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Changes of Volatiles from Apple Fruits during Maturity and Storage.

Part Ⅱ. Volatiles from the Fruits as Related to Storage Conditions

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사과 成熟 및 貯藏中 香氣成分의 變化

第二報. 果實의 貯藏條件에 따른 香氣成分含量

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초 록

사과의 저장조건에 따른 품질보존 및 저장효과를 높이기 위한 목적으로 우리 나라에서 주로 생산되고 있는 후지, 국광 및 홍옥과실을 preclimacteric 단계에서 수확하여 상온(20°C) 및 저온(1°C)에서 각각 상압(760mmHg)과 감압(380mmHg)으로 처리하여 저장중 향기성분의 변화를 조사하였다. 저장중 향기성분의 함량변화는 상온에서 저장 30일경까지는 급격히 증가하다가 그 이후에는 급격히 감소하는 경향이였으며 감압이 상압보다 증감의 경향이 완만하였고, 저온에서는 저장 30~60일경까지 전반적으로 완만하게 증가하다가 그 이후에는 감소하는 경향이였으며 감압이 상압보다 함량의 변화폭이 적었다. 저장중 향기성분의 종류가 증가하는 경향이였으며, 향기성분중 ester는 alcohol과 aldehyde에 비하여 급격히 감소하였다. 후지를 저온감압하에서 90일간 저장한 후 상압에서 20°C로 보존하였을 때 3일경에 이러러 향기성분의 함량이 거의 최대치에 도달하였다.

Introduction

The volatiles produced by metabolism of apple fruit tissues are important in the storage of apples because the fruit is exposed to the volatiles for long periods of time. Some workers[1~3] believe that the storage disorder of scald and premature ripening are due to apple volatiles. Attempts to control these problems by storage practices, such as the use of shredded oiled paper, air purifiers and chemicals have been partially successful in some instances.[2,4~6]

A survey of the literature revealed a large number of reports[4,7~12] dealing with the emanation of volatiles from apples during storage. Most of these reports[4,9,12,13] attempted to relate volatile emanation with scald or internal breakdown during storage of whole apples. Thompson *et al.*[14] showed that apples stored at 0°C appeared to increase steadily in ester production, while those stored at 20°C increased to a maximum of ester production and then decreased. Huelin[15] also identified the volatile aldehyde sand ketones produced by Granny Smith apples during storage. Meigh[5,6] reported that apples stored in normal air produced all the volatile compounds at a greater rate than those stored in controlled atmosphere storage. He pointed out that the air storage rates of volatile production tended to increase, while in gas storage rates of volatile production tended to remain constant or decrease through the storage season. Brown *et al.*[16,17] reported on the studies of apple volatiles in relation to variety, maturity and ripeness, and storage. Brown *et al.*[18] and Somogyi *et al.*[19] presented evidence that volatile constituents of apple fruit are influenced by the mineral nutrition of the tree.

To date, no quantitative information relating to the volatile content of apples stored under the subatmospheric pressure has appeared in the literature. Since many fruit flavors are dependent upon the volatile components of the fruits, we have monitored the volatile content of apples under various storage conditions.

Materials and Methods

Raw materials: Fuji, Ralls Janet and Jonathan apples from the near Taegu district of Gyeongbug were picked at the preclimacteric stage in 1982. Apples of each variety were picked in about equal numbers from upper and lower portions of the trees. Fruit was selected at random and small or poorly colored apples were not picked. Picked apples were taken to laboratory, the same day and stored.

Storage treatments: Apples were stored under the normal atmospheric pressure of 760mm Hg and subatmospheric pressure of 380mmHg at the temperature of 1 and 20°C each. Apples were stored in the apparatus[20] at subatmospheric pressures and controlled temperature (Fig. 1) and in order to get rid of CO_2 produced during storage CO_2 adsorber was controlled in storage

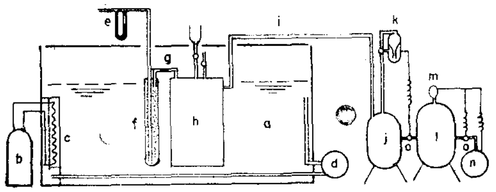

Fig. 1. Storage apparatus.
a: Constant-temp. water bath, b: Refrigerating app., c: Cooling app., d: Water circulating pump, e: Flow meter, f: Humidity controller, g: Porous plug, h: Storage chmaber, i: Vent pipe, j: Vacuum control tank, k: Vacuum controller, l: High vacuum tank, m: High vacuum controller, n: Vacuum pump, o: Solenoid valve.

