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Quality characteristics of field muskmelon seed oil extracted by different processes

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Abstract

Field muskmelon seeds contain plenty of oil. However, its potential as vegetable food oil has not been explored comprehensively. This study used three different processes, cold extrusion (CE), coasting followed by cold extrusion (R-CE), and supercritical fluid extraction (SFE), for the extraction of field muskmelon seed oil (FMSO) and studied its quality characteristics such as color, fatty acid composition, and volatile components. The study found that FMSO is abundant in unsaturated fatty acids (UFA) and has a pleasant aroma. Gas chromatography-mass spectrometry (GC-MS) revealed that FMSO contains five main fatty acids, palmitic (11.85 ± 0.03 to12.52 ± 0.03%), linoleic (60.94 ± 1.31 to 64.78 ± 0.77%), oleic (16.64 ± 0.26 to 18.95 ± 0.47%), elaidic (0.85 ± 0.05 to 1.06 ± 0.03%), and stearic (5.67 ± 0.03 to 8.44 ± 0.06%) acids. The relative content of fatty acids showed significant variation depending on the extraction process ($P < 0.05$). Furthermore, volatile components were obtained by headspace solid-phase microextraction (HS-SPME) and analyzed by GC-MS. In total, 42, 53, and 91 volatile components were identified in FMSO extracted by CE, R-CE, and SFE, respectively. R-CE extraction promoted pyrazines content (51.51 ± 3.15%) and reduced esters and acids, while SFE extraction promoted the contents of hydrocarbons (26.00 ± 2.10%) and aldehydes (26.00 ± 2.78%). Meanwhile, the contents of esters (13.43±0.6%), alcohols (12.81 ± 0.16%), and acids (11.41 ± 0.23%) were higher in CE extracted FMSO than that extracted by R-CE and SFE. These results suggest that FMSO with high UFA content and pleasant aroma could be a potential source of vegetable food oil.

Keywords: field muskmelon seed oil; FMSO; fatty acid composition; volatile components; cold extrusion; supercritical fluid extraction; headspace solid-phase microextraction.

Practical Application: This study used cold extrusion (CE), coasting followed by cold extrusion (R-CE), and supercritical fluid extraction (SFE), for the extraction of field muskmelon seed oil (FMSO) and studied its quality characteristics. The study found that FMSO is abundant in unsaturated fatty acids (UFA) and has a pleasant aroma, the relative content of fatty acids showed significant variation depending on the extraction process ($P < 0.05$). These results suggest that FMSO could be a potential source of vegetable food oil.

1 Introduction

Field muskmelon (*Cucumis melo L. var. agrestis Naud*) is an annual wild herb of the *Cucurbitaceae* family (Figure 1a). It blossoms and bears in summer. Since ancient times muskmelon has been a subject of human selection and plant breeding efforts. *Cucumis melo* L. (melon) is a morphologically diverse species including tropical and subtropical wild and weedy kinds along with some domesticated ones (Decker-Walters et al., 2002). The geographical origin of melon remains uncertain (Thakur et al., 2019). Consumer preference for horticultural crops such as muskmelon is largely influenced by quality traits such as taste (sugar content), flavor/aroma, texture, and health-promoting properties involving bioactive compounds (Jifon & Lester, 2009). The previous field works on muskmelon have been on the fruits, leaves, stems, and seed oil. Muskmelon is nutrition-rich due to its high fiber and mineral content such as potassium, vitamin A, and vitamin C. In China, muskmelon fruits and roots are used as an emetic, the leaves and seeds are used to treat hematoma, and the stems to treat hypertension (Thakur et al., 2019). Muskmelon, an extremely healthy food, is rich in ascorbic acid, carotene, folic acid, potassium, and other bioactive compounds (Thakur et al., 2019). The seeds of muskmelon (Figure 1b) are rich in protein, vitamins, minerals, and omega-3 fatty acids, which promote cardiovascular health (Ahmed et al., 2018). Notably, the seeds also contain a considerable quantity of oil (33-38%). Vegetable oils are important nutrients for humans (Lima et al., 2022). Muskmelon seeds contain a good amount of crude fat up to 30% (Amin et al., 2018).

