temperatures of 4 and 25°C under different storage conditions in terms of light and oxygen presence. The loss of vitamin C at each sample followed the first-order kinetic model. During storage, predicted half-life of vitamin C ranged from 137.586 to 467.486 min for tangerine; 105.444 to 203.100 min for grapefruit; 365.702 to 1044.668 min for orange and 540.076 to 722.016 min for lime juices. These results indicated that the highest and lowest retentions of vitamin C were observed in orange and grapefruit juices respectively during storage. Additionally, storage time, light penetration and oxygen presence were the most effective factors on vitamin C degradation while the storage temperature revealed no significant effect on the vitamin C content.

Key words: citrus juices, kinetic modelling, storage, vitamin C.

INTRODUCTION

Vitamin C or L-ascorbic acid is a water-soluble and highly unstable vitamin. The primary function is to prevent scurvy (Karim & Adebowale 2009). It is used as an additive in many foods due to its antioxidant potential. Thus, it increases their quality and technological features of foods as well as the nutritional value (Burdurlu et al. 2006). Nowadays, there is an increasing demand for nutritious food, and many attempts have been made to maximize the retention of nutrients in the storage as much as the processing. Vitamin C is often considered to be a nutrient quality indicator undergoing the processing and storage of foods, since it is seen that other nutrients are well preserved if vitamin C is well preserved (Sapei & Hwa 2014).

The vitamin C content in citrus juices is different from each other depending on processing conditions and raw material, such as 38 mg·100 g^{-1} for grapefruit juice, 46 mg·100 g^{-1} for lemon juice, 50 mg·100 g^{-1} for orange juice and 31 mg·100 g^{-1} for mandarin juice (Baysal et al. 1991). According to available biochemical, clinical, and epidemiological studies, the current recommended daily acceptance (RDA) for vitamin C is advised to be 100–120 mg·day^{-1} for obtaining cellular saturation and optimum risk reduction of stroke, heart diseases, and cancer in healthy individuals (Klimczak et al. 2007). Citrus juices are rich in vitamin C and seem to be quite effective in meeting the need for daily vitamin C. However, vitamin C of citrus juices is generally readily oxidized and therefore lost storage. There are many factors affecting this oxidation process, such as light exposure, level of dissolve oxygen, storage temperature, sugar and metal ions presence (Sapei & Hwa 2014). During storage, L-ascorbic acid oxidizes to dehydroascorbic acid (DHAA) (Cruz et al. 2008). This fact does not cause the loss of vitamin C because DHAA can be converted back to ascorbic acid (Kırca & Cemeroğlu 2001). But, DHAA is easily hydrolyzed to 2,3-diketogulonic acid (DKGA) due to it is highly unstable. DKGA has no biological activity (Wibowo et al. 2015). It has been found that these oxidation steps are particularly sensitive to availability of oxygen, long-term heat treatment in the presence of oxygen and exposure to light (Cruz et al. 2008).

The degradation of vitamin C during storage is the main problem of nutritional quality loss in fresh home-made citrus juices, which also determine their shelf life. This is of great importance for consumers to properly store the citrus juice under suitable conditions until they are consumed. Thus, maximum benefit from vitamin C content of citrus juices could be achieved by consumer (Sapei & Hwa 2014). It is necessary to determine the shelf life and proper storage conditions of citrus juices by investigating the degradation kinetics of vitamin C throughout storage. Kinetic models can be used to evaluate food quality objectively, quickly and economically. Kinetic modelling can also be utilized to estimate the effects of processing or storage on the critical quality parameters (Valdramidis et al. 2010). In the literature, it has been reported that degradation of vitamin C is a major deteriorative reaction occurring throughout storage of citrus juices. A number of researchers have investigated such a phenomenon that contains the effect of various factors on vitamin C degradation during the storage of different citrus juice types (Burdurlu et al. 2006, Klimczak et al. 2007, Al-Zubaidy & Khalil 2007, Abbasi & Niakousari 2008, Torres et al. 2011, Bacigalupi et al. 2013, Wibowo et al. 2015, Remini et al. 2015). However, as far as we know, no study has been yet conducted, which examine the concurrent effects of light, temperature, and oxygen on vitamin C content of different fresh home-made citrus juice varieties during storage. In the studies to date, it has been reported that vitamin C degradation can be explained by zero-, first- and second-order rate constants. This shows that the degradation of vitamin C is highly variable and depends on various factors such as the factors investigated and the type of product (Al-Zubaidy & Khalil 2007). The objective of this study is to develop an approach to modelling the degradation of vitamin C as a quality and nutritional index to determine the optimal storage conditions in fresh home-made citrus juice varieties. Therefore, the kinetic of vitamin C degradation was described quantitatively in order to evaluate the combined effect of temperature, light and oxygen within a constant period of storage time. Moreover, the half-time and D-value (storage time required to reduce the compound by 90%) of vitamin C in fresh home-made citrus juices were calculated. This approach will provide information on the storage conditions and time required to benefit from the vitamin C content of fresh home-made citrus juices at the maximum rate.