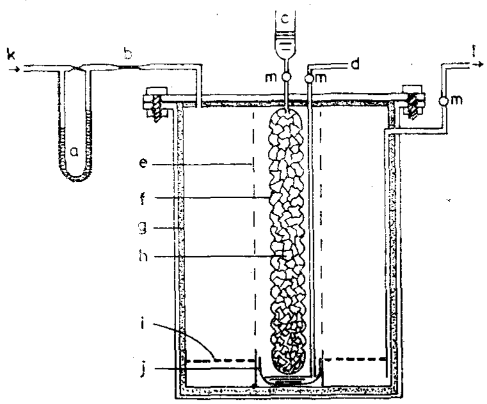

Fig. 2. Diagram of storage chamber.
a: Flow meter, b: Porous plug, c: CO_2 adsorber, d: CO_2 adsorber recovery app., e: PVC pipe, f: CO_2 adsorption app., g: Insulator, h: Splinters of glass, i: Storage chamber plate, j: CO_2 adsorber receiver, k: Air, l: Vacuum tank, m: Cock.

chamber as shown in Fig. 2.

Sample preparation: For Tenax GC trapping of apple volatiles by the methods of Shimoda *et al.*[21] and Simon *et al.*[22] as described in previous work,[23] six replications of each sample were prepared by removing the peel, core and seed from 5 apples to supply a desired sample weight (ca. 100 g), and grinding these samples in a Waring blendor with an equivalent weight of distilled water until pureed (approximately 30 sec). Each replicate with 0.1ml of 0.2% 1,2-dichloroethane and cyclohexanol as internal standard was then transferred to a 300 ml boiling flask, and volatiles were collected on Tenax GC traps for 25 min under a nitrogen flow of 20ml/min bubbled through the mixture. Sample flasks were held for 15 min at 30°C in a water bath. Collection was also made at 30°C and with stationary flasks in preliminary trials. Traps were prepared with 100 mg of Tenax GC between glass wool plugs in a small-bore glass colum. After sampling, traps were backflushed at room temperature 2min, sealed, and refrigerated at −15°C, and volatiles were eluted with 300μl diethyl ether by shake in a Vortex mixer for 2min and 1,000rpm centrifugation for 1min. Gas chromatography was performed on 2μl injection.

Gas chromatography: Gas chromatography was carried ont using Shimadzu Model GC-6A gas chromatograph equipped with flame ionization detectors and 3m×3mm glass columns packed with 10% PEG 20M on 60 : 80 mesh Chromosorb W and programmed at 3°C/min from 60 to 165°C with a nitrogen flow of 30ml/min.

Determination of volatiles: Determination of each component in the collected headspace volatiles was calculated on the basis of peak areas by data processor for chromatography (Shimadzu, C-E1B).

Results and Discussion

Changes of the volatiles during storage

The contents of volatiles produced by the Fuji, Ralls Janet and Jonathan apples during storage are shown in Tables, 1, 2, 3, 4, 5 and 6.

The production rates of the volatiles from Fuji which had been in storage as shown in Tables 1 and 2 were related to the length of the storage period. The amount of volatiles given off by apples was also greatly dependent on the storage temperature. The content of most volatiles produced in the storage at 20°C increased markedly up to around 30 days on storage, whereas that of the volatiles in the storage at 1°C increased slowly up to around 30 or 60 days. After this period the amount of volatiles decreased. The changing pattern of volatiles produced at the normal atmospheric pressure storage was more remarkable than that of volatiles produced at the subatmospheric pressure storage. However, isopentyl propionate during storage at 1°C continuously increased and isobutyl butyrate decreased. Among volatiles from apples stored under the subatmospheric pressure, 2-pentanol, 1-hexanol, ethyl acetate, ethyl valerate, pentyl hexanoate and hexanal increased slowly up to around 60 days on storage and then decreased. During storage, kinds of volatiles were increased out of relation to storage conditions.

