Journal of Food Studies
ISSN 2166-1073
2018, Vol. 7, No. 1

Aroma Components from Baked Soybean Oil Extracted by CO_2 Supercritical Fluid Extraction

Xinchu Weng

School of Food Engineering, Qinzhou University, 12 Binghai Avenue, Qinzhou, Guangxi, China

School of Life Sciences, Shanghai University, Shanghai, China

Tel: 86-13045678885 E-mail: wxch@staff.shu.edu.cn

Tuo Wang

School of Life Sciences, Shanghai University, Shanghai, China

Chenxiao Zhang

School of Food Engineering, Qinzhou University, 12 Binghai Avenue, Qinzhou, Guangxi, China

Received: July 9, 2017 Accepted: December 2, 2017 Published: December 5, 2017

doi:10.5296/jfs.v7i1.11527 URL: https://doi.org/10.5296/jfs.v7i1.11527

Abstract

Baked soybean oil has desired aroma which is loved by most of people. Soybean oil is one of most important vegetable oils consumed in the world. Analysis of aroma components from Baked Soybean Oil extracted by CO_2 Supercritical Fluid Extraction (SFE-BSO) was performed by Gas Chromatography-Mass Spectrometry (GC-MS). The aroma components of SFE-BSO were extracted by Simultaneous Distillation Extraction (SDE). Thirty four aroma compounds in SFE-BSO were identified. 3-Methyl-1-butanol and other eleven compounds were the key aroma compounds of SFE-BSO, which were analyzed by GC-Sniffing technique.

Keywords: Baked soybean oil (BSO), Supercritical fluid extraction (SFE), Flavor analysis, Aroma component

1. Introduction

Soybean oil plays an important role in Chinese market as well as in the world edible oil market because of its abundant raw material source. It is significant to develop new types of soybean oil to meet different consumers' requirements. Traditional processes of soybean oil are mainly two types: solvent extraction and mechanical pressing. Solvent extraction can increase the yield, but lead to solvent residues in oils and environmental pollution (Boutin & Badens, 2009). Furthermore, it is impossible to produce the special oils with strong pleasant flavor which consumers prefer, e.g., strong aroma sesame oil and olive oil etc., on account of the great loss of aroma happening in the solvent recovery process.

Cold-pressing is a kind of environment-friendly and mechanical process, it preserves soybean oil nutrient components completely. However, because lipoxygenases exists in soybean, cold-pressing soybean oil usually has an inherent beany flavor which affects its commercial value of products. In the hot-pressing process, the inherent beany flavor in soybean oil is produced very little and is covered by intensive roasted soybean aroma formed in the *Maillard* reaction between amino acids and reducing sugars. But low oil yield restricts the industrial application of the technique (Liu et al., 2009).

CO_2-Supercritical fluid extraction (SFE) is considered to be a green process with a fast extraction speed, simple post-processing, high efficiency and high yield, because CO_2 is non-toxic, non-flammable, odorless, solvent residue-free and recyclable (Friedrich et al., 1982; Han et al., 2009; Rui et al., 2009). SFE is carried out under a relatively low extraction temperature, which overcomes the decomposition of unstable substances and flavor loss in traditional process, so that the natural flavor and nutrients can be well preserved in the extract.

Considering the advantages of CO_2-SFE process, a method to produce a new type of baked soybean oil (SFE-BSO) was established: CO_2-SFE process was introduced to extract soybeans after baked and powdered. SFE-BSO was totally different from the traditional soybean oil for its full-bodied baked soybean flavor and no beany flavor can be smelled because lipoxygenases are completely inactivated during baking under high temperature. There is no solvent residue problem because there are not any solvents to be used in the whole processing. By now, no such SFE-BSO production process was reported in our knowledge.

In the earlier experiment, we investigated the preparation technique of SFE-BSO by introducing CO_2-SFE method into extracting baked soybean, and satisfactory results were obtained (Wang et al., 2009). The detailed methods and results of preparation of SFE-BSO have been reported in our recently published paper (Wang et al., 2009). On basis of the previous research (Wang et al., 2009), aroma and volatile components in SFE-BSO were isolated, analyzed and identified, and compared to those in soybean oil produced from traditional solvent-extraction in this study.

2. Materials and Methods

2.1 Soybean Samples and Reagents

Soybean, *Glycine max* (L.) Merr., purchased from local market, was rinsed with distilled water, and dried to a moisture content of 10% in an oven under the temperature of 50 ºC. Then the dried soybean was baked under the temperature of 170 ºC for 30 min. After cooling to ambient temperature, it was powdered and sieved through a 40-mesh sieve.

All the reagents were of analytical grade and purchased from Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China).

