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ORIGINAL PAPER

Oils in the Seeds of Caneberries Produced in Korea

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Abstract Seed and oil contents, and fatty acid compositions of oils of 20 caneberries grown in Korea were determined. Fatty acid compositions of the oils were analyzed using GC for the extracted and methylated oils from the berry seeds. The seeds comprised 4–10% (w/w) of the wet berries and accounted for 26–62% of the dry berries. Moisture and oil contents of the berry seeds were 8–17 and 13–28% (dry basis), respectively. More than 90% of the total fatty acids in the oils from the berry seeds were unsaturated. Linoleic and linolenic acids comprised 49–70 and 13–34%, respectively, of the oils in the berry seeds.

Keywords Blackberry · Caneberry · Fatty acid composition · Raspberry · *Rubus* · Seed oil

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Introduction

Production of caneberries (*Rubus* spp.) has rapidly increased in recent years in Korea since these berries are believed to have beneficial effects on human health. Koreans traditionally believe that these berries improve eye sight, ease urination, enhance sexual function, and prevent aging, although the beliefs remain not fully scientifically proven [1]. These berries, however, have been shown to have antioxidant and anti-microbial activities [2–5].

In 2004, the production of caneberries in Korea was 1,840 metric tons (personal communication from Agricultural Technology Service Center, Gochang, Korea). Of this, 950 metric tons of the berries were used for wine production in Korea (personal communication from Agricultural Technology Service Center). Pomace from the wine making, which contains pulp and seeds, was mostly used as animal feed or fertilizer.

According to previous reports, seeds constituted 9–12% (wet weight basis) of different types of *Rubus* [6] and contained 10–23% oils (dry weight basis) [6–9]. The major fatty acids composing the oils were linoleic (41–70%), linolenic (13–36%), and oleic (11–19%) acids [6–9]. These oils are known to have excellent anti-inflammatory activity compared to virgin avocado oil, grape seed oil, and wheat germ oil [10]. Oomah et al. [9] reported that total tocols in raspberry seed oils were detected at levels about six times greater than those in safflower oil and grape seed oil. They also reported that raspberry seed oils were fairly stable with regard to oxidation, although the oils were highly unsaturated. High oil content in the berry seeds, unique fatty acid composition of the oils, high tocol content, oxidative stability, and anti-inflammatory activity indicate that it is worthwhile considering *Rubus* as a source of a specialty oil.

The objective of the study was to compare the seed contents (seed weight to berry weight) and oil contents (oil weight to seed weight) among the berry types and to characterize the fatty acid compositions of the oils extracted from a variety of caneberries produced in Korea.

Materials and Methods

Raspberries and Blackberries

Samples of black raspberry (*Rubus occidentalis*), Korean raspberry (*Rubus coreanus*), mountain raspberry (*Rubus crataegifolius*), blackberry (*Rubus fruticosus*), raspberry (*Rubus idaeus*) and Boysenberry (*Rubus ursinus* × *idaeus*) were harvested and collected in 2005 in Korea. The source and production method for each type of caneberry are summarized in Table 1. Pomace of black raspberry was obtained from a raspberry wine producer in Gochang, Korea.

Separation of Seeds from the Berries

The berry fruits were crushed by hand in cold tap water and allowed to soak in a 10-L container of water for approximately 24 h. After soaking, gentle rubbing between the

Table 1 Contents of seeds in caneberries, and moisture and oil contents in the berry seeds