Similar to studies on olive, sesame, and soybean oils, field muskmelon seed oil (FMSO) must also be examined for color, fatty acid composition (FAC), and volatile components. FAC, especially the content of polyunsaturated fatty acid (PUFA), is an important indicator of vegetable oil quality. Notably, FMSO also has a pleasant aroma. Volatile components play an important role in the overall flavor/aroma of vegetable oils. Therefore, this study examined the volatile components of FMSO by the HS-SPME method that has been widely used for the isolation and determination of volatiles components from fruits, wines, and spices since 1989 (Ye et al., 2017). HS-SPME is a simple, sensitive, and fast method to analyze the natural fragrance components

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in plants (Xing et al., 2019). Clarified composition and content of volatile compounds can help optimize the manufacturing of edible plant oil to improve flavor and other sensory qualities (Liu et al., 2016).

Nowadays, oilseeds are thermally processed or roasted before oil extraction to inactivate enzymes, coagulate protein, impart flavor/aroma, facilitate the release of oil constituents during extraction, and increase oil yield (Suri et al., 2019). Maillard's reaction during the roasting process imparts aroma to the vegetable oils. Alkylated pyrazines and 2-acetylpyrroles contribute to the typical nutty/roasted flavor of roasted pumpkin seeds at high temperatures of up to 130 °C (Dun et al., 2019). However, the high roasting temperature may spoil the quality of seed oil increasing peroxide, acid, and color values. The process of cold extrusion (CE) limits the loss of nutrients in vegetable oils from heat. Recently, consumption of cold-pressed vegetative oils has increased due to their better nutritional properties (Özcan et al., 2019). Meanwhile, supercritical fluid extraction (SFE) is a new extraction technology with low operating temperature, high product quality, and short operating time. It is considered a "green" method to extract natural products of high quality and purity including fats and oils (Siraj, 2022). Therefore, the above three processes were selected for the extraction of FMSO in this study.

There are many oilseed plant studies regarding their role in the human diet (Hazrati et al., 2019). This study examined the quality characteristics to determine the nutritional value of FMSO and provide a theoretical basis for its commercial development and application.

2 Materials and methods

2.1 Samples

The very-ripe field muskmelons were obtained from the local farmland. The seeds were removed from fruits and then dried at room temperature (RT) after cleaning. The cleaned seeds were placed in a glass desiccator until analysis.

2.2 Experimental methods

Extraction methods

Cold Extrusion (CE)

The cleaned field muskmelon seeds (200 g) were extruded at 60 °C and the collected oil was centrifuged at 6000 r/min for 15 min to remove impurities (precipitate). Finally, water was removed from the oil using anhydrous sodium sulfate and the oil sample was stored at 4 °C.

Roasting followed by cold extrusion (R-CE)

Field muskmelon seeds were oven roasted at 130 °C for 30 min and then cooled to RT. The extraction was performed as described in Cold Extrusion (CE).

Supercritical Fluid Extraction (SFE)

The cleaned field muskmelon seeds were pulverized and then passed through an 80-mesh sieve. About 80 g of seed powder was placed into the extraction vessel with mesh filters on both ends with CO_2 flow maintaining the desired extraction pressure. The extraction parameters were as follows: pressure, 200 bar; temperature, 40 °C; CO_2 flow rate, 10 mL/min; static extraction time, 60 min; dynamic extraction time, 40 min.

Determination of color value

The color value of FMSO obtained from different oil-making processes was determined by the Lovbind colorimeter.

Fatty acid composition analysis

Fatty acid methyl esterification

The FMSO (0.05 g) was dissolved in 2.0 mL ether/petroleum mixed solvent (1 : 1, v/v) in a 10 mL stoppered test tube. Next, 1.0 mL potassium hydroxide: methanol solution (0.4 mol/L) was added and mixed by vortexing for 1 min. The mixture was allowed to stand to clarify. The organic phase was separated and added with 1.0 g Na_2SO_4. The final mixture was filtered through a microporous membrane (0.22 μm) before GC-MS analysis.