2.2 Preparation of BSO by CO_2 Supercritical Fluid Extraction

The 40-mesh baked soybean powder was placed into the stainless-steel extraction vessel of HA220-50-06 SFE apparatus (Hua'an Inc., Nantong, China) and extracted by supercritical fluid CO_2 under Pressure 25 MPa at 50 ºC for 2.5 h, and BSO was obtained in separation vessel (Wang et al., 2009). In addition, other two oil samples were obtained for comparison by extracting the raw soybean powder and the baked soybean powder with Soxhlet extraction method.

2.3 Volatile Extract of BSO Prepared by SDE

Volatile extract from BSO was obtained by Simultaneous Distillation Extraction (SDE) with a modified Likens- Nickerson apparatus. The mixture of 100 g BSO sample and 250 ml deionized water was added into a 500 ml round-bottomed flask and heated at 135 ± 1 ºC in an oil bath. A hundred milliliter mixed solvent (Ethyl ether: n-Pentane = 1:1, v/v) was added to a 250 ml round-bottomed flask and heated at 38 ± 1 ºC in a water bath. The BSO was extracted in the SDE apparatus for 4 h at atmosphere pressure and cooled to 1 ± 0.5 ºC by a Super-cool bath. After extraction, the SDE extract was dried with anhydrous sodium sulphate and refrigerated for 12 h, and then the sodium sulphate was removed. Finally, the SDE extract was concentrated to approximate 10 ml by an evaporator, filtered by 0.45 μm organic filter membrane and then concentrated to 0.5 ml for injection by a stream of nitrogen.

2.4 Identification by GC–MS and GC–olfactometry

1 μL SDE extract of BSO was injected into a Varian CP 3800 gas chromatography coupled with a Saturn 2200 mass spectrograph (Varian Inc., U.S.A.). Separation of volatile components was achieved on a 30 m × 0.25 mm × 0.25 μm VF-5ms fused silica capillary column (Varian Inc., U.S.A.). Carrier gas: Nitrogen gas with a constant flow rate of 1 ml/min and the split ratio is 100:1. The oven temperature was programmed from 60 to 150 ºC at a rate of 2 ºC /min and then increased to a final temperature of 280 ºC at a rate of 20 ºC /min and with final holding time of 10 min. For the mass spectrometry, the electron ionization energy was set at 70 eV. The mass range was set at m/z 29-400. Injector and ion source temperatures were maintained at 250 and 260 ºC, respectively. Volatile compounds were tentatively identified both by matching mass spectral data with known compounds in National Institute of Standards and Technology (NIST) and Wiley's database, and by comparison of retention times with authentic compounds, then quantified by using 0.015 g dodecane as internal standard. The volatile extract of SFE-BSO was also injected into GC with the column purged into a tube of 1 ml 25 ºC distilled water, and immediately sent to perform description analysis by a panel made up of 6 trained, experienced panelists.

3. Results and Discussion

3.1 Identification of Volatile Compounds from BSO

SFE-BSO exhibited a pleasant nutty, oily, and baked odor. The chromatogram of volatile extract and the volatile components from SFE-BSO is shown in Figure 1 and Table 1 respectively. As can be seen from Table 1, thirty-four volatile components from SFE-BSO were identified by GC-MS spectrometer, including 6 alcohols (12.88%), 3 aldehydes (1.8%), 3 ketones (1.99%), 2 acids (2.78%), 1 ester (0.76%), 6 phenols (37.28%), 13 nitrogen-containing compounds (42.5%), among them, furfuryl alcohol (4), 2.17%; hexanol (5), 7.30%; guaiacol (16), 4.17%; 4-vinyl phenol (18), 10.18%; 4-vinylguaiacol (20), 19.26%; pyrrole (22), 5.89%; 2-methyl pyrazine (23), 2.35%; 2,5-dimethyl pyrazine (24), 11.12%; ethyl methyl pyrazine (28), 3.21%; trimethyl pyrazine (29), 4.77%; ethyltrimethyl pyrazine (30), 5.39%; 2,3-diethylpyrazine (31), 3.57% were the major components in SFE-BSO with an amount more than or equal to 2%. These twelve compounds accounted for 79.38% of total volatile components in SFE-BSO and the others accounted for the rest 20.62 %.