Berry sample code	Berries	Seed content in berries		Seeds	
		Wet basis (%)	Dry basis (%)	Moisture (%)	Crude oil (%, db)
Black raspberry (*Rubus occidentalis*)					
1	Black raspberry, cultivated, I	7.9 (0.1)^{a}	52.9 (4.0)^{a}	16.0 (0.5)^{ab}	17.3 (1.1)^{a}
2	Black raspberry, cultivated, II	9.6 (0.7)^{b}	53.5 (6.5)^{a}	17.1 (2.4)^{a}	17.8 (0.5)^{a}
3	Black raspberry, cultivated, III	7.3 (0.6)^{a}	47.8 (4.9)^{a}	12.8 (0.7)^{b}	27.9 (1.8)^{b}
Korean raspberry (*Rubus coreanus*)					
4	Korean raspberry, cultivated, II	6.7 (0.4)^{a}	43.2 (2.8)^{a}	9.7 (0.3) ^{a}	18.9 (0.5)^{ab}
5	Korean raspberry, wild, IV	4.6 (0.9)^{a}	33.8 (7.5)^{a}	8.7 (0.1)^{b}	19.9 (1.2)^{bc}
6	Thornless Korean raspberry, cultivated, IV	5.5 (0.5)^{a}	37.6 (3.2)^{a}	10.2 (0.6)^{c}	22.2 (1.0)^{c}
7	Golden Korean raspberry, cultivated, IV	7.2 (2.2)^{a}	49.2(8.7)^{a}	10.1 (0.2)^{c}	16.0 (0.3)^{a}
Mountain raspberry (*Rubus crataegifolius*)					
8	Mountain raspberry, cultivated, II	5.2 (0.6)^{ac}	41.7 (6.7)^{a}	11.4 (0.2)^{a}	18.3 (1.1)^{a}
9	Mountain raspberry, cultivated, III	3.9 (0.1)^{a}	26.2 (0.4)^{a}	14.2 (0.5)^{b}	13.9 (1.5)^{a}
10	Mountain raspberry, wild, IV	4.8 (0.3)^{ac}	34.5 (4.3)^{a}	11.0 (0.1)^{ac}	18.9 (2.3)^{a}
11	Ulleung Island-origin mountain raspberry, cultivated, II	9.9 (1.2)^{b}	57.0 (5.5)^{b}	9.8 (0.5)^{cd}	18.5 (5.0)^{a}
12	Chinese origin mountain raspberry, cultivated, II	5.9 (0.1)^{c}	45.2 (1.1)^{ab}	9.6 (0.6)^{d}	20.4 (1.5)^{a}
Blackberry (*Rubus fruticosus*)					
13	Blackberry, cultivated, II	9.1 (1.5)^{a}	61.6 (5.2)^{a}	9.0 (0.1)^{ac}	15.5 (0.5)^{ab}
14	Blackberry, cultivated, III	7.2 (0.7)^{ab}	51.4 (5.4)^{ab}	12.4 (2.3)^{b}	17.6 (3.2)^{b}
15	Thornless blackberry, cultivated, II	7.8 (0.1)^{ab}	58.4 (2.4)^{ab}	11.4 (0.5)^{bc}	12.8 (0.3)^{a}
16	Thornless blackberry, cultivated, IV	4.2 (0.1)^{c}	37.7 (0.6)^{c}	13.3 (0.1)^{b}	21.9 (0.4)^{c}
17	Groundling blackberry, cultivated; II	5.7 (0.4)^{bc}	47.6 (3.5)^{bc}	7.8 (1.5)^{a}	16.2 (0.4)^{ab}
Raspberry (*Rubus idaeus*)					
18	Red raspberry, cultivated, II	9.7 (0.7)^{a}	59.4 (2.6)^{a}	13.4 (1.2)^{a}	20.1 (4.3)^{a}
19	Yellow raspberry, cultivated, II	9.5 (0.4)^{a}	57.2 (4.6)^{a}	9.6 (0.2)^{b}	15.7 (0.1)^{a}
Boysenberry					
20	Boysenberry, cultivated, IV	5.4 (0.1)	54.5 (0.9)	14.3 (0.2)	12.9 (0.3)
Pomace					
21	Pomace of black raspberry	–	–	5.5 (0.3)	17.0 (4.0)
	Mean of 21 samples	6.9 (2.0)	47.5 (9.8)	11.3 (2.8)	18.1 (3.4)

Values are means (standard deviation) (n = 3)

I: From a farmer in Gochang, II: from Raspberry Experiment Station, Agricultural Technology Service Center in Gochang, III: from a farmer in Goseong, IV: from a farmer in Wanju

[a–d] Values within a column and the same types of berries with the same superscript are not significantly different ($p > 0.05$)

palms of hands separated residual berry pulp from the seeds. Pulp remained suspended in the water while the seeds were allowed to sink to the bottom of the container. After sufficient time for seed settling, the pulp and water mixture was decanted off from the seeds. Seeds were removed from the container and collected on a screen. Pigments on the seeds were washed off with tap water until the washing water was clear. Excess water was drained off from the seeds using a screen. Following the final washing, the seeds were spread onto cotton gauze to dry at room conditions for approximately 24 h. The seeds were stored in a plastic bag at room temperature and all analyses completed within 15 days.