MATERIALS AND METHODS

Preparation of citrus juice samples

Tangerines (*Citrus reticulata*), grapefruits (*Citrus paradise*), oranges (*Citrus sinensis*) and limes (*Citrus aurantifolia*) were harvested in 2017 and purchased from a local fruit supplier (Tesco Kipa Mass Marketing Trade Logistics and Food Industry Inc., Izmir, Turkey). Fresh juices were obtained using a household table top citrus juice extractor (Arçelik, Istanbul, Turkey). Then, they were filtered by a double layer cheese cloth to remove their pulps and immediately analyzed.

In this study, there were six samples for each juice and each sample had different storage conditions. Sample 1 and Sample 4 were put in glass cups, while Sample 2 and Sample 5 were placed in capped glass bottles. Sample 3 and Sample 6 were put in capped glass bottles wrapped around with aluminum foil.

Sample 1, Sample 2 and Sample 3 were stored at room temperature of 25°C, whereas Sample 4, Sample 5 and Sample 6 were kept at refrigerated temperature of 4°C. All samples were stored for 4 hours and analyzed every 60 minutes. They were prepared in triplicate.

Determination of vitamin c

Firstly, DHAA was converted to ascorbic acid according to the method of Wibowo et al. (2015). Then, the vitamin C contents as the sum of ascorbic acid and DHAA were determined following the spectrophotometric analytical procedure outlined by Hışıl (2013). The standard curve was formed by ascorbic acid solutions (1-5 mg·100 mL^{-1}). The ascorbic acid solutions were prepared from stock ascorbic acid solution (0.1% (w/v)) containing pure ascorbic acid and oxalic acid solution (%0.4 (w/v)). The blank solution was a mixture of 1 part (in volume) water and 9 parts (in volume) 2,6-dichorophenol indophenol solution while the colored solution was prepared with 1 part (in volume) ascorbic acid solution/sample and 9 parts (in volume) 2,6-dichorophenol indophenol solution. Subsequently, the absorbance was measured at 518 nm using a UV-vis spectrophotometer (Optizen Pop, Mecasys Co., Ltd., Korea). Results were expressed as mg of ascorbic acid·100 mL^{-1} of juice.

Kinetic modelling

To determine the influence of storage conditions on the vitamin C content of citrus juices, vitamin C degradation was kinetically modeled as a function of the storage conditions such as time, temperature and packaging type. In this study, the zero- (Eq. (1)) and first-order (Eq. (2)) kinetic models were respectively applied, assuming previous related studies (Burdurlu et al. 2006, Al-Zubaidy & Khalil 2007, Abbasi & Niakousari 2008, Valdramidis et al. 2010, Torres et al. 2011, Remini et al. 2015).

$$C_t = C_0 - k_0 \cdot t \tag{1}$$

$$C_t = C_0 \exp(-k_1 \cdot t) \tag{2}$$

where C_t is the concentration of vitamin C (mg ascorbic acid·100 mL^{-1} of juice) at any given time (t), C_0 is the initial vitamin C concentration, k_0 and k_1 are the (apparent) reaction rate constants (min^{-1}), and t is the reaction time (min).

The reaction order and the relevant coefficients were determined through non-linear regression analyses by comparing the coefficient of determination (R^2) and root mean square error (RMSE) (Eq. (3)) amongst zero- and first-order kinetic models, respectively. The model with both higher value for R^2 and the lower value for RMSE shows a better fit with the results (İçier et al. 2014, Süfer et al. 2017).

