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Effect of ascorbic acid on the odours of cloudy apple juice

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Abstract

Ascorbic acid is used in apple juice as an antibrowning agent. This study investigated the effect of ascorbic acid (0.0–0.2% w/v) on the odours of cloudy apple juice using sensory evaluation and gas chromatography (GC). The increase in ascorbic acid concentration in the apple juice resulted in increases in green and unnatural odours and decreases in fresh, fruity and apple-like odours. In the GC determination, 23 volatile compounds were detected in apple juice. Aroma value, which showed the relative importance of volatile compounds, was used to elucidate the changes in odours of apple juice due to the addition of ascorbic acid. The aroma values of hexanal and *trans*-2-hexenal in the apple juice with 0.2% w/v ascorbic acid increased about 4 and 5-fold from those in the ascorbic acid-free apple juice, respectively. On the other hand, the aroma values of esters insignificantly changed in the apple juice with ascorbic acid. The increases in aroma values of aldehydes corresponded well with the increase in green odour in the apple juice with ascorbic acid.

Keywords: Ascorbic acid; Antibrowning agent; Cloudy apple juice; Odour

1. Introduction

Apple juice is one of the popular fruit juices widely marketed in the European countries, the United States, and also in Japan (Miller & Rice-Evans, 1997; Rao, Acree, Cooley, & Ennis, 1987; Zierler, Siegmund, & Pfannhauser, 2004). A great number of apples are harvested for processing to juice every year. The high commercial value of apple juice is ascribed to its pleasant sensory qualities such as colour, taste and odour (Hoehn, Gasser, Guggenbühl, & Künsch, 2003; Karlsen, Aaby, Sivertsen, Baardseth, & Ellekjær, 1999; Song, Gardner, Holland, & Beaudry, 1997; Stow, 1995).

In the present day, there are two major types of apple juice products available in the market, namely clarified and cloudy apple juices (Lozano, Drudis-Biscarri, & Ibarz-Ribas, 1994). Clarified apple juice has a typical amber-like hue with a little browning. On the contrary, cloudy apple juice, containing a high portion of pulp in suspension, is expected to have a yellowish or greenish colour. The cloudy apple juice has a growing share in the current market due to its sensory and nutritional qualities which are close to those of fresh product (İyidoğan & Bayındırlı, 2004; Özoğlu & Bayındırlı, 2002)

Enzymatic browning is an undesirable reaction leading to quality losses and thus a diminution of commercial value in horticultural products (Lea, 1995; Lee & Whitaker, 1995; Sapers & Douglas JR., 1987). Polyphenol oxidases (PPOs), metalloenzymes containing copper as a prosthetic group, are key enzymes of the browning (Bro & Heimdal, 1996; Piretti, Gallerani, & Brodnik, 1996). These enzymes are ubiquitous in plants, and particularly exist in high amount in apple, pear, litchi, mango, potato, and mushroom (Jiang, Duan, Joyce, Zhang, & Li, 2004; McEvily & Iyengar, 1992). The enzymatic browning can be briefly explained by two major reactions, that is an oxidation of phenolic substrates by PPOs to reactive *o*-quinones and a subsequent polymerization of the *o*-quinones to brown-coloured pigments (Amiot,

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Tacchini, Aubert, & Nicolas, 1992; Golan-Goldhirsh & Whitaker, 1984; Saper, 1993). These two reactions proceed very rapidly after the alteration of tissue structure. The most remarkable negative effect of enzymatic browning against the qualities of food products is well known as the deterioration of colour. Not only the discolouration, the enzymatic browning also impairs the nutritional and other sensory qualities including odour, taste and texture (Coseteng & Lee, 1987; Martinez & Whitaker, 1995;Severini, Baiano, Pilli, Romaniello, & Derossi, 2003).