Moisture and Crude Oil Contents

The moisture content of the berry seeds was determined using a drying oven (F-600M; Jeio-Tech. Co., Seoul, Korea) set at 104 °C for approximately 24 h. Crude oil content in the berry seeds was determined by the Soxhlet method using diethyl ether. About 3 g of the seeds were used for each determination of moisture and crude oil contents.

Oil Extraction for Fatty Acid Composition Analysis

Oil was extracted according to the Bligh and Dyer [11] method: dry seeds were ground in a mortar using a pestle by hand until all the seeds were crushed. Ground seeds (10 g) were blended for 30 s with 50 mL chloroform (Oriental Chemical Inc., Seoul, Korea), 100 mL methanol (Oriental Chemical Inc.), and 50 mL 0.88% KCl (Oriental Chemical Inc.) solution using a homogenizer (M133/1281-0; Biospec Products, Inc., Bartlesville, OK, USA). An additional 50 mL chloroform and 40 mL 0.88% KCl solution were added to the homogenized mixture. The mixture was blended again for an additional min. The blended mixture was transferred to a 250 mL centrifuge bottle and centrifuged for 20 min at 4,000 rpm (2,307×*g*) using a Supra 25 K centrifuge (Hanil Science Industrial Co., Incheon, Korea). The supernatant was transferred to a separatory funnel and allowed to settle for 40 min. The chloroform layer was collected through a Whatman No. 1 filter paper (Whatman International Ltd., Maidstone, England) with dry Na_2SO_4 to remove the moisture in the layer. Solvents in the chloroform layer were evaporated using an Eyela rotary vacuum evaporator (N-N; Tokyo Rikakikai Co, Ltd., Tokyo, Japan) connected with an Eyela aspirator (A-3S; Tokyo Rikakikai Co, Ltd.). The extracted oils, remaining after solvent evaporation, were flushed with nitrogen and stored in 15 mL test tubes at –40 °C until completion of the oil analysis.

Methylation of Oils

Fatty acid methyl esters (FAME) of the extracted oils were prepared according to an AOCS method [12]. Oil (0.2 g) was placed into a 50 mL round bottom flask. Four milliliter 0.5 N-methanolic NaOH (Jin Chemical Co., Ltd., Shiheung, Korea) was added into the flask. A condenser connected to cold tap water was attached on to the flask. The flask was heated on a mantle heater (SHE-106; Glas-Col Combo Mantle, Terre Haute, IN, USA) set at 80 °C for 10 min. Five mL BF_3–methanol (BDH Laboratory, Poole, England) was added through the condenser and the contents boiled for two additional min. Five milliliter hexane (H302-4; Fisher Scientific Korea Ltd., Seoul, Korea) was added through the condenser and the contents boiled for an additional min. After the mixture cooled to room temperature, saturated NaCl (Junsei Chemical Co., Tokyo, Japan) solution was added until the hexane floated into the neck of the flask. One mL of hexane layer was transferred into a 2 mL vial. The vial was flushed with nitrogen and sealed with a Teflon-faced screw cap. The vial was stored at –40 °C until the fatty acid profile was completed.