The production of volatiles produced by Ralls Janet in storage nearly resembled that of Fuji as shown in Tables 3 and 4. Among the changes of the volatiles from apples stored at 20°C (Table 3), the changing pattern of volatiles under the normal atmospheric pressure storage was more remarkable than that of volatiles under the subatmospheric pressure storage, and the contents of esters such as hexyl acetate, isobutyl propionate, isopentyl propionate, butyl butyrate and pentyl butyrate decreased more rapidly than those of alcohols and aldehydes among the volatiles. The production pattern of volatiles from apples stored at 1°C (Table 4) was similar to that evidenced in storage at 20°C, but the contents of volatiles such as 1-hexanol, ethyl acetate, isobutyl butyrate, isopentyl propionate and butyl hexanoate produced by

Table 1. Changes of the volatiles in Fuji apple during storage with different pressure at 20°C (μg/100g)

atm	760mmHg				380mmHg			
Days	0	30	60	90	0	30	60	90
2-Pentanol	38.0	47.5	42.0	27.5	38.0	44.5	37.2	23.7
1-Butanol	53.8	60.2	55.2	50.0	53.8	58.0	57.0	53.9
1-Pentanol	18.0	22.6	17.0	12.4	18.0	20.4	18.1	15.5
1-Hexanol	12.0	22.0	17.2	11.5	12.0	21.4	18.0	14.4
trans-2-Hexenol	15.3	19.4	17.0	13.0	15.3	18.7	17.5	16.5
Ethyl acetate	4.6	5.8	4.9	3.8	4.6	5.5	5.2	4.6
Isobutyl propionate	17.0	22.4	19.8	12.2	17.0	20.5	18.8	11.4
Ethyl valerate	33.8	58.5	45.5	30.0	33.8	45.0	42.5	32.4
Isobutyl butyrate	37.0	43.8	38.2	22.0	37.0	39.0	33.8	26.5
Isopentyl propionate	1.4	17.6	13.6	6.8	1.4	16.5	14.5	9.9
Butyl butyrate	7.6	9.6	7.2	5.2	7.6	8.8	7.6	5.9
Hexyl acetate	16.8	23.2	17.4	11.0	16.8	22.0	18.8	14.2
Pentyl butyrate	16.0	21.8	17.8	14.0	16.0	21.2	18.5	15.0
Butyl hexanoate	16.2	18.2	12.0	7.2	16.2	17.5	15.0	12.3
Pentyl hexanoate	11.4	20.5	18.4	8.5	11.4	19.4	17.4	13.8
Hexanal	34.0	46.5	36.0	28.6	34.0	41.0	38.5	31.9
2-Hexenal	13.2	20.4	14.0	10.0	13.2	19.2	16.0	12.4
Kinds of the volatiles	23	25	26	28	23	32	35	47

Table 2. Changes of the volatiles in Fuji apple during storage with different pressure at 1°C (μg/100g)

atm	760mmHg				380mmHg			
Days	0	30	60	90	0	30	60	90
2-Pentanol	38.0	39.6	39.4	37.0	38.0	37.5	38.4	34.9
1-Butanol	53.8	56.5	55.7	54.4	53.8	55.2	54.5	53.8
1-Pentanol	18.0	19.8	19.3	18.4	18.0	19.1	18.4	17.9
1-Hexanol	12.0	19.7	19.4	18.4	12.0	18.0	18.5	18.0
trans-2-Hexenol	15.3	18.0	18.0	16.0	15.3	17.5	17.5	17.2
Ethyl acetate	4.6	5.3	5.4	4.9	4.6	5.1	5.3	5.0
Isobutyl propionate	17.0	19.5	18.2	17.0	17.0	18.5	17.4	15.0
Ethyl valerate	33.8	41.0	39.2	37.5	33.8	37.2	37.4	35.6
Isobutyl butyrate	37.0	36.5	35.5	28.0	37.0	35.4	35.0	30.1
Isopentyl propionate	1.4	10.8	11.5	12.4	1.4	9.8	10.8	11.4
Butyl butyrate	7.6	8.4	8.2	7.2	7.6	8.2	8.0	7.6
Hexyl acetate	16.8	20.8	20.8	18.0	16.8	20.4	19.9	18.9
Pentyl butyrate	16.0	20.3	19.8	17.0	16.0	19.7	19.4	18.5
Butyl hexanoate	16.2	16.8	16.4	15.5	16.2	16.5	16.0	15.7
Pentyl hexanoate	11.4	18.5	18.0	16.9	11.4	16.4	17.2	16.8
Hexanal	34.0	37.8	42.0	38.0	34.0	35.0	39.1	35.8
2-Hexenal	13.2	17.6	17.1	15.6	13.2	16.8	16.7	15.8
Kinds of the volatiles	23	25	31	40	23	24	37	42