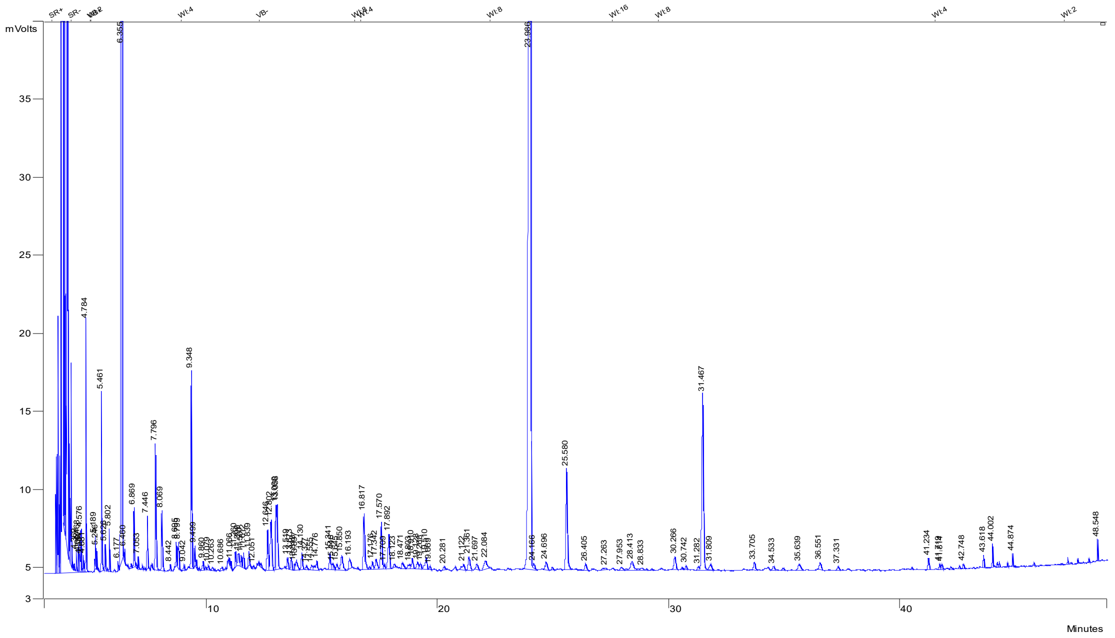

Figure 1. Gas chromatogram of volatile components in SFE-BSO

The experiment was performed by a Varian CP 3800 gas chromatography coupled with a Saturn 2200 mass spectrograph; Separation was performed by a VF-5ms fused silica capillary column (5% phenyl 95% dimethylpolysiloxane, 30 m × 0.25 mm × 0.25 μm); Oven temperature: programmed from 60 to 150 ºC at a rate of 2 ºC /min, then increased to a final temperature of 280 ºC at a rate of 20 ºC /min and finally held for 10 min; Injector and ion source temperatures were maintained at 250 and 260 ºC, respectively.

With the same experimental condition, soybean oils extracted by solvent extraction from raw soybean powders and baked soybean powders were also tested. No typical aroma components in raw soybean oil were significantly detected. Comparisons were made between SFE-BSO and the roasted soybean oil obtained by Soxhlet extraction (Soxhlet-BSO) according to volatile components. The chromatogram of volatile extract and the volatile components from Soxhlet-BSO are showed in Figure 2 and Table 2 respectively. As can be seen from Table 2, only twelve volatile components from Soxhlet-BSO were identified by GC-MS spectrometer, and were fairly low in concentration. Both the amounts and varieties of volatile compounds detected in Soxhlet-BSO were less than those in SFE-BSO. Alcohols, aldehydes, ketones, acids, ester, phenols, and nitrogen-containing compounds were enriched the comprehensive roasted soybean flavor in SFE-BSO, however, only 5 alcohols, 1 aldehyde and 6 nitrogen-containing compounds consisted of the overall flavor in Soxhlet-BSO.