For maintaining the qualities of food products, control of enzymatic browning is an important issue for the food industry. The methods widely used in controlling enzymatic browning, and their advantages/disadvantages are summarized as follows: (1) heat treatment (70–90 °C), effective and easy but adversely affects the sensory qualities (Chutintrasri & Noomhorm, in press; Severini et al., 2003); (2) control of pH ($\leqslant$4), convenient but deteriorates the food taste (Laurila, Kervinen, & Ahvenainen, 1998); (3) use of antibrowning agents, convenient and effective but adversely affects the sensory qualities (Martinez & Whitaker, 1995); (4) exclusion of oxygen (controlled/modified atmosphere, oxygen-impermeable film), safe but temporary and decreases the volatile production (Aaby, Haffner, & Skrede, 2002; Fellman, Rudell, Mattinson, & Mattheis, 2003; Le Tien, Vachon, Mateescu, & Lacroix, 2001; Peiyin & Margaret, 1998; Thybo, Christiansen, Kaack, & Petersen, 2006); (5) use of natural additives (honey, onion extract), safe but relatively ineffective (Kim, Kim, & Park, 2005; Oszmianski & Lee, 1990).

Among the aforementioned methods, the use of antibrowning agents has been the most common method of controlling enzymatic browning. The antibrowning agent is usually used either in the form of a single agent or in combination with other agents or other methods (Lee, Park, Lee, & Choi, 2003; Monsalve-Gonzalez, Barbosa-Cánovas, Cavalieri, McEvily, & Iyengar, 1993; Parpinello, Chinnici, Versari, & Riponi, 2002). In the past, sulfiting agents were used extensively because of their potent inhibitory effect on browning. However, the use thereof has been restricted by the Food and Drug Administration since 1986 due to their harmfulness to sensitive consumers (Langdon, 1987; Lee & Whitaker, 1996; Molnar-Perl & Friedman, 1990). Therefore, safer and practical antibrowning agents have been currently sought to use as substitutes for sulfiting agents. Among the non-sulfiting agents, ascorbic acid is the most popular since it is effective in controlling enzymatic browning and is safe for consumers. The action of ascorbic acid in the prevention of enzymatic browning is to reduce the intermediate *o*-quinones to the original phenolic compounds before they can undergo further reaction to form the pigments. However, the effectiveness of ascorbic acid in antibrowning is temporary. The enzymatic browning can re-generate after the ascorbic acid has been completely reduced to dehydroascorbic acid.

Recently, many studies have been devoted to the inhibitory effect of ascorbic acid on the enzymatic browning in several food products (Janovitz-Klapp, Richard, Goupy, & Nicolas, 1990; Sapers & Miller, 1992; Sapers et al., 1989; Son, Moon, & Lee, 2001). Since enzymatic browning plays an important role in the colour of foods, most studies have focused on the effect of ascorbic acid on the change in colour. However, the effect of ascorbic acid on the changes in other sensory qualities has been overlooked. One literature report indicated that the ascorbic acid at high concentration imposed an unpleasant taste on the apple slice (Laurila et al., 1998).

The cloudy apple juice is very susceptible to the enzymatic browning because the apple tissue is completely disrupted. In a previous paper, we reported changes in odours of cloudy apple juice due to enzymatic browning (Komthong, Katoh, Igura, & Shimoda, in press). In this study, we investigated the effect of ascorbic acid on the odours of cloudy apple juice using sensorial and instrumental analyses.

2. Materials and methods

2.1. Materials

Ripe apples of 'Jonagold' were purchased from a local food store and stored in a cold room at +4 °C inside sealed plastic bags until use. L-Ascorbic acid and sodium chloride (NaCl) obtained from Nacalai tesque, Kyoto, Japan were used as the antibrowning agents.

2.2. Sample preparation

Approximately 3 kg of apples were washed, cored and peeled. Apple juice was obtained by squeezing the prepared apples with a juicer (Stamina Juicer JC-4000W, Toshiba Co., Tokyo, Japan). These processes were performed under low temperature to avoid enzymatic browning. Excessive pulp and foam were removed from the juice by a 100-mesh filter. The juice samples (200 ml) were poured into flasks containing NaCl 2% w/v and ascorbic acid at different concentrations (0.0–0.2% w/v). The samples were stirred with a magnetic stirrer for about 2 min. The pH of all juice samples were then adjusted to 3.4 with 0.5 M hydrochloric acid. Finally, the flasks were capped and stood in a water bath at 25 ± 1 °C for 2 h. The reason of addition of NaCl to the juice samples was to prevent the enzymatic browning. Our previous paper reported the control of enzymatic browning of apple juice using 2% w/v NaCl without the colourimetric change at 25 °C for as long as 6 h (Komthong et al., in press). The juice sample containing the 2% NaCl without ascorbic acid was therefore used as a control. The entire procedure of sample preparation was repeated every time in the replications of sensorial and instrumental analyses.