Analysis of Fatty Acid Composition Using GC

Compositions of the FAME were analyzed on a Hewlett-Packard 6980 Series Gas Chromatograph (Hewlett-Packard Co., Wilmington, DE, USA) equipped with a flame ionization detector and a split/splitless injector. The column was a DB-23 (0.25-mm i.d. × 30-m column with 0.25-μm film thickness; J&W Scientific, Folsom, CA, USA). Helium was the carrier gas and set at a flow of 1.4 mL/min. The column temperature was initially held at 160 °C for 2 min and then programmed at 3.5 °C/min to 250 °C and at 25 °C/min to 260 °C with a final hold of 5 min. Injector was set at 250 °C in a split mode with split ratio of 50:1. The detector temperature was 260 °C. One microliter of sample was injected. The FAME standards were purchased from Nu-Chek-Prep, Inc. (Elysian, MN, USA) and Supelco Co. (Bellefonte, PA, USA). The peaks of the FAME were identified comparing the retention times of the standards and fatty acid composition was calculated by the weight-based response factors of the standards.

Experimental Design and Statistical Analysis

Seed content, seed oil content and seed oil fatty acid composition within each type of the berries and among the different berry types were observed in an unstructured, random design. The observed mean values of 3 measurements for seed content, seed oil content and seed oil fatty acid composition within a berry type and among the different berry types were analyzed by one-way ANOVA