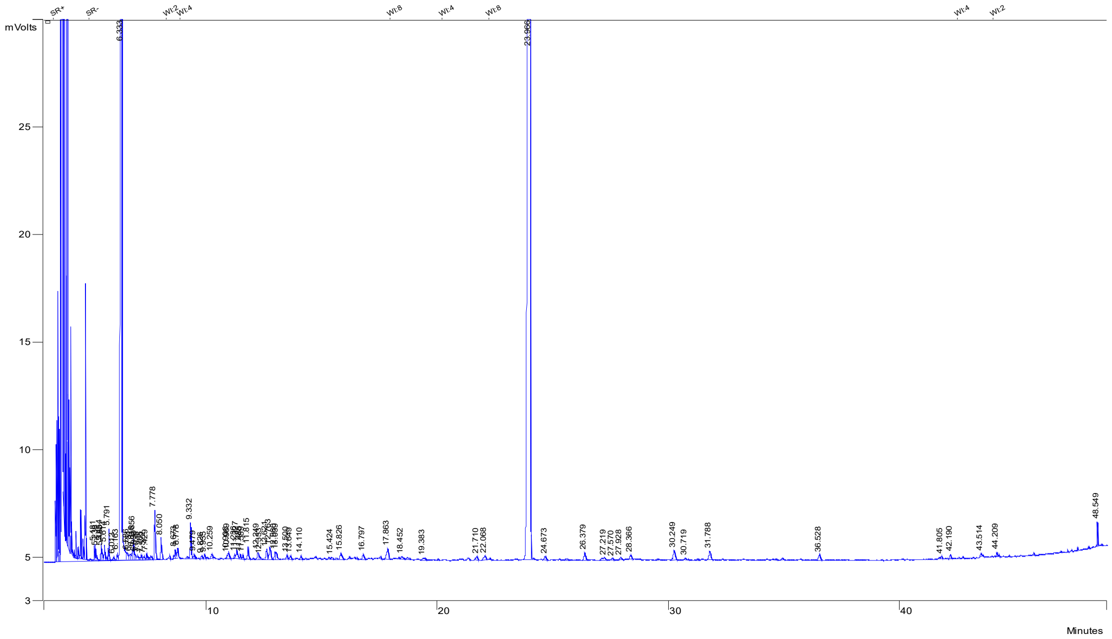

Figure 2. Gas chromatogram of volatile components in Soxhlet-BSO

The experiment was performed under the exactly same conditions as shown in Figure 1.

Flavors in raw soybean oil mainly originated from lipids and fat-soluble components in soybean and most volatile compounds were from fatty acids, especially unsaturated fatty acids. In addition, some other volatile compounds came from lipids oxidation, such as thermal decomposition of oleic acid, linoleic acid, and linolenic acid, or secondary products of hydroperoxides formed in the lipids oxidation (Li et al., 1992).

Beany odor or green odor, often described as unpleasant and smelly was primary flavor in traditional soybean oil which was extracted from raw soybeans. Most consumers dislike beany odor, so manufacturers remove this beany flavor by high temperature and high vacuum deodorization so as to obtain satisfied sensory performance. Lipoxygenases exist in raw soybeans could speed up oxidation of polyunsaturated fatty acids (Hildebrand et al., 1990), such as linoleic acid and linolenic acid, which contained 1,4-(E,E)-pentadiene structure, and produce hydroperoxides with conjugated double bond. On the other hand, such a similar non-enzymatic mechanism may occur in raw soybean by autoxidation of linolenic, isolinolenic acid (Smouse, 1979). These hydroperoxides decomposed into huge amounts of volatile components, such as various kinds of short-chain alcohols, ketones, aldehydes etc., which brought unpleasant beany flavor to soybean and soybean products. Many researchers have investigated volatile substances related to beany odor in soybean and soybean oil. (Kao et al., 1998; King et al., 1998; Jackson & Giaherio, 1977; Mattick & Hand, 1969).

Table 1. Volatile flavor compounds in SFE-BSO

No.	RT	Compound Name	Area (counts)	Concentration (μg/g)	Percentage (%)
		Alcohols			
1	5.189	3-Methyl-1-butanol	3108	0.69	0.99
2	5.246	2-Methyl-1-butanol	1833	0.41	0.59
3	5.626	Pentanol	3284	0.73	1.05
4	7.446	Furfuryl alcohol	6786	1.52	2.17
5	7.796	Hexanol	22840	5.10	7.30
6	11.839	1-Octen-3-ol	2444	0.55	0.78
		Aldehydes			
7	6.177	Hexanal	1229	0.27	0.39
8	7.053	Furfural	1763	0.39	0.56
9	31.809	2,4-Decadienal	2671	0.60	0.85
		Ketones			
10	8.442	2-heptanone	1057	0.24	0.34
11	36.551	β-Damascenone	2672	0.60	0.85
12	43.618	Megastigmatrienone	2499	0.56	0.80
		Acids			
13	5.802	Butyric acid	4467	1.00	1.43
14	11.396	Hexanoic acid	4219	0.94	1.35
		Esters			
15	48.548	Methyl palmitate	2385	0.53	0.76
		Phenols			
16	17.57	Guaiacol	13036	2.91	4.17
17	18.91	Maltol	3116	0.70	1.00
18	25.58	4-Vinyl phenol	31871	7.12	10.18