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{N} (C_{\exp,i} - C_{pre,i})^2}{N}} \tag{3}$$

While the half-life ($t_{1/2}$) of vitamin C is the estimated time where the concentration of vitamin C is decreased by 50% from its initial value, the decimal reduction time (D-value) is the heating time where causes 90% degradation of vitamin C in a heated medium at constant temperature (Özkan et al. 2010, Sapei & Hwa 2014). Half-life and decimal reduction time of Vitamin C in each citrus juice were calculated according to the kinetic model (Eq. (1) or Eq. (2)) that has the best fit between model and experimental data.

Statistical analysis

All experiments were performed in duplicate. Mean values with standard deviation were calculated using standard statistical procedures. The data obtained were subjected to statistical evaluation, and non-linear regression analysis for kinetic data analysis performed with SPSS v.20.0

statistical package. To understand the mutual importance of the storage conditions for vitamin C degradation among each other, a multivariate data analysis (MANOVA) and Duncan's multiple range test were applied. In kinetic data analysis, among the relevant coefficients related to reaction order, RMSE was calculated by Microsoft Excel 2010 program, while R^2 was determined by the SPSS v.20.0 program. Estimated kinetic parameters were compared using one-way analysis of variance (ANOVA) and Duncan's multiple range test to determine differences among storage conditions. Evaluations were based on the $p<0.05$ significance level.

RESULTS AND DISCUSSION

The vitamin C content determined at the start of storage in fresh home-made citrus juices were 31.35 ± 0.72 mg·100 g^{-1} for tangerine juice, 45.75 ± 0.65 mg·100 g^{-1} for grapefruit juice, 31.37 ± 0.97 mg·100 g^{-1} for orange juice and 34.34 ± 1.21 mg·100 g^{-1} for lime juice. These values were close to those reported by other researchers (Klimczak et al. 2007, USDA 2018). Figure 1 demonstrates the percentages of vitamin C degradation calculated for fresh home-made citrus juices stored under different conditions assayed. During storage, vitamin C contents of all samples were decreased significantly with time at a rate depending on the storage temperature, light and oxygen presence ($p<0.05$). It was determined that the loss of vitamin C varied between 14.73% (Sample 6 for orange juice) and 79.36% (Sample 1 for grapefruit juice) depending on the type of sample and storage conditions ($p<0.05$). As storage time increases, vitamin C loss occurs by the more or less cumulative effects of storage conditions such as temperature, light, and oxygen presence. This is in agreement with the findings of Wibowo et al. (2015), Remini et al. (2015) and Abbasi & Niakousari (2008).

Temperature is one of the parameters that influence the content of vitamin C during storage. During the storage of fresh home-made citrus juices for 240 min, the change of temperature from 4°C to 25°C was not determined to have a significant effect on vitamin C loss of all samples depending on the time ($p>0.05$). This is thought to be due to storage at temperatures close to each other. This result in the study correlates with the finding of Kavousi (1997) who reported