Table 3. Changes of the volatiles in Ralls Janet apple during storage with different pressure at 20°C (μg/100g)

atm	760mmHg				380mmHg			
Days	0	30	60	90	0	30	60	90
2-Pentanol	27.5	32.0	24.0	12.4	27.5	29.4	22.0	15.0
1-Butanol	40.1	48.4	42.4	35.0	40.1	46.6	43.7	39.3
1-Pentanol	19.0	19.8	17.5	16.2	19.0	19.5	19.2	16.8
1-Hexanol	17.4	29.4	26.4	21.4	17.4	26.3	25.1	23.0
trans-2-Hexenol	6.2	12.5	9.2	6.4	6.2	11.8	10.0	7.8
Ethyl acetate	3.0	4.0	3.3	2.7	3.0	3.7	3.0	2.4
Isobutyl propionate	15.0	17.8	12.2	8.8	15.0	16.8	11.5	7.7
Ethyl valerate	21.4	36.0	28.0	12.6	21.4	30.0	25.0	14.2
Isobutyl butyrate	44.2	58.8	46.0	35.5	44.2	55.0	48.0	38.1
Isopentyl propionate	13.6	16.4	13.8	10.5	13.6	15.5	14.5	11.7
Butyl butyrate	5.2	8.3	6.1	4.0	5.2	7.6	6.4	5.2
Hexyl acetate	11.5	14.5	11.2	7.0	11.5	13.8	11.8	10.0
Pentyl butyrate	10.2	18.4	15.8	13.0	10.2	17.6	16.3	14.1
Butyl hexanoate	12.0	18.6	15.2	12.2	12.0	17.6	16.3	14.4
Pentyl hexanoate	13.1	17.2	11.3	9.8	13.1	16.9	14.2	13.0
Hexanal	20.0	28.1	19.0	11.2	20.2	20.7	20.0	14.1
2-Hexenal	11.6	15.8	10.5	7.5	11.6	14.8	11.5	8.5
Kinds of the volatiles	22	20	32	33	22	27	32	40

Table 4. Changes of thevolatiles in Ralls Janet apple during storage with different pressure at 1°C (μg/100g)

atm	760mmHg				380mmHg			
Days	0	30	60	90	0	30	60	90
2-Pentanol	27.5	25.6	24.0	22.5	27.5	26.0	25.0	20.6
1-Butanol	40.1	45.5	45.4	43.3	40.1	44.1	44.4	42.4
1-Pentanol	19.0	19.2	19.0	18.6	19.0	18.5	18.5	18.0
1-Hexanol	17.4	24.5	24.6	24.0	17.4	23.8	23.7	23.0
trans-2-Hexenol	6.2	11.1	10.8	9.4	6.2	10.8	10.4	10.0
Ethyl acetate	3.0	3.4	3.5	3.2	3.0	3.3	3.4	3.0
Isobutyl propionate	15.0	15.8	14.9	13.0	15.0	15.1	14.0	12.2
Ethyl valerate	21.4	22.5	21.0	19.5	21.4	20.4	18.6	16.9
Isobutyl butyrate	44.2	49.0	51.4	42.5	44.2	45.4	49.5	44.5
Isopentyl propionate	13.6	14.5	14.6	13.3	13.6	14.0	14.3	13.6
Butyl butyrate	5.2	7.3	7.1	6.1	5.2	6.9	6.8	6.5
Hexyl acetate	11.5	13.2	13.0	11.8	11.5	12.2	12.2	12.0
Pentyl butyrate	10.2	17.1	17.0	15.5	10.2	16.4	16.6	16.0
Butyl hexanoate	12.0	16.8	17.1	16.0	12.0	16.5	16.7	16.4
Pentyl hexanoate	13.1	15.7	15.6	14.5	13.1	15.3	15.2	13.1
Hexanal	20.2	20.6	20.5	20.2	20.2	20.4	20.2	19.0
2-Hexenal	11.6	13.8	13.0	10.3	11.6	12.8	12.3	11.2
Kinds of the volatiles	22	23	30	36	22	22	32	37