2.3. Sensory evaluation

Quantitative descriptive analysis (Stone, Sidel, Oliver, Woolsey, & Singleton, 1974) was derived to evaluate the

effect of ascorbic acid on the odours of cloudy apple juice. Sensory panelists were selected according to Shimoda et al. (2003). The procedures of training panelists were described in detail in the previous paper (Komthong et al., in press). Briefly, the panelists were trained with simulated solutions of apple juice and real apple juices with/without ascorbic acid. The simulated solutions contained water and odour-active compounds of apple at different concentrations. The panelists received eight repetitions of the trainings in 4 weeks. After the panelists became skilled in the odour evaluation, the odour evaluation of cloudy apple juice was commenced.

The juice samples were prepared according to the method in Section 2.2 on the day of evaluation. After standing the juices in the water bath, the juice samples (50 ml) were poured into 100-ml brown glass bottles in order to mask the differences in colour. The juice samples were allowed to equilibrate at room temperature at 25 °C for 15 min before the odour evaluation. The juice samples with ascorbic acid at different concentrations were coded randomly and served together with the control (ascorbic acid 0%). The evaluation of juice odours was conducted in a lecture room where the panelists could have a private area for evaluation. The odour attributes used to profile the juice qualities were green, sweet, fresh, fruity, apple-like, sour and unnatural. Definitions of these odour attributes were orally explained in detail as given in Table 1. The panelists were asked to score the intensities of odour attributes to the juice samples after comparing them to the control as follows: −3, extremely weaker than control; −2, weaker than control; −1, relatively weaker than control; 0, same as control; +1, relatively stronger than control; +2, stronger than control; +3, extremely stronger than control. The odour evaluation was performed in four replications.

Statistical analysis of the sensory data was performed by one-way ANOVA. *P*-value at 0.05 was used to determine the significant differences in the intensities of each odour attribute. When significant, student's *t*-test was applied to determine what differences existed.

Table 1
Definition of odour attributes used in profiling of Jonagold apple juice

Attribute name	Definition
Green[a]	Associated with odour of freshly cut green grass (hexanol)
Sweet	Associated with a sweet odour (e.g., boiled or burnt sugar)
Fresh[b]	Associated with a fresh, new odour
Fruity[a]	Odour of fruit (e.g., pear, banana, peach (2-/3-methylbutanol))
Apple-like[b]	Odour of Jonagold apple
Sour[a]	Associated with a fresh, sour odour
Unnatural	Odour of untypical apple juice, undesirable odour

[a] As described in Karlsen et al. (1999).
[b] As described in Aaby et al. (2002).

2.4. Instrumental analysis

2.4.1. Extraction of volatile compounds

Liquid–liquid direct extraction method was adopted to extract volatile compounds in the apple juice. The juice sample (200 ml) with an internal standard of cyclohexanol (final concentration 2.5 mg/l) was put into a 500 ml-Erlenmeyer flask. The volatile compounds were extracted with a mixture of diethyl ether (50 ml) and pentane (50 ml). The juice sample with solvents was shaken periodically and left for 2 h at room temperature. The solvent fraction was then separated from the juice sample using a separating funnel. The solvent extract was dried over anhydrous sodium sulfate for 3 h and concentrated to about 0.3 ml. The volatile compounds in the concentrate were determined by a gas chromatograph (GC) as described in Section 2.4.2.

2.4.2. Volatile quantification and identification

For characterization of volatile odours, a technique of olfactometry was employed together with the GC in this study (Blank, 1996; Honma, Higashi, Shimoda, & Hayakawa, 2004). The human nose was used as the detector of volatile odours, while the flame ionization detector (FID) was used to quantify the volatile concentrations. One microlitre of the concentrate was introduced into a Shimadzu GC 14 B equipped with a DB-WAX column (30 m × 0.25 mm i.d., 0.25 μm film thickness; J&W Scientific, Folsom, CA). The conditions of GC were programmed as follows: oven temperature, 40 °C (2 min)–3 °C/min–230 °C (10 min); injection port, 230 °C; FID, 250 °C; helium carrier gas, 30 cm/s at sprit ratio 10:1. At the exit of the capillary column, the effluents were split 1:1 (by vol) into the sniffing port and the FID by deactivated fused silica capillaries (30 cm × 0.25 mm i.d.) and a Y-type effluent splitter. The odours of volatile compounds eluted from the sniffing port were characterized by two experienced judges. The characterization of volatile odours was performed in duplicate by each judge. On the other hand, the relative concentrations of volatile compounds were calculated by comparing peak areas of the compounds to that of the internal standard. The quantification of volatile concentrations was carried out in three replications.