19	28.413	4-Ethyl guaiacol	5711	1.28	1.82
20	31.467	4-Vinyl guaiacol	60288	13.46	19.26
21	33.705	2,6-Dimethoxyl phenol	2653	0.59	0.85
N-containing compounds					
22	5.461	Pyrrole	18430	4.12	5.89
23	6.869	2-Methyl pyrazine	7357	1.64	2.35
24	9.348	2,5-Dimethyl pyrazine	34811	7.77	11.12
25	9.499	2-Ethyl pyrazine	3309	0.74	1.06
26	9.86	2,3-Dimethyl pyrazine	2259	0.50	0.72
27	12.051	2-Pentylfuran	1061	0.24	0.34
28	12.646	Ethyl methyl pyrazine	10053	2.25	3.21
29	13.058	Trimethyl pyrazine	14927	3.33	4.77
30	16.817	Ethyltrimethyl pyrazine	16866	3.77	5.39
31	17.892	2,3-Diethylpyrazine	11169	2.50	3.57
32	19.51	2-Acetyl-3-methyl pyrazine	4950	1.11	1.58
33	21.122	2,3-Diethyl-5-methyl pyrazine	2685	0.60	0.86
34	21.361	3,5-Diethyl-2-methyl pyrazine	5144	1.15	1.64
	23.986	Dodecane (Internal standard)	671615	—	—

3-Methyl-1-butanol (Table 1, No. 1), hexanol (Table 1, No. 5), 1-octen-3-ol (Table 1, No. 6) hexanal (Table 1, No. 7) were considered as the major contributors of beany odor (Katoa et al., 1981; Sugawara et al., 1985). Mattick and Hand (1969) reported that ethyl vinyl ketone formed in the catalytic oxidation of unsaturated fatty acids, mainly by lipoxygenases, attributed to the beany odor in soybeans. Hexanal is often considered as an indicator of flavor quality of soybean oil. The more hexanal there is in soybean oil, the lower the flavor quality of oil is (Steenson et al., 2002). In our study, hexanal, hexanol, 1-octen-3-ol, 3-methyl-1-butanol were also detected in SFE-BSO and Soxhlet-BSO, and could be considered as raw bean flavor with beany odor. The concentration of hexanal in SFE-BSO was 0.27 μg/g with a relative percentage of 0.39%, as compared with 23.5% in flavor extract of soybean oil which has a peroxide value is 5 meq/kg (Steenson et al., 2002), which reflects low oxidation of soybean oil and fresh raw soybean material.

Soybean oil could be gifted with strong aroma flavors after heat treatment of soybeans such as roasting, baking and frying for proper time under proper temperature. In the baking process, numerous non-enzymatic reactions occurred within soybeans, especially *Maillard* reaction, degradation of vitamins, decompositions of lipids, monosaccharides and amines (Belitz, Grosch, & Schieberle, 2004). Complex products, such as *Strecker* aldehydes, furans, pyrazines, pyrroles, and pyridines, were formed in the matrix of amino acids and reducing sugar by carbonyl-ammonia reaction due to the abundant protein in soybeans (Boekel, 2006).

Table 2. Volatile flavor compounds in Soxhlet-BSO

No.	RT	Compound Name	Area (counts)	Concentration (μg/g)	Percentage (%)
		Alcohols			
1	5.181	3-Methyl-1-butanol	1288	0.27	4.97
2	5.238	2-Methyl-1-butanol	848	0.18	3.27
3	5.614	Pentanol	1907	0.40	7.35
4	7.778	Hexanol	7437	1.57	28.7
5	11.815	1-Octen-3-ol	1975	0.42	7.61
		Aldehydes			
6	6.163	Hexanal	863	0.18	3.33
N-containing compounds					
7	6.586	2-Methyl pyrazine	1688	0.36	6.51
8	9.332	2,5-Dimethyl pyrazine	4918	1.04	19
9	9.479	2-Ethyl pyrazine	762	0.16	2.94
10	12.333	2-Pentylfuran	610	0.13	2.35
11	12.621	Ethyl methyl pyrazine	1995	0.42	7.69
12	13.039	Trimethyl pyrazine	1648	0.35	6.35
	23.966	Dodecane (Internal standard)	710563	—	—