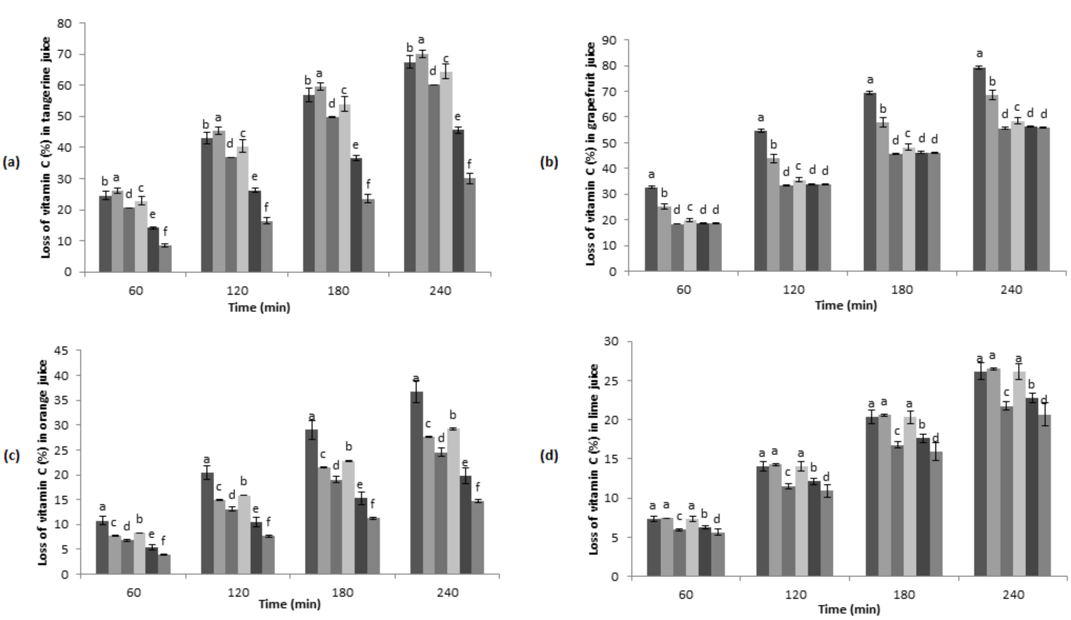

Figure 1. Comparison of vitamin C loss in fresh home-made citrus juices ((a) tangerine juice, (b) grapefruit juice, (c) orange juice, (d) lime juice) during storage [Sample 1 (■), Sample 2 (■), Sample 3 (■), Sample 4 (■), Sample 5 (■), Sample 6 (■)].

that the change of vitamin C in commercially pasteurized lime juice showed a low dependence on the temperature change between 4ºC and 25ºC. However, Burdurlu et al. (2006), Wibowo et al. (2015), and Remini et al. (2015) expressed that loss of vitamin C increased with the increasing storage temperature, while Zerdin et al. (2003) determined that the level of ascorbic acid in pasteurized orange juices stored at 4°C was higher than those stored at 25°C.

When the effect of light presence on the loss of vitamin C was investigated depending on the time, it was determined that the presence of light caused a significant decrease in vitamin C content of all samples except Sample 3, Sample 5 and Sample 6 for grape juice and Sample 1, Sample 2 and Sample 4 for lime juice ($p<0.05$). In Sample 3 and Sample 6 for each type of citrus juice, vitamin C was generally better preserved. The lower vitamin C losses in these samples are associated with lower light penetration from capped glass bottles wrapped with aluminum foil (Abbasi & Niakousari 2008). This finding correlates with the result of Abbasi & Niakousari (2008).

While Sample 1 and Sample 5 were in constant contact with oxygen due to storage in open glass cups, the other samples were stored in capped glass bottles. The highest time-dependent losses of vitamin C in orange and lime juices were observed in Sample 1 and Sample 5 ($p<0.05$). In Sample 1 and Sample 2 for tangerine and grapefruit juices, it was determined that the time-dependent vitamin C losses were higher than other samples ($p<0.05$). In the packed juice, oxygen can be present as dissolved oxygen, which is included during processing and preparation, as well as headspace oxygen. Addition, it can enter to the package from the environment by diffusion (Wibowo et al. 2015). Oxygen accelerates vitamin C oxidation, thereby increasing the tendency to further reaction of the carbonyl compounds formed via aldol condensation or reaction with amino groups to yield brown pigments that have no vitamin C activity (Rassis & Saguy 1995). Therefore, it is thought that one of the reasons of the decrease in vitamin C contents of the citrus juices is oxygen presence. Many researchers reported that oxygen was really important for the loss of vitamin C in the citrus juice (Rassis & Saguy 1995, Zerdin et al. 2003, Wibowo et al. 2015).

Multivariate data analysis was performed to determine the mutual importance of the investigated storage conditions for vitamin C loss. According to the result of analysis, statistically significant correlations were found between the type of fresh home-made citrus juice and the loss of vitamin C during storage ($p<0.05$). The vitamin C losses in fresh home-made citrus juices increased with the increasing storage time ($p<0.05$). Other storage conditions were evaluated statistically by taking into account the storage period as a whole. The type of fresh home-made citrus juice which lost most of its vitamin C throughout storage was grapefruit juice and followed by tangerine juice, orange juice and lime juice, respectively ($p<0.05$). It was also determined that when the effect of the packaging type on the loss of vitamin C was examined among the fresh home-made citrus juices stored with different packaging types, it was observed that the highest loss of vitamin C belonged to Sample 1 and followed by Sample 2, Sample 4, Sample 3, Sample 5 and Sample 6, respectively ($p<0.05$). When the effect of increase in temperature on the amount of vitamin C during storage was examined, statistically insignificant correlations were observed between temperature change and vitamin C loss of fresh home-made citrus juices ($p>0.05$). Ascorbic acid degrades by two ways as oxidative and non-oxidative mechanism. Temperature is one of the factors related to the non-oxidative degradation mechanism. The non-oxidative degradation rate of ascorbic acid is lower than the oxidative rate between 15ºC and 20ºC (Wallington et al. 2013). Therefore, it is an expected result that there is no significant effect of moderate temperatures ranging from 4ºC to 25ºC on vitamin C loss during storage. Furthermore, it was determined that packaging types (namely, the presence of oxygen and light), citrus juice types and storage time had mutual and concurrent significant effects on the loss of Vitamin C (p<0.05). Temperature was not observed as a significant function when the mutual and concurrent effects of all parameters were evaluated (p>0.05).