Volatile identification was achieved on a GC (Hewlett–Packard 5890 Series II)–mass spectrometry (MS; Jeol Automass 50). The mass spectra were obtained by electron impact ionization at a voltage of 70 eV and ion source temperature of 200 °C. The GC conditions and capillary column were the same as those in the GC analysis. The identification of volatile compounds was based on the comparison of mass spectra by library matches (*Wiley/NBS Registry of Mass Spectral Data*). In addition, the detectable volatile compounds were confirmed by comparing their kovat indices to those of authentic commercial standards and data of Girard and Lau (1995) who studied the volatile compounds in Jonagold apples.

3. Results and discussion

3.1. Sensory evaluation

The effect of ascorbic acid on the odours of cloudy apple juice is shown in Fig. 1. The increase in ascorbic acid concentration in the apple juice resulted in the increase in green odour and the decreases in fresh, fruity and apple-like odours. The intensities of these odours were significantly different from those of the control at ascorbic acid concentration of 0.05% w/v. However, the intensities of fresh, fruity and apple-like odours slightly increased in the juice with 0.005% w/v ascorbic acid. Sensory panelists did not recognize the remarkable changes in sweet and sour odours. These two odours of apple juice were not affected by the addition of ascorbic acid. On the other hand, the unnatural odour steadily increased with the increase in ascorbic acid concentration. This might be attributable to the increase in green odour and the decreases in fresh, fruity and apple-like odours.

The changes in odours of apple juice showed the negative effect of ascorbic acid on the odours of apple juice. The addition of ascorbic acid at high concentration to the apple juice led to the deterioration of its odours, that is the increases in green and unnatural odours as well as the decreases in fresh, fruity and apple-like odours. The green odour which is the background odour of unripe apple was reported to be undesirable in the apple juice