Pyrazines had baked nut-like and typical baked peanut aroma (Maga et al., 1973), often detected abundantly in baked peanuts, baked coffee bean and other baked foods, and were also primary contributors to the overall flavor of baked soybeans. As seen in Table 1 and Table 2, 11 pyrazines and 5 pyrazines in SFE-BSO and Soxhlet-BSO were identified respectively, which provided evidence to the formation of pyrazines in soybeans when they were baked. This is the main reason that flavor of soybeans changed to pleasant baked odor from beany odor when baking, because the flavor of newly formed pyrazines masked the innate beany odor. Furthermore, the thermal process inactivated lipoxygenases, which prevented soybeans from generating new off-flavors. These enzymatic reactions take place only in fresh raw soybeans without baking when soybeans were cracked and powdered. Therefore, soybeans powdered after being baked released overall satisfying aromas with a trait of beany odor. The concentration of pyrazine from Soxhlet-BSO barely exceeded 1.0 μg/g as shown in Table 2, but eight from eleven pyrazines in SFE-BSO were of higher concentration comparatively as seen in Table 1. Among 11 pyrazines in SFE-BSO, the most significant was 2,5-dimethylpyrazine (Table 1, No. 24), its concentration is 7.77 μg/g, which is about 7 times of that from Soxhlet-BSO (1.04 μg/g). Jung and others (1997) reported that 2,5-Dimethylpyrazine was the most abundant among 9 pyrazines produced from baked soybean oil. 2,5-Dimethylpyrazine could be detected in cysteine-pyruvaldehyde model reaction system, and considered degradation by-products of *Maillard* reaction and *Heyns* arrangement (Li et al., 1992). For its significance, 2,5-dimethylpyrazine could be seen as an indicator of pyrazine compounds and baked flavor. The significant difference in concentration of 2,5-dimethylpyrazine between SFE-BSO and Soxhlet-BSO resulted in different aroma extraction methods. In the Soxhlet extraction, huge amounts of aroma components including volatile pyrazines are lost greatly by vacuum evaporation in the process of solvent recovery, but this could not happen in the supercritical fluid extraction. Therefore, much more pyrazines could be extracted in SFE-BSO than in Soxhlet-BSO. The content of other aroma components confirmed that the performance of SFE-BSO is better than Soxhlet-BSO in sensory evaluation.

Lipids in soybeans could be decomposed to large quantities of aromas by thermal oxidation, and these fat-soluble volatiles would be extracted in the extracts of BSO. Soybeans contain plenty of unsaturated fatty acids which are mainly oleic, linoleic, linolenic acids approximately 85%. These unsaturated fatty acids could be deteriorated to aldehydes, olefinic alcohol, olefinic aldehydes, or alkylfurans. 2-Pentylfuran (Table 1, No. 27) might be the possible product of unsaturated lipids degradation. Chang and others (1983) considered 2-pentylfuran as a product of linoleic acid autoxidation which contributed to the reversion flavor of soybean oil. Shown in Tables 1 and 2 showed that there was only 0.24 and 0.13 μg/g 2-pentylfuran from SFE-BSO and Soxhlet-BSO respectively, which reflects less green and beany odors.

β-Damascenone (Table 1, No. 11) (0.60 μg/g) and Megastigmatrienone (Table 1, No. 12) (0.56 μg/g) from SFE-BSO might be the thermal degradation products of carotenoids like β-carotene when soybeans were baked. The low concentration of these ketones may contribute to carotenoids in soybean. None of ketones were detected from Soxhlet-BSO.

Some phenols occurred in the baking of soybeans, such as guaiacol and its derivatives. The formation of these phenols might be related to the degradation of lignin with plenty of aromatic groups (Liu & Zhou, 1992). Soybean contained huge amount of lignin which provide the possibility to produce characteristic aroma of baked soybean. Six phenols, including guaiacol (Table 1, No. 16), maltol (Table 1, No. 17), 4-vinyl phenol (Table 1, No. 18), 4-ethyl guaiacol (Table 1, No. 19), 4-vinyl guaiacol (Table 1, No. 20), and 2,6-dimethoxyl phenol (Table 1, No. 21), which accounted 37.28% of volatile components were detected from SFE-RSO. None of them were detected from Soxhlet-BSO. 4-Vinyl guaiacol was the most abundant volatile compound in baked soybean aroma with concentration of 13.46 μg/g, accounted 19.26% of total volatile mass. Guaiacol related compounds are characteristic volatile components in the thermal process of soybeans and had very low odor thresholds in water (Belitz et al., 2004). For instance, the threshold of guaiacol (2.91 μg/g) in water was 0.02 ppm (Wu & Cadwallader, 2002). Therefore, guaiacol related compounds had a relatively high aroma value (Belitz et al., 2004). The Aroma Value (AV) is equal to Concentration/Threshold, which indicates the contribution of component to the odor of sample.