Kinetics of vitamin c degradation

During storage, the changes in vitamin C content of all fresh home-made citrus juices were fitted to zero- and first-order kinetic models given in Eq. (1) and Eq. (2), respectively. The best fit between model and experimental data was obtained from first-order kinetic models with higher R^2 values (0.750-0.995) and lower RMSE (0.409-4.667) (Table I), conversely, these coefficients were much worse with zero-order kinetic models (with R^2 range values of 0.655–0.891 and RMSE range values of 0.530–5.138) (not shown). Although the light presence and citrus juice type affect the loss of vitamin C, oxygen is

Table I. Kinetic parameters of the first-order kinetic model for vitamin C degradation in fresh home-made citrus juices during storage.

Samples	Types	The parameter of first-order kinetic model					
		k_1 (min^{-1})	C_0 (mg/100 mL)	R^2	RMSE	$t_{1/2}$ (min)	D-value (min)
Tangerine juice	Sample 1	-0.0047 ± 0.0003b,a	29.467 ± 0.813b,c	0.896	2.405	148.181 ± 8.854c	493.935 ± 29.513c
	Sample 2	-0.0050 ± 0.0002a	28.654 ± 0.203c	0.857	3.096	137.586 ± 4.365c	458.621 ± 14.551c
	Sample 3	-0.0038 ± 0.0000c	29.918 ± 0.421b,c	0.935	1.689	181.099 ± 0.544c	603.663 ± 1.814c
	Sample 4	-0.0043 ± 0.0003b,c	28.826 ± 0.257c	0.844	2.795	161.497 ± 10.714c	538.324 ± 35.713c
	Sample 5	-0.0025 ± 0.0001d	30.916 ± 0.329a,b	0.961	1.490	273.596 ± 7.715b	911.985 ± 25.718b
	Sample 6	-0.0015 ± 0.0001e	32.333 ± 0.205a	0.916	1.797	467.486 ± 31.542a	1558.286 ±105.141a
Grapefruit juice	Sample 1	-0.0066 ± 0.0001a	43.357 ± 0.026b	0.929	3.396	105.444 ± 1.788c	351.481 ± 5.960c
	Sample 2	-0.0048 ± 0.0002b	45.688 ± 0.514a	0.995	0.636	144.112 ± 7.396b	480.374 ± 24.654b
	Sample 3	-0.0034 ± 0.0000c	45.539 ± 0.938a	0.960	2.620	202.880 ± 1.907a	676.265 ± 6.358a
	Sample 4	-0.0037 ± 0.0001c	44.087 ± 0.388a,b	0.961	2.260	189.230 ± 6.244a	630.766 ± 20.813a
	Sample 5	-0.0034 ± 0.0000c	44.873 ± 0.272a,b	0.976	1.785	200.991 ± 1.981a	669.969 ± 6.605a
	Sample 6	-0.0034 ± 0.0000c	41.401 ± 0.484c	0.754	4.667	203.100 ± 1.309a	676.999 ± 4.364a
Orange juice	Sample 1	-0.0019 ± 0.0001a	33.038 ± 0.369a	0.750	2.648	365.702 ± 27.910d	1219.007 ± 1219.00d
	Sample 2	-0.0013 ± 0.0000b,c	31.560 ± 0.496a,b	0.958	0.579	514.220 ± 2.670c	1714.067 ± 8.9009c
	Sample 3	-0.0012 ± 0.0000c	30.963 ± 0.599b	0.924	0.923	592.025 ± 22.469c	1973.418 ± 74.8973c
	Sample 4	-0.0014 ± 0.0000b	31.346 ± 0.393b	0.992	1.622	481.039 ± 3.004c,d	1603.463 ± 10.0147c,d
	Sample 5	-0.0009 ± 0.0001d	31.262 ± 0.444b	0.947	0.409	757.893 ± 70.244b	2526.308 ± 234.1457b
	Sample 6	-0.0007 ± 0.0000e	30.884 ± 0.332b	0.899	0.452	1044.668 ± 28.319a	3482.228± 94.3977a
Lime juice	Sample 1	-0.0013 ± 0.0001a	32.565 ± 0.616a	0.808	1.590	549.264 ± 26.920b	1830.880 ± 89.7348b
	Sample 2	-0.0013 ± 0.0000a	33.116 ± 0.489a	0.908	1.338	540.076 ± 3.997b	1800.254 ± 13.3248b
	Sample 3	-0.0010 ± 0.0000b	33.632 ± 0.183a	0.878	0.843	678.462 ± 19.574a	2261.540 ± 65.2474a
	Sample 4	-0.0013 ± 0.0001a	33.917 ± 0.534a	0.942	1.257	549.258 ± 24.542b	1830.860 ± 81.8059b
	Sample 5	-0.0011 ± 0.0000b	32.701 ± 0.695a	0.808	1.266	643.637 ± 20.300a,b	2145.455 ± 67.6674a,b
	Sample 6	-0.0010 ± 0.0001b	33.377 ± 0.581a	0.910	0.765	722.016 ± 56.805a	2406.719 ± 189.3485a