Table 2 Fatty acid compositions of the oils extracted from caneberry seeds

Berry sample code	Fatty acid (%, w/w)											
	16:0	18:0	18:1 (oleic)	18:1 (vaccenic)	18:2	18:3	20:0	20:1	20:2	20:3	22:0	USFA
Black raspberry (*Rubus occidentalis*)												
1	2.0^{a} (0.0)	0.0 (0.0)	8.7^{a} (0.1)	0.6 (0.0)	53.4^{a} (0.3)	32.5^{a} (0.2)	0.3 (0.0)	0.2 (0.0)	0.1 (0.0)	0.1 (0.1)	0.2 (0.0)	95.6^{a} (0.3)
2	2.0^{a} (0.0)	0.8 (0.0)	9.6^{b} (0.0)	0.6 (0.0)	53.0^{a} (0.1)	32.1^{a} (0.0)	0.4 (0.0)	0.3 (0.0)	0.1 (0.0)	0.0 (0.0)	0.2 (0.0)	95.8^{a} (0.1)
3	2.0^{a} (0.0)	0.8 (0.0)	8.3^{c} (0.0)	0.6 (0.0)	53.2^{a} (0.2)	33.6^{b} (0.2)	0.4 (0.0)	0.2 (0.0)	0.1 (0.0)	0.0 (0.0)	0.2 (0.0)	96.0^{a} (0.2)
Means	2.0^{A} (0.0)	0.5 (0.5)	8.9^{A} (0.7)	0.6 (0.0)	53.2^{A} (0.2)	32.7^{A} (0.8)	0.4 (0.1)	0.2 (0.1)	0.1 (0.0)	0.0 (0.1)	0.2 (0.0)	95.8^{A} (0.2)
Korean raspberry (*Rubus coreanus*)												
4	5.0^{a} (0.0)	2.8 (0.0)	10.9^{a} (0.1)	0.7 (0.0)	58.5^{a} (0.1)	20.0^{a} (0.1)	0.6 (0.0)	0.3 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	90.5^{ab} (0.2)
5	5.5^{b} (0.1)	2.5 (0.0)	13.1^{b} (0.1)	0.8 (0.0)	58.7^{a} (0.1)	17.5^{b} (0.2)	0.7 (0.0)	0.3 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	90.7^{a} (0.3)
6	5.4^{c} (0.0)	2.5 (0.0)	12.7^{c} (0.1)	0.8 (0.0)	57.9^{b} (0.2)	18.7^{c} (0.2)	0.7 (0.0)	0.3 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	90.6^{a} (0.1)
7	5.6^{b} (0.0)	2.5 (0.0)	10.3^{d} (0.0)	0.8 (0.0)	56.4^{c} (0.1)	22.1^{d} (0.1)	0.6 (0.0)	0.3 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	90.1^{b} (0.2)
Means	5.4^{B} (0.3)	2.6 (0.1)	11.8^{AB} (1.4)	0.8 (0.1)	57.9^{A} (1.0)	19.6^{B} (2.0)	0.7 (0.1)	0.3 (0.0)	0.1 (0.0)	0.1 (0.1)	0.1 (0.0)	90.5^{B} (0.3)
Mountain raspberry (*Rubus crataegifolius*)												
8	4.2^{ac} (0.0)	2.1 (0.0)	11.4^{a} (0.0)	0.7 (0.0)	61.9^{a} (0.1)	17.5^{a} (0.1)	0.8 (0.0)	0.3 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	92.1^{ac} (0.2)
9	4.2^{a} (0.0)	2.6 (0.0)	11.5^{a} (0.0)	0.7 (0.0)	61.3^{b} (0.1)	17.7^{a} (0.0)	0.6 (0.0)	0.2 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	91.6^{a} (0.1)
10	3.7^{b} (0.0)	1.4 (0.0)	13.8^{b} (0.0)	0.7 (0.0)	60.0^{c} (0.1)	18.4^{b} (0.1)	0.9 (0.0)	0.5 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	93.5^{b} (0.1)
11	4.1^{c} (0.0)	2.4 (0.0)	11.9^{c} (0.1)	0.6 (0.1)	59.2^{d} (0.2)	19.9^{c} (0.0)	0.6 (0.0)	0.3 (0.0)	0.1 (0.0)	0.1 (0.1)	0.1 (0.0)	92.0^{ac} (0.3)
12	3.9^{d} (0.0)	2.1 (0.0)	9.8^{d} (0.1)	0.7 (0.0)	60.7^{e} (0.3)	20.8^{d} (0.2	0.7 (0.0)	0.2 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	92.4^{c} (0.2)
Means	4.0^{C} (0.2)	2.1 (0.5)	11.7^{AB} (1.4)	0.7 (0.0)	60.6^{AB} (1.1)	18.9^{B} (1.4)	0.7 (0.1)	0.3 (0.1)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	92.3^{C} (0.7)
Blackberry (*Rubus fruticosus*)												
13	4.2^{a} (0.0)	2.4 (0.0)	9.2^{a} (0.0)	0.7 (0.0)	67.9^{a} (0.1)	13.4^{a} (0.0)	1.0 (0.0)	0.3 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	91.6^{a} (0.1)
14	4.2^{a} (0.0)	1.6 (0.0)	7.5^{b} (0.0)	0.7 (0.0)	69.8^{b} (0.2)	13.5^{a} (0.3)	0.9 (0.0)	0.4 (0.0)	0.2 (0.0)	0.1 (0.0)	0.1 (0.0)	92.1^{b} (0.2)
15	4.2^{a} (0.0)	2.7 (0.0)	10.9^{c} (0.0)	0.6 (0.0)	66.8^{c} (0.1)	12.5^{b} (0.0)	1.1 (0.0)	0.4 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	91.4^{a} (0.1)
16	4.1^{b} (0.0)	2.8 (0.0)	10.7^{c} (0.4)	0.4 (0.4)	66.4^{d} (0.1)	13.4^{a} (0.0)	1.0 (0.0)	0.3 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	91.6^{a} (0.2)
17	3.6^{c} (0.1)	1.8 (0.0)	15.4^{d} (0.4)	0.7 (0.0)	60.8^{e} (0.1)	15.3^{c} (0.2)	0.7 (0.0)	0.5 (0.0)	0.1 (0.0)	0.1 (0.0)	0.2 (0.0)	92.8^{c} (0.1)
Means	4.1^{C} (0.3)	2.3 (0.5)	10.7^{AB} (2.9)	0.6 (0.1)	66.3^{B} (3.4)	13.6^{B} (1.0)	0.9 (0.2)	0.4 (0.1)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	91.9^{BC} (0.6)
Raspberry (*Rubus idaeus*)												
18	3.0^{a} (0.0)	0.7 (0.0)	12.3^{a} (0.0)	0.7 (0.0)	48.5^{a} (0.1)	32.5^{a} (0.1)	0.3 (0.0)	0.3 (0.0)	0.1 (0.0)	0.0 (0.0)	0.3 (0.0)	94.4^{a} (0.2)
19	2.5^{b} (0.1)	0.7 (0.0)	11.1^{b} (0.1)	0.7 (0.0)	50.4^{b} (0.2)	32.4^{a} (0.3)	0.4 (0.0)	0.3 (0.0)	0.1 (0.0)	0.1 (0.0)	0.3 (0.0)	95.0^{a} (0.6)
Means	2.8^{D} (0.4)	0.7 (0.0)	11.7^{B} (0.8)	0.7 (0.0)	49.5^{A} (1.3)	32.5^{AB} (0.1)	0.4 (0.1)	0.3 (0.0)	0.1 (0.0)	0.1 (0.1)	0.3 (0.0)	94.7^{C} (0.4)
Boysenberry												
20	3.6 (0.0)	1.9 (0.0)	17.1 (0.1)	0.6 (0.0)	59.9 (0.1)	14.1 (0.1)	0.8 (0.0)	0.5 (0.0)	0.1 (0.0)	0.0 (0.0)	0.2 (0.0)	92.4 (0.1)