Table 5. Changes of the volatiles in Jonathan apple during storage with different pressure at 20°C (μg/100g)

atm	760mmHg				380mmHg			
Days	0	30	60	90	0	30	60	90
2-Pentanol	35.1	40.2	32.9	22.5	35.1	37.5	29.0	21.5
1-Butanol	50.1	56.4	53.2	47.0	50.1	54.5	52.4	49.0
1-Pentanol	15.8	18.5	15.0	13.2	15.8	17.8	15.6	14.0
1-Hexanol	22.4	26.0	23.5	13.4	22.4	25.5	24.6	20.5
trans-2-Hexenol	15.0	17.0	14.5	12.5	15.0	16.3	15.5	15.8
Ethyl acetate	4.2	5.5	4.4	3.8	4.2	5.2	4.7	4.3
Isobutyl propionate	16.9	22.2	18.7	13.6	16.9	21.6	17.5	12.4
Ethyl valerate	21.0	40.2	32.9	22.5	21.0	34.2	26.5	23.9
Isobutyl butyrate	40.0	49.8	30.2	20.0	40.0	42.8	33.0	22.5
Isopentyl propionate	13.8	18.2	17.0	12.7	13.8	17.5	16.2	13.8
Butyl butyrate	6.8	9.8	6.9	3.5	6.8	9.0	7.5	4.9
Hexyl acetate	12.0	17.7	13.5	9.4	12.0	16.4	14.5	11.7
Pentyl butyrate	13.2	14.4	9.5	6.5	13.2	13.5	11.5	8.8
Butyl hexanoate	5.8	8.6	5.6	3.5	5.8	7.6	6.7	5.4
Pentyl hexanoate	10.2	14.1	12.3	7.5	10.2	13.5	12.8	11.0
Hexanal	30.9	40.4	22.4	17.4	30.9	36.4	26.8	20.0
2-Hexenal	12.5	17.4	13.8	8.2	12.5	16.0	14.8	12.3
Kinds of the volatiles	21	21	24	28	21	25	28	29

Table 6. Changes of the volatiles in Jonathan apple druing storage with different pressure at 1°C (μg/100g)

atm	760mmHg				380mmHg			
Days	0	30	60	90	0	30	60	90
2-Pentanol	35.1	33.1	31.8	27.5	35.1	32.5	30.2	26.2
1-Butanol	50.1	53.2	53.2	51.5	50.1	51.8	51.0	50.5
1-Pentanol	15.8	17.0	17.0	16.2	15.8	16.4	16.0	15.8
1-Hexanol	22.4	24.4	25.4	22.4	22.4	23.4	23.0	21.7
trans-2-Hexenol	15.0	15.8	16.0	15.1	15.0	15.5	15.8	14.6
Ethyl acetate	4.2	5.0	4.9	4.8	4.2	4.7	4.7	4.6
Isobutyl propionate	16.9	19.2	19.4	17.5	16.9	18.5	18.2	16.8
Ethyl valerate	21.0	30.5	31.6	26.8	21.0	27.5	30.0	25.0
Isobutyl butyrate	40.0	39.2	37.3	29.5	40.0	37.9	35.2	31.9
Isopentyl propionate	13.8	15.8	15.6	14.5	13.8	15.0	14.9	14.8
Butyl butyrate	6.8	8.3	8.1	6.5	6.8	7.9	7.8	6.9
Hexyl acetate	12.0	15.5	15.5	13.6	12.0	14.8	15.0	14.2
Pentyl butyrate	13.2	13.4	12.8	11.0	13.2	12.7	12.4	11.8
Butyl hexanoate	5.8	7.2	7.4	6.7	5.8	7.6	6.9	6.8
Pentyl hexanoate	10.2	13.5	13.6	12.6	10.2	12.8	12.6	12.3
Hexanal	30.9	34.0	33.2	32.0	30.9	30.9	30.5	28.5
2-Hexenal	12.5	15.0	15.5	14.0	12.5	14.0	14.2	13.5
Kinds of the volatiles	21	24	26	33	21	24	31	44