3.2 GC-olfactometry Analysis of Volatile Compounds of SFE-BSO

In the GC-olfactometry analysis, outflow of volatile components of SFE-BSO from the chromatographic column were purged into a small tube with 1ml 25 ºC distilled water, and immediately sent to perform description analysis by a panel. As shown in Table 3, twelve compounds were found to contribute to the overall flavor from SFE-BSO, and each compound was evaluated by sensory description. Fusel alcohol, whisky, ether, beany, grass, woody, caramel, earthy, burning, sweet, baked, harsh, smoky, nutty, fruity, rose, clove were the major odors in SFE-BSO. These volatile substances expressed different sensory properties involving in characteristic and intensity, the former made odors identified and the latter showed the odor strength that always evaluated by odor threshold. Pyrrole (Table 1, No. 22) accounts for 5.89% in the flavor extract from SFE-BSO, but it only showed extremely light sweet odor. On the contrary, 2,3-diethyl-5-methyl pyrazine (Table 1, No. 33) and β-damascenone gave strong odor impressions in spite of less than 1%. 2,5-Dimethylpyrazine, trimethylpyrazine (Table 1, No. 29), guaiacol, 2,3-diethyl-5-methyl pyrazine, 4-vinyl phenol mainly expressed burning, caramel, baked, smoky, nutty, fruity, rose, harsh, sweet aroma, and these aromas exhibited agreeable baked soybean flavor which masked the unacceptable odor from hexanal, hexanol, 2-pentylfuran, for instance beany and grass green odors. The most significant five volatile compounds which have four more "+" could only detected from SFE-BSO, thus aroma from Soxhlet-BSO was not as acceptable as that from SFE-BSO.

Table 3. Sniffing Evaluation of Volatile Aromas from SFE-BSO (ordered by Retention Time)

RT [a]	Aroma description	Odor intensity	Compound name	Percentage (%)
5.189	Fusel alcohol, whisky	+ + [b]	3-Methyl-1-butanol	0.99
5.461	Ether, sweet	+	Pyrrole	5.89
6.177	Beany	+ + +	Hexanal	0.39
7.796	Grass, woody	+ +	Hexanol	7.30
9.348	Burning, caramel	+ + +	2,5-Dimethylpyrazine	11.12
12.051	Green	+ + +	2-Pentylfuran	0.34
13.058	Earthy	+ + +	Trimethylpyrazine	4.77
17.570	Smoky, burning, sweet	+ + + +	Guaiacol	4.17
21.122	Earthy, roasted, burnt	+ + + +	2,3-Diethyl-5-methyl pyrazine	0.86
25.580	Harsh, smoky	+ + + +	4-Vinyl phenol	10.18
31.467	Baked, nutty, fruity, clove	+ + + +	4-Vinyl guaiacol	19.26
36.551	Rose	+ + + + +	β- Damascenone	0.85

[a] RT: Retention time; [b] "+"means the odor intensity, the more "+", the stronger the odor.

4. Conclusions

A kind of novel aromatic soybean oil with high quality was successfully obtained employing CO_2-SFE technique to extract baked soybeans, and this technique could produce specific soybean oil with fantastic flavors and excellent edible qualities. The volatile compounds in SFE-BSO were identified by GC-MS as comparing to those from Soxhlet-BSO. Apparently, SFE-BSO exhibited more satisfying flavor than Soxhlet-BSO, not only in subjectively sensory evaluation, but also in tentatively qualification and quantification results. These results provided evidence that SFE could mostly retain much more volatile components or flavor than solvent extraction. Great loss of aroma components occurred when solvent was removed from Soxhlet-BSO, which led to unsatisfying sensory performance. SFE had no such problem because of its relatively low separation temperature and high pressure, thus abundant aroma substances retained in the SFE-BSO. Simulated commercial soybean oil was extracted by solvent extraction from raw soybean powders, in which no typical aroma component could be significantly detected, as the concentration of aroma substances was extremely low so that it could not reach the limit of detection in such experimental condition. Major characteristic components, such as 3-methyl-1-butanol, pyrrole, hexanal, hexanol, 2,5-dimethylpyrazine, 2-pentylfuran, trimethylpyrazine, guaiacol, 2,3-diethyl-5-methyl pyrazine, 4-vinyl phenol, 4-vinyl guaiacol and β-damascenone, contributed to overall flavor were evaluated by GC- olfactometry.

References

Belitz, H. D., Grosch, W., & Schieberle, P. (2004). *Food chemistry*, (3rd revised edition.) Belin: Springer.

Boekel, M. V. (2006). Formation of flavour compounds in the Maillard reaction. *Biotechnology Advances, 24*, 230-3. https://doi.org/10.1016/j.biotechadv.2005.11.004

Boutin, O., & Badens, E. (2009). Extraction from Oleaginous Seeds Using Supercritical CO_2: Experi- mental Design and Products Quality. *Journal of Food Engineering, 92*, 396-402. https://doi.org/10.1016/j.jfoodeng.2008.12.007

Chang, S. S., Shen, G. H., & Tang, J. (1983). Isolation and identification of 2-pentenylfurans in the reversion flavor of soybean oil. *J Am Oil Chem Soc, 60*(3), 553-7. https://doi.org/10.1007/BF02679785