Table 2 continued

Berry sample code	Fatty acid (%, w/w)										
	16:0	18:0	18:1 (oleic)	18:1 (vaccenic)	18:2	18:3	20:0	20:1	20:2	20:3	22:0	USFA
Pomace												
21	2.3 (0.0)	0.9 (0.0)	9.1 (0.1)	0.6 (0.0)	54.3 (0.1)	31.8 (0.2)	0.4 (0.0)	0.2 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	96.0 (0.0)
Mean of 21 samples	3.8 (1.1)	1.8 (0.9)	11.2 (2.3)	0.7 (0.1)	59.0 (5.7)	21.4 (7.6)	0.7 (0.2)	0.3 (0.1)	0.1 (0.0)	0.1 (0.1)	0.1 (0.1)	92.8 (1.9)

Values are means (standard deviation) ($n = 3$) within the same types of berries

Statistical analyses were done only for palmitic, oleic, linoleic, linolenic, and total unsaturated fatty acids

USFA: sum of unsaturated fatty acids

1–21: See the sample codes in Table 1

[a–e] Values within a column and the same types of berries with the same small superscript are not significantly different ($p > 0.05$)

[A–D] Means within a column with the same capital superscript are not significantly different ($p > 0.05$) among the types of berries

($p < 0.05$). Significant means were compared using Sheffe's multiple range test ($p < 0.05$) with SPSS 12.0 (Chicago, IL, USA).

Results and Discussion

Seed Content

The caneberries, cultivated on farms and grown wild throughout the country (Korea), contained diverse amounts of seeds on a wet weight basis (Table 1). On average, the seeds comprised 4–10% (w/w) of the wet berries and accounted for 26–62% (w/w) of the dry berries. The same types of mountain raspberries and blackberries from different regions showed noticeable differences in seed weights per berry weights per type. However, the black raspberries cultivated in three different regions had similar amounts of seeds on a weight basis (code numbers 1–3). The cultivated Korean raspberry (code number 4) contained more seeds than the wild one (code number 5) on a weight basis without statistical significance. The wild mountain raspberry (code number 10) had the second smallest amount of seeds on a weight basis among the same five mountain raspberries (code numbers 8–12); however, the weights were not significantly different ($p > 0.05$). Similarly, Johansson et al. [6] observed that seeds within four different types of wild *Rubus* collected in Finland accounted for 8.5–12.2% of the fresh berry weight.

Moisture and Oil Contents

Moisture and oil contents of the berry seeds were also variable, ranging from 8 to 17% moisture (wet basis) and from 13 to 28% oil (dry basis) (Table 1). The same types of berries from different regions had significantly different amounts of oils in the seeds on a weight basis except mountain raspberries. No apparent connection was observed between the cultivation practices or harvest regions and the seed and oil contents in the berries. Therefore, it is difficult to infer anything about the influence of cultivation practices or harvest regions on seed and oil contents in the same types of berries. Oil contents of 10–23% [6], 11–18% [7], 16–18% [8], and 11% [9] on a dry weight basis for *Rubus* berry seeds were measured and reported by other researchers.