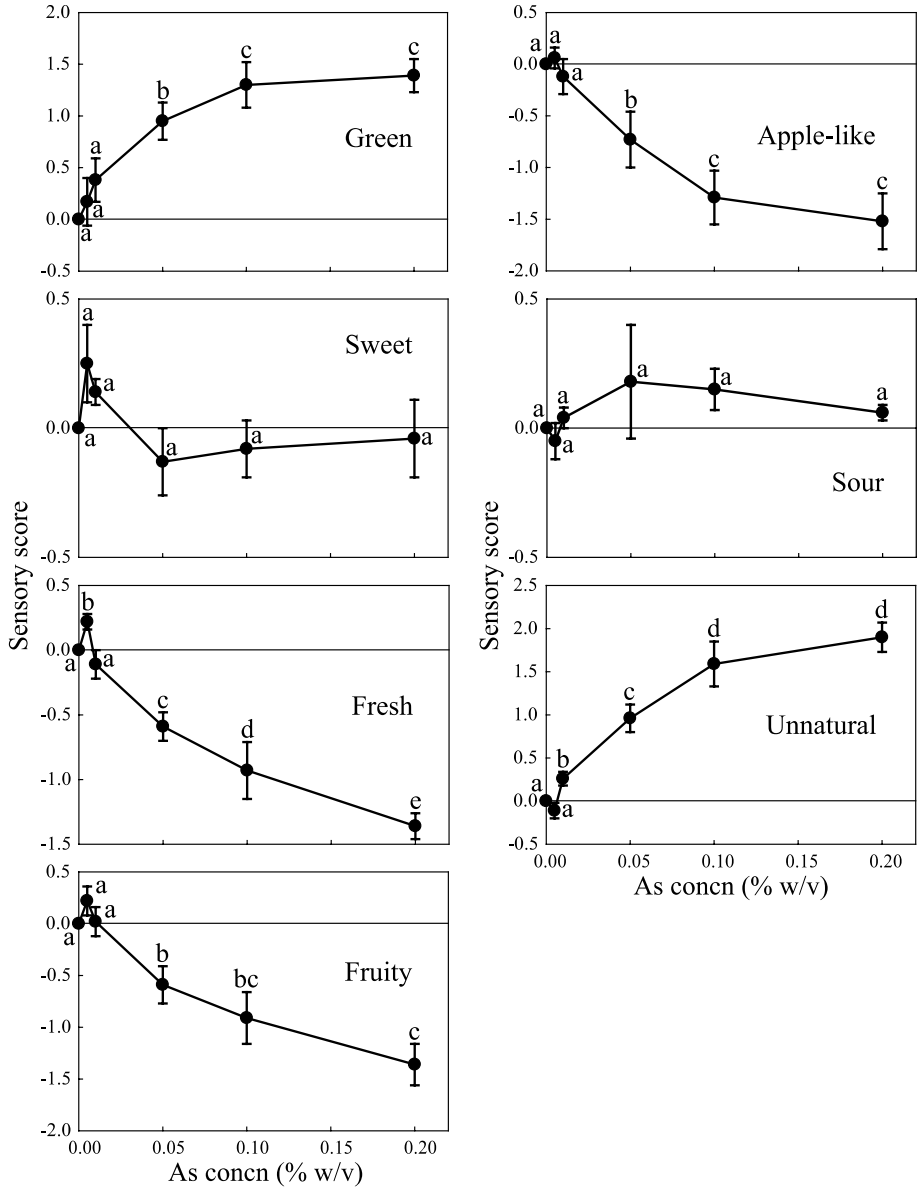

Fig. 1. Effect of ascorbic acid concentration (As concn) on the odours of cloudy apple juice. Juice samples were scored relative to control (As concn 0%) as follows: −3, extremely weaker; −2, weaker; −1, relatively weaker; 0, same; +1, relatively stronger; +2, stronger; +3, extremely stronger. Control was scored 0 in every odour attributes. Data and error bars show the means and standard errors of four replications, respectively. Means with different letters in the same attribute are significantly different at $P = 0.05$.

(Komthong et al., in press). In addition, Kato et al. (2003) and Shimoda et al. (2003), who studied the odours of squeezed and reconstituted apple juices, revealed that the preferable odours of apple juice were observed in the high levels of fresh and fruity odours and the low levels of green, burnt and heavy odours.

3.2. Instrumental analysis

3.2.1. Volatile compounds in apple juice

Volatile compounds in Jonagold apple juice and their odour properties are listed in Table 2. GC–olfactometry was described as the effective method for characterizing the odours of volatile compounds in the apple juice (Komthong, Hayakawa, Katoh, Igura, & Shimoda, in press; Plotto & McDaniel, 2001). Twenty three volatile compounds were detected by the MS and FID, only 15 compounds of which were characterized odours. The detectable volatile compounds could be classified into six groups, namely esters, aldehydes, alcohols, hydrocarbons, acid and phenol. The esters and alcohols which are the products of fatty acid metabolization were the major groups in the apple juice, accounting for 44% and 41% of total volatiles, respectively (Echeverría, Graell, López, & Lara, 2004; Song & Bangerth, 2003). In comparison with the esters and alcohols, the aldehydes were found at lower concentration. This might be due to the full ripeness of the apple used in this experiment. During ripening, the aldehydes are enzymatically reduced to alcohols and subsequently esterified with carboxylic acids (Girard & Lau, 1995).

Each group of volatile compound gave a typical odour characteristic to the apple juice. Esters were the