apples stored under the normal atmospheric pressure and those of volatiles such as 1-butanol, ethyl acetate, isobutyl butyrate, isopentyl propionate, pentyl butyrate and butyl hexanoate produced by apples in subatmospheric pressure storage increased slowly up to around 60 days on storage and then decreased. During storage, the contents of 1-butanol and isobutyl butyrate were most prominent regardless of storage temperature and its pressure.

The changing pattern of the volatiles in Jonathan apples during storage at 20°C as shown in Table 5 was smilar to that evidenced Fuji and Ralls Janet(Tables 1 and 3). They increased markedly up to around 30 days on storage and then decreased. The content of each volatile was much in order of 1-butanol, isobutyl butyrate, ethyl valerate, 2-pentanol and hexanal among the volatiles, and content of volatiles from Jonathan stored under the subatmospheric pressure for 90 days were higher than under the normal atmospheric pressure. Volatiles in Jonathan during storage at 1°C(Table 6) were slowly changed like Fuji and Ralls Janet(Tables 2 and 4) and they were much in order of 1-butanol, isobutyl butyrate, hexanal, 2-pentanol and ethyl valerate. Most volatiles after storage for 90 days were lower in content under the subatmospheric pressure than under the normal atmospheric pressure.

As the results of the above statements, the amounts of the volatiles produced by Fuji, Ralls Janet and Jonathan apples at 20°C increased markedly up to around 30 days on storage and production pattern of volatiles under the normal atmospheric storage was more remarkable than that of volatiles under the subatmospheric pressure storage. During storage at 1°C, the changes of volatiles increased slowly up to around 30 or 60 days and then decreased. Among 17 compounds from 3 kinds of apples, 1-butanol, isobutyl butyrate, ethyl valerate, 2-pentanol and hexanal were most prominent. The amount of volatiles produced at the beginning of the storage period at 1°C was also lower than the amount produced at 20°C. However, at this higher temperature the emanations decreased greatly during storage, so that, finally, the quantity of volatiles produced at 1 and 20°C was nearly the same.

Brown *et al.*[16,17] reported that the production rates of the volatiles from apples which had been in storage were related to the length of the storage period, as well as to the variety and date of harvest. Grevers *et al.*[7] noted that in most storage conditions the greatest amount of volatiles was produced at the end of a storage of two months. The quantity of volatiles produced was lower at 3°C than at 6 or 15°C. Meigh[5,6] found that apples produced volatile alcohols, aldehydes, ketones and esters at a much greater rate in air than in gas storage. Wills *et al.*[18] showed that an increased rate of water loss during cool storage increased the loss of hexyl, isopentyl and butyl acetates but decreased the loss of the corresponding alcohols. The loss of hexyl, isopentyl and butyl acetates was highest at 10°C and decreased markedly with decreasing temperature. Drawert *et al.*[24] reported that Cox Orange and Glockenapfel synthesize butyl acetate, hexyl acetate, hexyl caproate, hexyl butyrate, 2-mehtyl-1-butanol and 2-methyl-1-propanol primarily during the various climacteric phases while in storage at 17°C and decompose them after they have reached their maximum concentration. The results reported here are nearly compatible with reports[7,16,17,24] by other workers.