Fatty Acid Composition

The oils extracted from the caneberry seeds were composed of 49–70% linoleic, 13–34% linolenic, 8–17% oleic, 2–5% palmitic and 0–3% stearic acids (Table 2). The oils

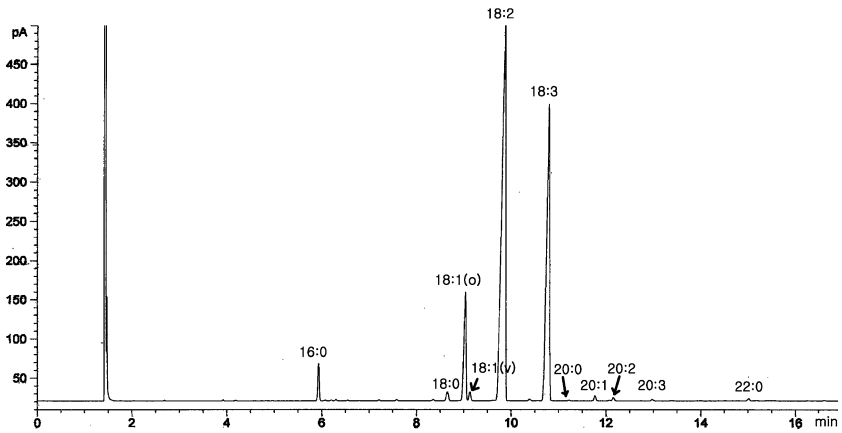

Fig. 1 Gas chromatogram of fatty acid composition of black raspberry seed oil

from the seeds in all the berries examined in this study consisted of more than 90% unsaturated fatty acids. The seed oils from the same types of berries were observed to have similar fatty acid compositions. For example, the seed oils from black raspberries (which are the major type of berries cultivated on farms in Korea) obtained from three different places (code numbers 1–3) contained 53% linoleic acid and 32–33% linolenic acid. Total unsaturated fatty acids comprised 96% of the oils from the black raspberries, which was the highest level among the tested berries. The fatty acid composition of the seed oil from the pomace of black raspberry (code number 21) was similar (Table 2; Fig. 1) to those of the black raspberries (code numbers 1–3) of this study. Levels of each of the major fatty acids within the same types of berries were significantly different. Variation of the fatty acid compositions appeared to be minimally influenced by cultivation practices or harvest regions. Significant differences among the fatty acid compositions of the oils from the different types of the berries were observed. In comparison, the oils from seeds of four different types of *Rubus* were composed of 41–70% linoleic, 13–36% linoleic, and 11–17% oleic acids, as reported by Johansson et al. [6]; the oils from seeds in five caneberry (*Rubus*) species were composed of 53–63% linoleic and 15–31% linoleic acids as reported by Bushman et al. [7]; the oils from seeds in *Rubus idaeus* were composed of 56% linoleic, 33% linoleic, and 19% oleic acids as reported by Pourat and Carnat [8]; and 55% linoleic, 29% linoleic, and 12% oleic acids as reported by Oomah et al. [9].

Seeds in caneberries can be a good source of oils due to their abundance in the berries and their high oil content. For example, if half of the seeds as by-products from production of berry wine in Korea were used for oil production, about 3 metric tons of oils would be produced annually from the berry seeds. Although this amount accounts for a very small portion of the oil production in Korea, the berry oil could be a specialty item, since more than 90% of the total fatty acids in the oils are unsaturated and that the content of linoleic and linolenic acids of the oils is notably higher than other vegetable oils. In comparison, soybean oil has 51% linoleic acid and 7% linolenic acid; sunflower seed oil has 66% linoleic acid and 0.4% linolenic acid; grape seed oil has 70% linoleic acid and 0.1% linolenic acid; and flax seed oil has 13% linoleic acid and 55% linolenic acid [13]. Additionally, other researchers [9, 10] observed high tocopherol contents, good lipid oxidation stability and anti-inflammatory activity in the berry oils, thus, the value of the oils appears to be great.

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