Friedrich, J. P., List, G. R., & Heakin, A. J. (1982). Petroleum-Free Extraction of Oil from Soybeans with Supercritical CO_2. *J Am Oil Chem Soc, 59*(7), 288-92. https://doi.org/10.1007/BF02662228

Han, X. J., Cheng, L. M., & Zhang, R. (2009). Extraction of Safflower Seed Oil by Supercritical CO_2. *Journal of Food Engineering, 92*, 370-6. https://doi.org/10.1016/j.jfoodeng.2008.12.002

Hildebrand, D. F., Hamilton-Kemp, T. R., & Loughrin, J. H. (1990). Lipoxygenase 3 Reduces Hexanal Production from Soybean Seed Homogenates. *J Agric Food Chem, 38*(10), 1934-6. https://doi.org/10.1021/jf00100a012

Jackson, H. W., & Giacherio, D. J. (1977). Volatiles and Oil Quality. *J Am Oil Chem Soc, 10*, 458-460. https://doi.org/10.1007/BF02671035

Jung, M. Y., Bock, J. Y., & Back, S. O. (1997). Pyrazine contents and oxidative stabilities of roasted soybean oils. *Food Chem, 60*(1), 95-102. https://doi.org/10.1016/S0308-8146(96)00316-0

Kao, J. W., Hammond, E. G., & White, P. J. (1998). Volatile Compounds Produced During Deodorization of Soybean Oil and Their Flavor Significance. *J Am Oil Chem Soc, 75*(9), 1103-7. https://doi.org/10.1007/s11746-998-0297-z

Katoa, H., Doia, Y., & Tsugitaa, T. (1981). Changes in volatile flavour components of soybeans during roasting. *Food Chem, 7*(2), 87-94. https://doi.org/10.1016/0308-8146(81)90053-4

King, J. M., Svendsen, L. K., Fehr, & W. R. (1998). Oxidative and Flavor Stability of Oil from Lipoxygenase-Free Soybeans. *J Am Oil Chem Soc, 75*(9), 1121-6. https://doi.org/10.1007/s11746-998-0300-8

Li, H., Li, P. W., & Yu, Z H. (1992). *Food Flavoring Chemistry: Heterocycle Aroma Compounds*. (1st ed.) Beijing: China Light Industry Press. https://doi.org/10.1021/jf00024a028

Liu, Q. K., & Zhou, R. B. (1992). The volatile components of sesame oil. *Journal of Zhengzhou Grain College, 3*, 1-14.

Liu, W., Fu, Y. J., & Zu, Y. G. (2009). Supercritical Carbon Dioxide Extraction of Seed Oil from Opuntia Dillenii Haw. and Its Antioxidant Activity. F*ood Chem, 114*, 334-9. https://doi.org/10.1016/j.foodchem.2008.09.049

Maga, J. A., & Sizer, C. E. (1973). Pyrazines in Foods. A Review. *J Agric Food Chem, 21*(1), 22-30. https://doi.org/10.1021/jf60185a006

Mattick, L. R., & Hand, D. B. (1969). Identification of a Volatile Component in Soybeans That Contributes to the Raw Bean Flavor. *J Agr Food Chem, 17*(1), 15-7. https://doi.org/10.1021/jf60161a006

Rui, H. M., Zhang, L. Y., & Li, Z. W. (2009). Extraction and characteristics of seed kernel oil from white pitaya. *Journal of Food Engineering, 93*, 482-6. https://doi.org/10.1016/j.jfoodeng.2009.02.016

Smouse, T. H. (1979). A Review of Soybean Oil Reversion. *J Am Oil Chem Soc, 56*(11), 747-51. https://doi.org/10.1007/BF02667435

Steenson, D. F., Lee, J. H., & Min, D. B. (2002). Solid Phase Microextraction of Volatile Soybean Oil and Corn Oil Compounds. *J Food Sci, 67*(1), 71-6. https://doi.org/10.1111/j.1365-2621.2002.tb11361.x

Sugawara, E., Ito, T., & Odagiri, S. (1985). Comparison of Compositions of Odor Components of Natto and Cooked Soybeans. *Agric Biol Chem, 49*(2), 311-7. https://doi.org/10.1080/00021369.1985.10866740

Wang, T., Xu, J. B., Hou, J. P., Li, L. H., & Weng, X. C. (2010). Development of Aromatic Soybean Oil and Its Oxidative Stability. *Food Science, 31*(8), 132-6.

Wu, Y. G., & Cadwallader, K. R. (2002). Characterization of the Aroma of a Meatlike Process Flavoring from Soybean-Based Enzyme-Hydrolyzed Vegetable Protein. *J Agric Food Chem, 50*(10), 2900-7. https://doi.org/10.1021/jf0114076

Copyright Disclaimer