Changes of the volatiles during ripening at 20°C after removing from subatmospheric pressure storage at 1°C

Table 7 illustrates changes of the volatiles in Fuji apples during ripening at the normal temperature(20°C) after removing from subatmospheric pressure(380mmHg) storage at the low temperature(1°C). Most of the volatiles increased in proportion to prolonged ripening period. They were nearly maximum at 3 days on ripening. However, pentyl hexanoate decreased markedly after 3 days on ripening.

Grevers *et al.*[7] reported that the amount of volatiles emanated by Golden Delicious and Cox Orange Pippin apples during ripening at 15°C after removing from storage for 1∼4 months at 3 and 6°C was higher than the amount produced from apples stored at 10°C. Golden Delicious apples produced a greater amount of volatiles during ripening when they had been stored 2∼4 months at 3°C than after storage at 6°C. The reverse effect was found with Cox Orange Pippin apples. Brown *et al.*[16] reported that apples produced a greater amount of volatiles during ripening when they had been kept about 20 days at 20°C after $4^1/_2$ months in cold storage. Guadagni *et al.*[25] noted that the rate and extent of apple volatile production were several times greater in peels than in flesh or whole apples. They observed that volatile production in apples after peeling increased rapidly at 22°C, reached a maximum in 1∼2 days and then gradually declined.

These investigations are similar to the results that have been reported in apples by other workers.[7,16,25] We believe that these results originate in the effect of controlling after-ripening by control of respiration and removal of ethylene during storage, and volatiles controlled by these effects will be able to recover their production during ripening when apples will be kept under normal conditions.

Abstract

The changes of the volatiles from apple fruits were examined with *Mallus pumila Miller var.* Fuji, Ralls Janet and Jonathan harvested at the preclimacteric stage and stored under the normal atmospheric pressure of 760mmHg and subatmospheric pressure of 380mmHg at the temperature of 1 and 20°C each. The production of the volatiles in the normal storage tempera-

Table 7. Changes of the volatiles in Fuji apple during keeping at 20°C after removing from subatmospheric storage at 1°C for 90 days

Volatiles	Days					
	0	1	2	3	5	7
2-Pentanol	34.9	35.1	35.8	36.2	36.8	36.9
1-Butanol	53.8	54.1	54.7	55.7	57.8	53.3
1-Pentanol	17.9	18.1	19.7	21.9	22.4	24.7
1-Hexanol	18.0	24.3	26.5	29.0	31.5	34.0
trans-2-Hexenol	17.2	23.5	24.7	26.6	30.2	31.8
Ethyl acetate	5.0	5.3	9.1	11.4	14.3	17.1
Isobutyl propionate	15.0	16.3	20.3	22.1	24.4	25.5
Ethyl valerate	35.6	38.1	40.9	44.6	46.5	44.6
Isobutyl butyrate	30.1	30.4	32.6	34.1	38.2	39.4
Isopentyl propionate	11.4	10.6	11.8	14.9	16.9	17.4
Butyl butyrate	7.6	8.6	10.6	12.1	15.6	16.6
Hexyl acetate	18.9	29.4	34.2	37.6	39.8	40.1
Pentyl butyrate	18.5	28.2	30.4	33.5	35.5	32.4
Butyl hexanoate	15.7	19.5	25.5	27.8	30.7	31.5
Pentyl hexanoate	16.8	17.9	18.7	15.6	14.2	10.5
Hexanal	35.8	35.8	38.7	44.6	48.7	49.9
2-Hexenal	15.8	17.5	20.8	23.3	25.9	25.4
Kinds of the volatiles	42	39	39	43	47	44

ture increased markedly up to around 30 days on storage and then decreased rapidly, whereas that of the volatiles in the low storage temperature increased slowly before decreasing. The changing pattern of volatiles from apples during storage at the normal atmospheric pressure was more remarkable than that of volatiles produced at the subatmospheric pressure. During storage, most of flavoring materials were increased, and the decrease of the content of esters was more rapid than that of alcohols and aldehydes among the volatiles. The amounts of the volatiles in Fuji apples during ripening at 20°C after removing from the subatmospheric pressure storage for 90 days at 1°C were nearly maximum at 3 days on ripening.

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