GC-MS analysis

GC-MS analysis was performed with an Agilent 7890B-7000B (Agilent Technologies, Wilmington, Del, USA.) instrument equipped with a flame ionization detector, automatic sample injector, and a separation column (30.0 m × 0.25 mm × 0.25 μm). The conditions were as follows: inlet temperature, 250 °C; column temperature, initial temperature 100 °C for 3 min then increased to 180 °C at a rate of 3 °C/min for 1 min, then to 220 °C at a rate of 1 °C/min for 1 min, and finally to 280 °C at a rate of 5 °C/min for 5 min; injection volume, 1.0 uL.

The mass spectrometer was operated in positive ion mode with an ionization energy of 70 eV. The temperatures of the transmission line, ion source, and four-stage rod were 280, 230, and 150 °C, respectively. Detection was performed in the full scan mode 50-650 amu. Helium (99.99%) was used as the carrier gas with a flow rate of 1.0 mL/min and a split ratio of 1 : 20. The components were identified by computer matching of corresponding mass spectra with the National Institute of Standards and Technology (NIST, 11.L). The relative amount of the individual fatty acid is expressed as % of the total fatty acids.

Volatile components analysis

HS-SPME process

A 2 cm fiber coated with divinylbenzene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS; 50/30 mm) from Supelco (Bellefonte, USA) was used for HS-SPME as described previously with slight modification (Borges et al., 2018). The FMSO sample was placed in a 20 mL vial to avoid any contact with the fiber and provide efficient extraction. The vial was sealed with a polypropylene cap with a silicone septum. The volatile components were released at selected extraction temperature (60 °C) in a water bath and allowed to equilibrate in the headspace. After the equilibrium (40 min), the DVB/CAR/PDMS fiber was exposed to the top of the vial (30 min)

for the adsorption of volatiles and then immediately inserted into the injection port of the GC system for thermal desorption and reconditioning (5 min at 250 °C).

GC-MS analysis of volatile components

Volatile components were also identified by GC-MS as described in GC-MS analysis. The mass spectrometer was operated in electron impact ionization mode at 70 eV and detection was performed in the full scan mode 30-420 amu. The injection and ion source temperatures were set to 250 and 150 °C, respectively. The temperature gradient was applied as follows: 40 °C for 8 min, then raised by 5 °C/min to 60 °C and held for 5 min, then increased by 3 °C/min to 120 °C for 5 min, and finally raised by 5 °C/min to 220 for 10 min. The flow rate of carrier gas (helium) was 1.0 mL/min. The volatile components were identified by comparing their mass spectra with NIST, 11.L using computer matching. The relative content of the individual volatile component is expressed as % of the total volatile components.

2.3 Sensory analysis

Sensory assessments were conducted in compliance with "Ethics Committee of Anhui Agricultural University" approved under number 22.5835.8706. In the sensory analysis laboratory,with the participation of 30 untrained tasters. The samples were placed in disposable cups and coded with random numbers. Each appraiser received one sheet containing a questionnaire and a hedonic scale to evaluate color, flavor, taste and transparency ranging from 9 to 1 (9- Liked it extremely, 8- Liked it a lot, 7- Liked it, 6-Somewhat liked it, 5- Indifferent, neither liked nor disliked, 4- Somewhat disliked, 3- Disliked, 2- Disliked moderately and 1- Disliked extremely), and another scale to gauge purchase intent previously reported Grigio et al. (2022) (1- Definitely would buy, 2- Probably would buy, 3- Maybe yes/maybe no, 4- Probably wouldn't buy, 5- Definitely wouldn't buy). Between evaluations, the evaluators drank water so that there was no interference between the formulations analyzed.

To calculate the Product Acceptability Index, we used the expression IA (%) = A × 100/B, where, A = average grade obtained for the product and B = maximum grade given to the product. Usually the acceptability index is considered to have good repercussion when ≥ 70%.

2.4 Statistical analysis

Experimental results were expressed as means ± SD of triplicate measurements.