mainly responsible for the loss of vitamin C. The vitamin C content of citrus juices decrease more rapidly at the beginning of storage due to the reaction of vitamin C with dissolved oxygen and then, the vitamin C degrades gradually (Sapei & Hwa 2014). The first-order kinetic model was used in most studies to describe the loss of vitamin C in citrus juices during storage, just as it is in this study (Burdurlu et al. 2006, Al-Zubaidy & Khalil 2007, Torres et al. 2011, Wibowo et al. 2015, Remini et al. 2015).

The vitamin C content decreased depending on time and packaging types for all juice type stored (Figure 2). The kinetic parameters k_1, C_0, D-value, $t_{1/2}$ together with their R_2 and RMSE values of the first-order kinetic models for vitamin C losses are given in Table I. All kinetic parameters were evaluated separately for each juice type and statistically important difference was determined among the samples evaluated (p<0.05). The k values that support the degradation ratios of vitamin C shown in Figure 1 ranged from 0.0015 to 0.0050 min^{-1} for tangerine juice, from 0.0034 to 0.0066 min^{-1} for grapefruit juice, from 0.0007 to 0.0019 min^{-1} for orange juice and from 0.0010 to 0.0013 min^{-1} for lime juice. The samples with the highest k values were Sample 1 and Sample 2 for tangerine juice, Sample 1 for grapefruit juice, Sample 1 for orange juice and Sample 1, Sample 2, Sample 4 for lime juice (p<0.05). The losses of vitamin C in these samples were faster and higher than in other samples. Samples with the highest $t_{1/2}$ according to the degradation rate of vitamin C were found as Sample 6 for tangerine juice, Sample 3, Sample 4, Sample 5, Sample 6 for grapefruit juice, Sample 6 for orange juice and Sample 3, Sample 5, Sample 6 for lime juice (p<0.05). It was observed that orange juice was the citrus juice type with the highest vitamin C retention (1044.668 min for $t_{1/2}$) and grapefruit juice was the lowest one (189.230 - 203.100 min for $t_{1/2}$). D-values of citrus juices varied from 458.621 to 1558.286 min for tangerine juice, from 351.481 to 676.999 min for grapefruit juice, from 1219.007 to 3482.228 min for orange juice and from 1800.254 to 2406.719 min for lime juice. The common point in all samples is that the degradation rates of citrus juices stored in glass cups are high and their vitamin C preservation are low whereas the degradation rates of citrus juices stored in capped glass bottles wrapped around with aluminum foil, are low and their vitamin C preservation are high.

