Qualities and Aroma of Watermelon Juice during Storage at 4°C

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Abstract. The watermelon juice was pasteurized by the ultra-high temperature treatment, and stored at 4°C for 2 weeks. The ultra-high temperature reduced the initial microbial counts of the watermelon juice. The aroma of the watermelon juice was reduced during the storage at 4°C for 2 weeks. The typical volatiles were reduced from 52.1 % to 37.2 % during the storage.

Introduction

Watermelon (*Citrullus lanatus*) juice provides consumers with the moisture and some physiological functions as well [1]. The intake of the watermelon juice increases the plasma concentrations of lycopene, β-carotene [2] and arginine [3, 4]. Consequently, the juice reduces the chemical-induced hepatotoxicity [5] and proliferation of the cancer cell line [6] and relieves the muscle soreness of athletes [7].

The ultra-high temperature technique is the conventional way to inactive the bacteria of fruit juice [8]. The UHT is not only used in milk production, but also used for fruit juices, cream, soy milk, yogurt, wine, soups, honey, and stews [9]. The UHT treatment has effectively inactivated the bacteria of the watermelon juice [10] and maintained the aroma of the sugarcane [11]. However, the qualities and aroma of the pasteurized juice during the shelf life had not been evaluated to the best of our knowledge.

Therefore, the watermelon juice was pasteurized by the UHT treatment, and then stored at 4 ℃. The qualities and aroma during the storage were evaluated.

Material and Methods

Processing of the Watermelon Juice

Mature watermelon (*Citrullus lanatus* var. Jingxin No.3) was purchased from a local fruit market. The fruits were round with regular stripes and weighted about 3~4 kg per fruit. The flesh of the fruits was red with a soluble solid content of 11.5~13.5 %.

The fruits were peeled and squeezed in a Philips juicer after stored at 4 ℃ for 24 h (HR1861, Philips Co. Beijing, China). The juice was mix with complex food additive including arboxymethylcellulose sodium, ascorbic acid, xanthan gum, ethylene diamine tetraacetic acid, carminum, sodium pyrophosphate and etc.. The mixture was fully stirred and adjusted to the pH 4.10 with the citric acid, and adjusted soluble solid content to 8.0 with the high fructose corn syrup (4502504-01, Fresh Juice Industry (Kunshan) Co. Ltd.). The formulated juice was homogenized at 50 MPa (NS101L2K, GEA, Parma, Italy). The juice was pasteurized by the UHT treatment at 135 ℃ for 2 s. And then the pasteurized juice was stored at 4 ℃ for 2 weeks. The qualities and aroma of the UHT was evaluated at 1st, 7th , and 14th d, which nominated as the UHT1, UHT7, and UHT14. The juice before pasteurization was nominated as the Unpasteurized.

Total Flora Counts

Juice was serially diluted, plated in total count agar for total flora counts. The plates were incubated at 30 ℃ for 48 h and the bacterial colonies was counted manually.

Electronic Nose Analysis

The aroma of the watermelon juice was compared by the electronic nose (PEN2, Airsense Analytics GmbH, Schwerin, Germany). The electronic nose was turned on for 30 min and flushed the testing system for 180 s. The sample of 2 mL was put in the testing tube. And then the electronic sensor was put into the testing tube to collect the results for 60 s.

GC-MS Analysis and Identification of Volatile Compounds

An aliquot of 10 mL of the juice was put into a glass vessel. The glass vessel was placed in a water-bath at 30 ℃. The headspace was purged with a constant flow of nitrogen at 20 mL/min for 10 min. The volatile compounds were trapped in a glass capillary tube (3 mm internal diameter) , and then disconnected from the system and placed in a Chrompack TCT/PTI 400 injector.

The volatiles of the sample were performed on an Agilent 6890 GC coupled to an Agilent 5973I MS (Agilent Technologies, Palo Alto, CA). The volatile compounds were separated on a DB-Wax column (30 m × 0.25 mm i.d., 0.25 μm film thickness, Agilent Technologies). The injection was performed in splitless mode (0.7 mm splitless inlet liner, Supelco) and injector temperature was 220 ℃. The purge valve was opened at 0.5 min at a 50mL/min flow rate. Helium (99.999%) was used as the carrier gas with a constant starting flow rate at 0.7 mL/min. The oven temperature was programmed as follows: 35 ℃ for 1 min, 5 ℃/min to 100 ℃, and 20 ℃/min to a final temperature of 250 ℃ with a final holding time of 5 min. The detector was fitted with an electron impact ionization source set at 230 ℃. The quadrupole temperature was set to 150 ℃ and the transfer line temperature was kept at 250 ℃. The solvent delay was set to 3 min. Total ion chromatograms were collected scanning from m/z 30 to 150 at a rate of 3.06 scans/s.