Table 2
Volatile compounds in Jonagold apple juice

Volatile name[a]	KI[b]	Odour property	Odour threshold[c] (mg l^{-1})	Concentration (mg l^{-1})[d]		Aroma value[g]	
				Control-juice[e]	Ascorbic acid-juice[f]	Control-juice[e]	Ascorbic acid-juice[f]
Ester							
Propyl acetate	973	Strong-sweet	2(1)	0.03 ± 0.01	0.04 ± 0.02	0.0	0.0
2-Methylpropyl acetate*	1024	Sweet, fresh	0.065(1)				
Ethyl butanoate	1041	Sweet, fruity	0.001(1)	0.17 ± 0.06	0.19 ± 0.05	170	190
Butyl acetate	1071	Sweet, fruity	0.066(1)	1.37 ± 0.15	1.42 ± 0.22	21	22
2-Methylbutyl acetate	1121	Fresh	0.011(1)	0.18 ± 0.05	0.17 ± 0.04	16	15
Pentyl acetate	1173	Fruity, fresh	0.043(1)	0.02 ± 0.01	0.03 ± 0.01	0.5	0.7
Butyl butanoate	1210	Fresh	0.1(1)	0.37 ± 0.31	0.43 ± 0.36	3.7	4.3
2-Methylbutyl butanoate	1253	Fresh		0.03 ± 0.03	0.04 ± 0.03		
Hexyl acetate	1273	Sweet, fruity	0.002(1)	4.34 ± 0.83	4.04 ± 0.69	2170	2020
Hexyl 2-methylbutanoate	1415	Pungent	0.022(2)	0.30 ± 0.05	0.30 ± 0.07	14	14
Hexyl hexanoate*	1620			0.03 ± 0.00	0.04 ± 0.01		
Aldehyde							
Hexanal	1080	Green, grassy	0.005(2)	0.07 ± 0.04	0.27 ± 0.06	14	54
trans-2-Hexenal	1215	Green, grassy	0.017(2)	0.16 ± 0.04	0.80 ± 0.08	9.4	47
Alcohol							
1-Butanol	1148	Light-fruity	0.5(1)	4.17 ± 2.29	5.87 ± 2.87	8.3	12
1-Pentanol	1238		4(1)	0.03 ± 0.01	0.03 ± 0.01	0.0	0.0
1-Hexanol	1356	Light-apple	0.5(1)	1.85 ± 1.39	2.10 ± 1.32	3.7	4.2
6-Methyl-5-hepten-2-ol	1455			0.07 ± 0.02	0.04 ± 0.01		
1-Octanol	1560		0.13(3)	0.04 ± 0.01	0.04 ± 0.01	0.3	0.3
3-Methylthio-l-propanol	1723			0.20 ± 0.09	0.16 ± 0.04		
Hydrocarbon							
Undecane	1096	Light-sweet		0.07 ± 0.02	0.10 ± 0.02		
α-Farnesene	1766			0.04 ± 0.01	0.01 ± 0.01		
Acid							
Acetic acid	1442			2.03 ± 0.41	2.07 ± 0.49		
Phenol							
Methyl chavicol*	1663			0.07 ± 0.01	0.07 ± 0.00		

[a] Volatile compounds with * are tentatively identified compounds. The compounds were identified on the basis of KIs which were reported by Girard and Lau (1995) without the matches of mass spectra.
[b] Kovat Index.
[c] Odour thresholds-in-water (mg l^{-1}) were cited from: (1), Echeverría et al. (2004); (2), Takeoka et al. (1990); (3), Aaby et al. (2002).
[d] Concentrations of volatile compounds (mg l^{-1}) were calculated relative to internal standard, cyclohexanol. Data show the means with standard errors of three replications.
[e] Concentration of the ascorbic acid in the control apple juice was 0% w/v.
[f] Concentration of the ascorbic acid in the apple juice was 0.2% w/v.
[g] Aroma values were calculated from the ratios of the volatile concentrations to the odour thresholds.

compounds responsible for sweet and fruity odours. Quantitatively, more than 80% of the esters in the apple juice were straight chain acetates. Hexyl- and butyl acetates which smelled strong sweet-fruity odour were the most prominent esters. The high concentrations of these two compounds were also reported in various apple cultivars (Dirinck & Schamp, 1989; Dixon & Hewett, 2000).

Two C6 aldehydes were identified in the apple juice, and their odours were recognized as green-grassy. These aldehydes have been described as the main contributors to the green odour of apple fruit and apple juice (Zheng, Kim, Kim, Leem, & Lee, 2004).

Alcohols were the second most abundant compounds in the apple juice. Almost of all detectable alcohols were straight chain-aliphatic. 1-Butanol was the most abundant alcohol in the apple juice and has been detected in the Jonagold apple at high concentration (Karlsen et al., 1999). We could perceive the odours of 1-butanol and 1-hexanol very lightly at the sniffing port. However, 1-hexanol was indicated as the negative odour contributor which suppressed the apple-like odour in the apple model mixture (Bult et al., 2002).

Two hydrocarbons, 1 acid and 1 phenol were also found in this apple juice. Acetic acid was measured at high concentration. However, no remarkable odour of these compounds was perceivable at the sniffing port.