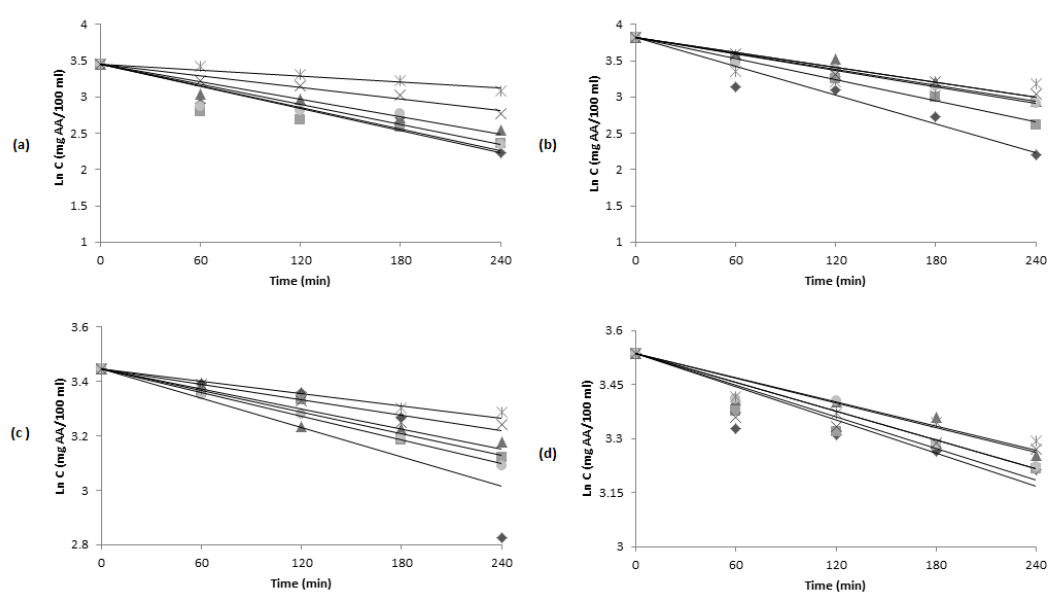

Figure 2. Degradation kinetics of vitamin C in the fresh home-made citrus juices ((a) tangerine juice, (b) grapefruit juice, (c) orange juice, (d) lime juice) during storage [Sample 1 (♦), Sample 2 (■), Sample 3 (▲), Sample 4 (●), Sample 5 (x), Sample 6 (ж)].

When all the samples stored for each fresh home-made citrus juice type were evaluated according to their kinetic parameters $t_{1/2}$ and D-values, the following information was obtained. The storage conditions did not have a significant effect on shelf life of vitamin C in tangerine juice stored at 25°C ($p>0.05$). But, a longer shelf life in 4ºC storage could be obtained by removing oxygen and light from the product, respectively.

Storage of grapefruit juice at both 4°C and 25°C with capped glass bottles wrapped around aluminum foil did not have a statistically significant effect on the shelf life of vitamin C ($p>0.05$) and provided the best protection. The worst protection of vitamin C was in the grapefruit juice stored at 4°C in capped glass bottles ($p<0.05$).

The best retention of vitamin C in orange juice was observed in the product with capped glass bottle wrapped around with aluminum foil at 4°C ($p<0.05$). The worst retention of that was obtained from the products stored in glass cups at 4°C and 25ºC. No significant difference was determined between them ($p>0.05$).

The products with the highest shelf life of vitamin C for lime juice were the juices in the capped glass bottles wrapped around with aluminum foil at both 4°C and 25°C and the juice in the capped glass bottle at 4°C. No statistically significant difference was found between these three products ($p>0.05$). There was also no significant difference among the other products ($p>0.05$) and shelf life of vitamin C was shorter than these.

CONCLUSIONS

This present study evaluated the effect of different storage conditions (time, temperature, light and oxygen presence) on the loss and kinetic behavior of vitamin C in the fresh home-made citrus juices. Vitamin C losses of citrus juices during storage were best explained by first-order kinetic model. Kinetic parameters such as a rate constant of degradation reaction, a half-life and decimal reduction time of vitamin C were determined for each sample. The length of storage period, light and oxygen presence were the most efficient factors in the degradation of vitamin C, while storage temperatures between 4°C and 25°C had no significant effect on vitamin C loss in the citrus juices during storage ($p>0.05$). Kinetic studies have shown that oxygen is the most important factor in vitamin C degradation. It should be preferred that fresh home-made citrus juices are stored primarily in an environment free from oxygen and then away from light. The shelf life of Vitamin C in the citrus juices can be extended by reducing the storage time and avoiding oxygen and light permeation through the packaging.

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