Volatile compounds were identified by comparison of their mass spectra and retention times with those of authentic standards, or by comparison of Kovats' retention indexes and mass spectrum, with those reported in the NIST Mass Spectral Search Program (version 2.0a) with < 80 % as a cutoff to match compounds. The K.I.s were calculated from the retention times of C6–C40 n-alkanes followed the recently method.[12]

Statistical Analysis

The figure was prepared by the Origin 8.5. All experiments were done in triplicates or more.

Results and Discussion

Total Microbial Counts of Watermelon Juice

The total microbial counts of the watermelon juice during the storage is shown in Fig. 1. The initial count of the Unpasteurized was 5.85 Log CFU/mL. The total microbial count of Unpasteurized was reduced to 1.85 Log CFU/mL after the UHT treatemtn. The final total microbial count of the UHT treatments was reached 3.8 Log CFU/mL on the 14th d. Therefore, the UHT treatment were effective to reduced the initial count of the watermelon juice.

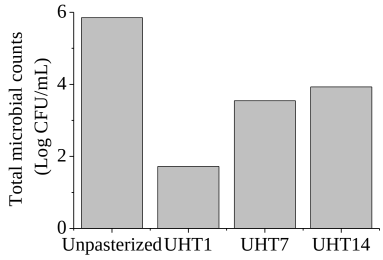

Figure.1. Effect of storage time on total microbial counts of the watermelon juice

Aroma of Watermelon Juice

The aroma of the juice was compared by the sensor array of 10 electrodes in the electric nose (Fig. 2). The dimensions of electrical responds were reduced by the principal component analysis. The main component 1 and 2 contributed 80.78 % and 18.66 % for the total watermelon aroma, respectively. The main component 1 represented the main aroma of the watermelon juice. The area of the Unpasteurized had no overlap with the other pasteurized watermelon juice. Consequently, the aroma of the UHT1, UHT7, and UHT14 was different to that of the Unpasteurized juice. Interestingly, the aroma of the berry juice pasteurized by the UHT is well maintained [13], while the heating at 90 ℃ for 28 s leads to a significant aroma change of the apple cider [14]. The UHT treatment was not good for the processing of the watermelon juice.

Volatiles of Watermelon Juice

Total 30, 29, 30, and 29 volatiles were indentified in the Unpasteurized, UHT1, UHT7 and UHT14, respectively (Table 1). The aldehyde, alcohol, ketone, alkane, and ester constituted 70.6 %, 15.8 %, 9.24 %, 4.42 %, and 0.26 %, respectively, in the Unpasteurized watermelon juice. The acid was not found in the Unpasteurized watermelon juice. Consequently, the aldehyde was the main component in Unpasteurized watermelon juice.

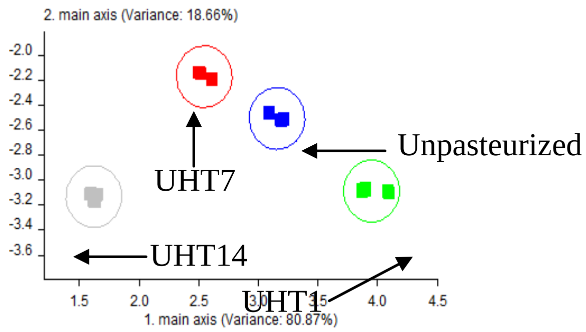

Figure.2. Effect of storage time on aroma of the watermelon juice

Remarkably, the aldehyde content of the Unpasteurized, UHT1, UHT7, and UHT14 was 70.6 %, 61.5 %, 34.7 %, and 19.3 %, respectively. The aldehyde content reduced significantly during the storage. The aldehyde, such as the 1-Nonanal, (E, Z)-2,6-Nonadienal, and (2E)-2-Nonenal, was believed to be the main aroma of the watermelon juice. Hence, the aroma of the watermelon was reduced during the storage. On the other hand, the alcohol, acid, and ester content of the juice were enhanced during the storage.

Table 1-1. Volatiles of the watermelon juice during the storage

Type	Volatiles	Unpasteurized	UHT 1	UHT 7	UHT 14
Alkane	Tetradecane	0.65	-*	-	-
	2-Pentylfuran	3.08	5.52	1.24	-
	1-Hexadecene	0.69	1.05	-	-
Subtotal		4.42	6.57	1.24	0
Alcohol	1-Nonanol	-	-	4.23	5.10
	(E)-2-Nonen-1-ol	4.31	3.07	5.55	6.37
	(3Z)-3-Nonen-1-ol	3.42	2.30	2.25	4.73
	(3E,6Z)-3,6-Nonadien-1-ol	-	-	7.00	5.22
	Phenethyl alcohol	3.06	4.04	-	-
	Hexyl alcohol	0.93	0.18	1.74	2.40
	2-Methyl-1-propanol	0.99	-	-	-
	1-Pentanol	-	-	-	1.56
	3-Methyl-1-butanol	0.19	-	-	-
	(2E)-2-Hexen-1-ol	-	-	-	1.70
	Capryl alcohol	0.37	0.37	0.44	2.75
	2-Hexyloctanol	-	0.69	-	-
	2-Octanol	1.04	-	-	-
	Geraniol	0.25	-	-	-
	1-Octen-3-ol	-	-	-	3.81
	(2E)-2-Octen-1-ol	-	-	-	3.24
	(2E)-2-Undecen-1-ol	-	-	3.36	-
	1-Undecanol	-	-	0.95	-
	Dodecenol	-	0.33	-	-