3 Results and discussion

3.1 Determination of the color value

As shown in Table 1 and Figure 2, the color of FMSO obtained by different extraction processes was significantly different ($P < 0.05$). The color of R-CE extracted oil was relatively dark (R 1.30 ± 0.12, Y 36.00 ± 0.82) (Figure 2b) due to the higher processing temperature. The color of CE (Figure 2a) and SFE (Figure 2c) extracted oil was pale yellow (R 1.00 ± 0.08, Y 53.67 ± 0.94) and light green (R 0.53 ± 0.12, Y 22.33 ± 0.47, B 0.77 ± 0.05), respectively. These processes avoided the darkening of FMSO.

3.2 Analysis of fatty acid composition

The FMSO samples were subjected to transesterification. The quality of resulting fatty acid methyl esters was assessed by GC-MS (Figure 3). The data indicated efficient conversion of triglycerides to methyl esters. Similar results were obtained for all three processes. Five stable and completely separated chromatographic peaks were detected in FMSO. According to the ion mass spectrum of the corresponding chromatographic peak and the retrieval from NIST 11.L, the fatty acids composition (%) of FMSO extracted by different processes was determined. The details are shown in Table 2.

Table 1. Effect of different processes on the color value of FMSO.

Color	CE	R-CE	SFE
R	1.00 ± 0.08^{b}	1.30 ± 0.12^{a}	0.53 ± 0.12^{c}
Y	53.67 ± 0.94^{a}	36.00 ± 0.82^{b}	22.33 ± 0.47^{c}
B	0.00	0.00	0.77 ± 0.05

R, Y, and B denote red, yellow, and blue, respectively. Values in each row with different letters are significantly different ($p < 0.05$).

Figure 1. Field muskmelon (a) and field muskmelon seeds (b).

As shown in Table 2, five major fatty acids, namely palmitic, linoleic, oleic, elaidic, and stearic acids, were found in all FMSO samples: their retention times ranged from 46.48 to 46.68, 57.89 to 58.12, 58.24 to 58.47, 58.54 to 58.76 and 60.09 to 60.33 min, respectively.

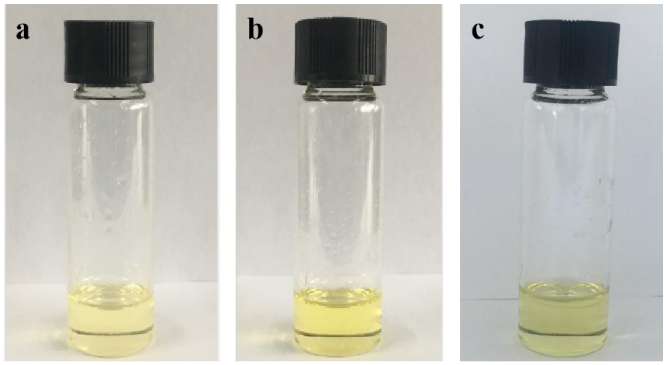

Figure 2. FMSO extracted by CE (a) R-CE (b) and SFE (c).

The quantitative analysis was performed by the area normalization method that showed significant differences in the relative content of fatty acids extracted by different processes ($P < 0.05$). The majority of fatty acids were unsaturated. The content of total unsaturated fatty acid (UFA) varied from 79.50 ± 1.03 to 82.48 ± 1.06% which was higher than those of total saturated fatty acid (SFA) (17.52 ± 0.00 to 20.5 ± 0.07%). The prevailing fatty acid in FMSO was linoleic acid (LA, C18:2, n-6) (60.94 ± 1.31 to 64.78 ± 0.77%), followed by oleic acid (16.64 ± 0.26 to 18.95 ± 0.47%). Palmitic (11.85 ± 0.03 to 12.52 ± 0.03%) and stearic (5.67 ± 0.03 to 8.44 ± 0.06%) acids were the main SFA in FMSO. CE oil showed the highest content of UFA (82.48 ± 1.06%), followed by SFE oil (80.82 ± 1.83%), and the lowest was observed for R-CE oil (79.5 ± 1.03%). This can be attributed to thermal polymerization and decomposition of UFA during the high-temperature process decreasing the content of UFA. FAC analysis suggested that linoleic and oleic acids are the major unsaturated fatty acids of FMSO that have great nutritional value. Linoleic acid is a long-chain polyunsaturated fatty acid (LC-PUFA), which can prevent cardiovascular disease by