The contribution of a volatile compound to the juice odour is dependent on its odour threshold and concentration (Echeverría, Fuentes, Graell, Lara, & López, 2004). According to the odour thresholds in Table 2, esters and aldehydes had the low odour thresholds whereas those of alcohols were very high. Therefore, the esters and aldehydes could contribute to the odours of the juice even if they were present at low concentration. Aroma value calculated from the ratio of the volatile concentration to its odour threshold was used to approximate the relative importance of volatile compound (Mosandl, 1992). The aroma values of volatile compounds are shown in Table 2. Six esters, 2 aldehydes and 2 alcohols with the aroma values above 1 were considered as the odour-active compounds in this apple juice. Hexyl acetate and ethyl butanoate had the highest aroma values up to 2170 and 170, respectively. These two compounds, consequently, were considered as the most important odourants in the Jonagold apple juice. This result was consistent with that of Kato et al. (2003) who suggested that hexyl acetate was the significant odourant in Jonagold apple juice. In addition, hexyl acetate and ethyl butanoate were reported as the main odour contributors in Fuji, Gravenstein and Golden Delicious apples (Aaby et al., 2002; Echeverría et al., 2004; Song & Bangerth, 1996). Hexanal and *trans*-2-hexenal showed the moderately high aroma values. Hexanal was described as the important contributor to the green odour of Starkspur Golden apple (Rizzolo, Visai, & Vanoli, 1997). The alcohols showed the lowest aroma values due to their high odour thresholds. These compounds, therefore, might not have the great impact on the odour of apple juice.

Since the aroma value is indicative of the relative importance of volatile compound, the aroma values of volatile compounds were used to elucidate the changes in odours of cloudy apple juice due to the addition of ascorbic acid.

3.2.2. Effect of ascorbic acid on the aroma values of volatile compounds

Changes in the aroma values of volatile compounds due to the addition of ascorbic acid (0.2% w/v) to the apple juice are shown in Table 2. The aroma values of esters and alcohols in the apple juice with ascorbic acid slightly changed from those in the control. On the other hand, the aroma values of hexanal and *trans*-2-hexenal in the apple juice with ascorbic acid increased about 4 and 5-fold from those in the control, respectively. Moreover, the aroma values of these two aldehydes were more than those of butyl- and 2-methylbutyl acetates. The increases in aroma values of aldehydes were attributed to the increases in their relative concentrations.

The increases in aroma values of the aldehydes corresponded well with the increase in green odour of apple juice by the addition of ascorbic acid. On the other hand, the insignificant change in sweet odour in the apple juice with ascorbic acid could be explained by the constants in aroma values of the esters. However, the changes in aroma values were insufficient to elucidate the changes in fresh, fruity and apple-like odours. The aroma values of some esters responsible for the fresh and fruity odours remained generally unchanged in the apple juice with ascorbic acid. We supposed that one reason for the decreases in fresh, fruity and apple-like odours might concern the increase in green odour. The excessive green odour was assumed to mask and then diminish the other odours. Although the green odour at small levels leads to the palatability of apple juice, at high levels it has the deleterious effect on the juice odour.

Due to the current technology limitations, it was quite difficult to establish a reaction mechanism which could overall explain the effect of ascorbic acid on the increases in aldehydes in the apple juice. In addition to the aldehydes, the ascorbic acid probably influenced other nonvolatile components and resulted in the changes in odours. The apple juice is the complex mixture of nonvolatile components. A large number of them are still obscure and remain questionable. It, thereby, was difficult to make clear the effect of ascorbic acid on the other components in the apple juice. However, from the results of this experiment, it could be concluded that the addition of ascorbic acid to the apple juice resulted in the increases in aldehyde concentrations and thus the increase in green odour of apple juice.

4. Conclusions

Ascorbic acid is widely used in the apple juice as an antibrowning agent. The effectiveness of ascorbic acid in antibrowning is temporary since it is reduced by the intermediate

o-quinones to dehydroascorbic acid. The ascorbic acid at high amount, therefore, is suggested as an additive to the apple juice for long-term inhibition of enzymatic browning. In this paper, the ascorbic acid was reported to negatively influence the apple juice odour, particularly the increase in green odour. For the good sensory qualities of apple juice, ascorbic acid should be used in the apple juice at suitable quantity which allowed for the quality optimization at a reasonable shelf-life.

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