Table 1-2. Volatiles of the watermelon juice during the storage

Type	Volatiles	Unpasteurized	UHT 1	UHT 7	UHT 14
	Dodecyl alcohol	0.47	-	-	-
	(E)-2-dodecen-1-ol	-	-	2.21	-
	1-Tridecanol	0.8	2.77	2.07	-
	1-Tetradecanol	-	-	-	-
	1-Pentadecanol	-	0.57	-	-
	1-Hexadecanol	-	0.53	-	-
	1-Nonadecanol	-	0.3	-	-
	1,6-Octadien-3-ol	-	-	-	3.58
Subtotal		15.83	15.15	29.8	40.46
Aldehyde	1-Nonanal	8.45	9.18	-	-
	(E,Z)-2,6-Nonadienal	25.8	22.6	16.97	9.17
	(2E)-2-Nonenal	10.1	9.22	8.15	6.62
	2-Hexenal (E)	4.32	4.21	-	-
	(E)-Hept-2-enal	1.23	-	-	-
	Octanal	5.21	3.22	2.05	1.01
	(E)-2-Octenal	0.83	-	0.57	-
	Decanal	6.08	5.87	4.32	2.14
	2-Undecenal	-	-	2.09	-
	(E)-2-Dodecenal	7.65	5.69	-	-
	Tetradecanal	-	0.66	0.59	0.34
	Pentadecanal	0.58	0.89	-	-
Subtotal		70.25	61.54	34.74	19.28
Ketone	6-Methyl-5-hepten-2-one	3.97	2.95	3.47	4.63
	6,10-Dimethyl-5,9-undecadien-2-one	2.83	5.31	4.18	1.96
	3-Octanone	-	-	-	0.58
	3-Hydroxy-2-butanone	1.47	-	-	-

Table 1-3. Volatiles of the watermelon juice during the storage

Type	Volatiles	Unpasteurized	UHT 1	UHT 7	UHT 14
	2-Pentadecanone	0.33	2.46	-	-
	2-Nonadecanone	0.64	-	-	-
	(Z)-6,10-Dimethyl-5,9-undecadien-2-one	-	-	3.77	-
Subtotal		9.24	10.72	11.42	7.17
Acid	Nonanoic acid	-	-	5.75	7.96
	Acetic acid	-	-	2.68	5.19
	2-Methyl butyric acid	-	-	2.71	3.87
	Hexanoic acid	-	-	1.52	2.31
	Octanoic acid	-	-	2.19	4.23
Subtotal		0	0	14.85	23.56
Ester	Octyl Formate	-	0.22	-	-
	Isopropyl palmitate	-	0.46	-	2.28
	Heptyl forMate	-	-	1.04	2.13
	Dodecyl Acetate	-	-	0.19	1.78
	Diisobutyl phthalate	0.26	2.51	2.43	0.05
	Allyl hexanoate	-	2.83	4.29	3.29
Subtotal		0.26	6.02	7.95	9.53

*: not detected.

The C9 alcohol and aldehyde are the key aroma of the watermelon juice. The 1-Nonanol, (E)-2-Nonen-1-ol, (3Z)-3-Nonen-1-ol, (3E, 6Z)-3, 6-Nonadien-1-ol, 1-Nonanal, (E,Z)-2,6-Nonadienal, and (2E)-2-Nonenal were designated as the typical volatiles of the watermelon in the watermelon juice. The content of the typical volatiles of the Unpasteurized, UHT1, UHT7, and UHT14 was 52.1 %, 46.4 %, 44.2 %, and 37.2 %, respectively (Fig. 3). Hence, the watermelon aroma of the pasteurized watermelon juice was reduced with the storage time.

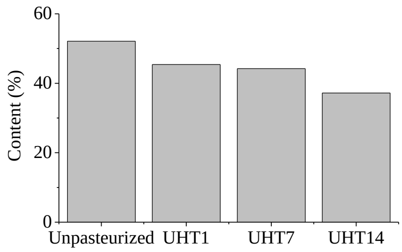

Figure.3. Effect of storage on typical volatiles of the watermelon juice

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