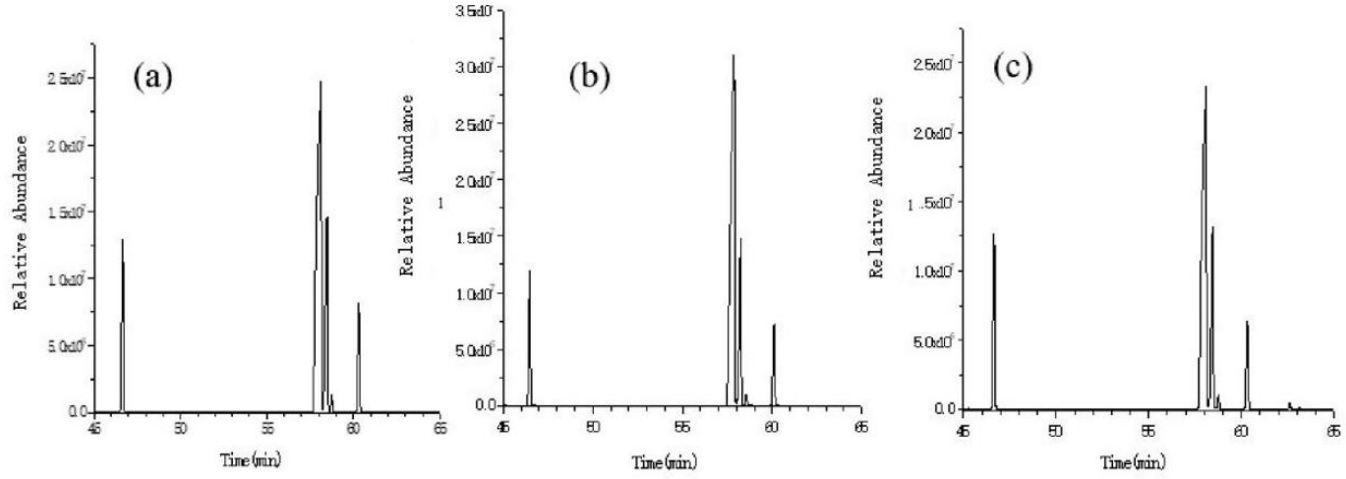

Figure 3. The total ion GC-MS chromatograms of fatty acids in FMSO that was obtained from CE (a), R-CE (b), and SFE (c).

Table 2. Fatty acid composition (%) of FMSO extract by different processes.

Fatty acids	Molecular formula	CAS	Fatty acids relative content (%)		
			CE	R-CE	SFE
Palmitic acid (C16:0)	$C_{17}H_{34}O_2$	112-39-0	11.85 ± 0.03^c	12.06 ± 0.02^b	12.52 ± 0.03^a
Linoleic acid (C18:2)	$C_{19}H_{34}O_2$	2462-85-3	64.78 ± 0.77^a	61.04 ± 0.67^b	60.94 ± 1.31^b
Olenic acid (C18:1)	$C_{19}H_{36}O_2$	112-62-9	16.64 ± 0.26^c	17.61 ± 0.31^b	18.95 ± 0.47^a
Elaidic acid (C18:1)	$C_{19}H_{36}O_2$	1937-62-8	1.06 ± 0.03^a	0.85 ± 0.05^b	0.93 ± 0.04^b
Steraric acid (C18:0)	$C_{19}H_{38}O_2$	112-61-8	5.67 ± 0.03^c	8.44 ± 0.06^a	6.66 ± 0.04^b
Saturated fatty acid			17.52 ± 0.00^c	20.5 ± 0.07^a	19.18 ± 0.01^b
Monounsaturated fatty acid (MUFA)			17.7 ± 0.29^b	18.46 ± 0.36^b	19.88 ± 0.514^a
Polyunsaturated fatty acid (PUFA)			64.78 ± 0.77^a	61.04 ± 0.67^b	60.94 ± 1.31^b
Unsaturated fatty acid			82.48 ± 1.06^a	79.5 ± 1.03^a	80.82 ± 1.83^a
Total			100	100	100

Values in each row with different letters suggest a significant difference ($p < 0.05$). CE: cold extrusion; R-CE: roasting followed by cold extrusion; SFE: supercritical fluid extraction. CAS: Chemical Abstracts Service.

increasing the content of high-density lipoprotein and lowering the content of low-density lipoprotein. LC-PUFA also plays important role in the regulation of the immune system, blood clots, neurotransmitters, cholesterol metabolism, and the structure of membrane phospholipids in the brain and retina (Abedi & Sahari, 2014). PUFA, also known as essential fatty acids (e.g., linoleic acid and linolenic acid), cannot be synthesized by the human body in the required quantity. Diet or dietary supplements are the major sources of essential fatty acids (Zhou et al., 2019). Oleic acid is an easily absorbed monounsaturated fatty acid that does not deposit to form a blood clot and therefore is beneficial to human health.

3.3 Volatile components analysis

The present study identified the volatile components in FMSO by comparing the mass spectrum information with corresponding standards and the data from Agilent NIST 11.L.

Analysis of volatile components in CE-FMSO

The volatile components of CE-FMSO were analyzed by GC-MS (Figure 4 and Table 3). The results showed 42 components based on the NIST 11.L data and literature. The major components included 10 esters, 8 aldehydes, 5 alcohols, 3 pyrazines, 3 acids, 2 ketones, 1 phenol, 1 pyridine, 1 thiazole, and 1 furan. The relative content of aldehydes (22.53 ± 0.58%) was much higher than most other ingredients. Aldehydes in edible oils are mainly produced via the lipid oxygenase pathway during oilseed cell fragmentation or by automatic oxidation of the oil during production and storage (Dun et al., 2019). Aldehydes, particularly aliphatic aldehydes, considerably impact the fragrance and flavor of FMSO, which is usually manifested as a fresh or fatty odor (Zviely, 2009). In addition, some esters (13.43 ± 0.60%), alcohols (12.81 ± 0.16%), and acids (11.41 ± 0.23%) also make a certain contribution to the flavors of CE-FMSO.

Analysis of volatile components in R-CE-FMSO

A total of 53 volatile compounds were identified in the R-CE-FMSO, including 13 aldehydes, 11 pyrazines, 5 thiazoles, 3 ketones, 3 pyridines, 3 alcohols, 2 esters, 2 phenols, 2 pyrimidines, 1 acid, and 1 pyrrole (Figure 5 and Table 3). Pyrazines and aldehydes were the majority of the substances. Pyrazines, the predominant volatile components, accounted for 51.51 ± 3.15% of the total volatile components. These majorly contribute to the nutty and roasted odor. Among all pyrazines, 2,5-dimethylpyrazine was in the highest amount and highly correlates to roasted flavor and aroma. Aldehyde compounds (23.92 ± 0.65%) mainly impart fresh and fatty flavor.

Analysis of volatile components in SFE-FMSO

In total, 91 components were detected in SFE-FMSO, including 30 hydrocarbons, 12 aldehydes, 12 hydrocarbons, 11 esters, 8 alcohols, 6 acids, 2 ketones, 2 phenols, 2 thiazoles, and 1 furan (Figure 6 and Table 3). SFE-FMSO contained a high amount of aldehydes (26.00 ± 2.78%), mainly hexanal (10.84 ± 0.06%) and pentanal (5.86 ± 0.02%), which provide the typical

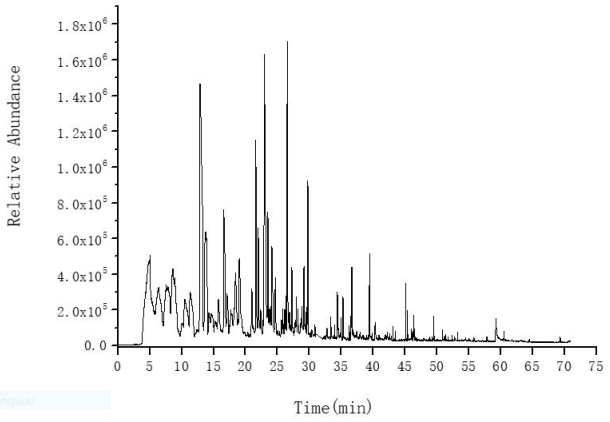

Figure 4. Total ion chromatogram showing volatile components of CE-FMSO.

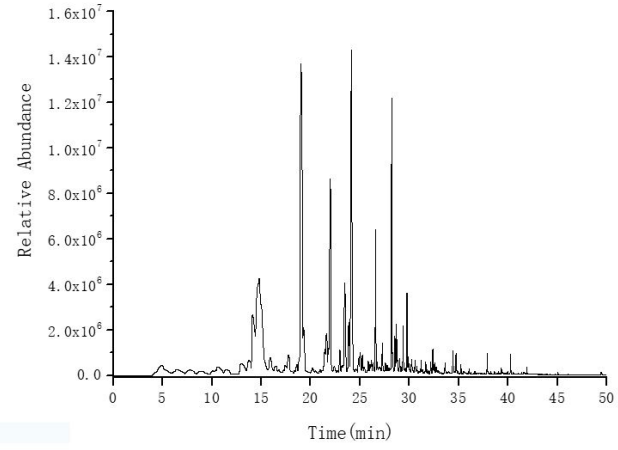

Figure 5. Total ion chromatogram of volatile components of R-CE-FMSO.

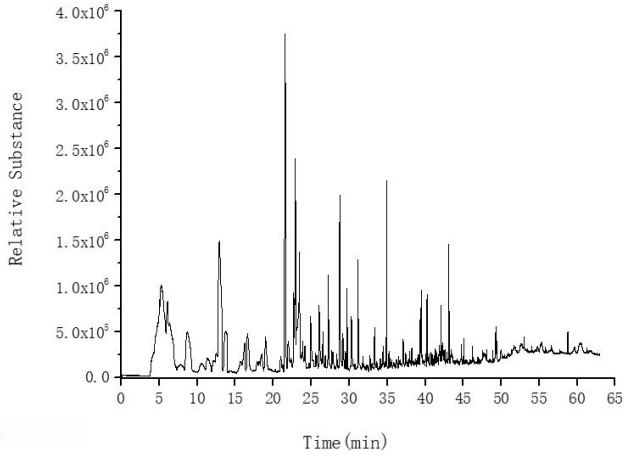

Figure 6. Total ion chromatogram of volatile components of SFE-FMSO.

Table 3. GC-MS identification of volatile components in FMSO.

NO.	Compounds	molecular formula	RC[a] (%)		
			CE[b]	R-CE[c]	SFE[d]
	Pyrazines				
1	*2-Methylpyrazine*	$C_5H_6N_2$	2.63±0.18	7.30±0.41	-
2	*2,5-Dimethyl pyrazine*	$C_6H_8N_2$	4.62±0.18	22.53±1.81	-
3	*3-ethyl-2,5-dimethylpyrazine*	$C_8H_{12}N_2$	0.52±0.03	7.09±0.33	-
4	*2-Ethyl-6-methylpyrazine*	$C_7H_{10}N_2$	-	2.01±0.02	-
5	*2,3,5-Trimethylpyrazine*	$C_7H_{10}N_2$	-	8.70±0.33	-
6	*2-ethenyl-5-methylpyrazine*	$C_7H_8N_2$	-	0.57±0.07	-
7	*2,3-Dimethyl-5-ethylpyrazine*	$C_8H_{12}N_2$	-	1.19±0.03	-
8	*2,5-Diethylpyrazine*	$C_8H_{12}N_2$	-	0.27±0.03	-
9	*2-Methyl-6-[(1E)-1-propen-1-yl]pyrazine*	$C_8H_{10}N_2$	-	1.03±0.08	-
10	*5-methyl-6,7-dihydro-5H-cyclopenta[b]pyrazine*	$C_8H_{10}N_2$	-	0.24±0.02	-
11	3,5-diethyl-2-methylpyrazine	$C_9H_{14}N_2$	-	0.58±0.02	-
	Esters				
12	*Ethyl acetate*	$C_4H_8O_2$	4.44±0.07	0.36±0.02	-
13	*2-methylbutyl acetate*	$C_7H_{14}O_2$	2.55±0.07	-	-
14	Heptyl methanote	$C_8H_{16}O_2$	0.90±0.09	-	-
15	*Butyl butanoate*	$C_8H_{16}O_2$	0.45±0.07	-	-
16	*Hexyl acetate*	$C_8H_{16}O_2$	1.46±0.01	-	-
17	*Utyl 2-methylbutyrate*	$C_9H_{18}O_2$	0.92±0.03	-	-
18	*γ-caprolactone*	$C_6H_{10}O_2$	0.47±0.02	-	0.36±0.04
19	*Octyl formate*	$C_9H_{18}O_2$	0.52±0.05	-	0.48±0.06
20	*Butyl Hexanoate*	$C_{10}H_{20}O_2$	0.74±0.07	-	-
21	*Exyl 2-methylbutanoate*	$C_{11}H_{22}O_2$	0.98±0.12	-	-
22	Isopropenyl formate	$C_4H_6O_2$	-	0.76±0.11	-
23	*Vinyl acetate*	$C_4H_6O_2$	-	-	0.66±0.04
24	*Methyl formate*	$C_2H_4O_2$	-	-	4.67±0.59
25	*Ethyl acetoacetate*	$C_6H_{10}O_3$	-	-	1.00±0.07
26	*Ethyl (2S)-lactate*	$C_5H_{10}O_3$	-	-	0.77±0.05
27	3-Butenoic acid ethyl ester;	$C_6H_{10}O_2$	-	-	1.28±0.11
28	D-(-)-pantolactone	$C_6H_{10}O_3$	-	-	0.14±0.02
29	*Methyl salicylate*	$C_8H_8O_3$	-	-	0.12±0.04
30	*9,12-octadecadienoic acid methyl ester*	$C_{19}H_{34}O_2$	-	-	0.96±0.03
31	*Ethyl hexadecanoate*	$C_{18}H_{36}O_2$	-	-	0.31±0.02
	Aldehydes				
32	*(Z)-2-heptenal*	$C_7H_{12}O$	7.80±0.07	-	-
33	Octanal	$C_8H_{16}O$	1.25±0.11	0.58±0.07	-
34	*Phenylacetaldehyde*	C_8H_8O	7.62±0.07	3.38±0.18	0.78±0.02
35	*(E)-oct-2-enal*	$C_8H_{14}O$	1.44±0.13	-	-
36	*Nonanal*	$C_9H_{18}O$	3.05±0.14	1.58±0.01	1.42±0.06
37	*Trans-2-nonenal*	$C_9H_{16}O$	0.20±0.02	-	0.29±0.01
38	*Decanal*	$C_{10}H_{20}O$	0.68±0.03	-	0.27±0.02
39	*(2E,4E)-deca-2,4-dienal*	$C_{10}H_{16}O$	0.49±0.01	0.35±0.02	-
40	*Pentanal*	$C_5H_{10}O$	-	1.53±0.01	5.86±0.02
41	*Hexanal*	$C_6H_{12}O$	-	1.70±0.03	10.84±0.06
42	*Heptaldehyde*	$C_7H_{14}O$	-	0.46±0.02	-
43	*Trans-2-Heptenal*	$C_7H_{12}O$	-	1.39±0.03	-
44	*5-Methyl furfural*	$C_6H_6O_2$	-	1.19±0.07	-
45	*Benzaldehyde*	C_7H_6O	-	10.74±0.11	1.33±0.03
46	*4-methylcyclohex-3-ene-1-carbaldehyde*	$C_8H_{12}O$	-	0.35±0.02	-
47	*2-phenylprop-2-enal*	C_9H_8O	-	0.26±0.08	-
48	Trans-2-Decenal	$C_{10}H_{18}O$	-	0.41±0.02	0.18±0.02
49	*Dimethoxymethane*	$C_3H_8O_2$	-	-	3.98±0.08

-: not detected. [a]RC: relative content. [b]CE: cold extrusion. [c]R-CE: roasting followed by CE. [d]SFE: supercritical fluid extraction.

Table 3. Continued...-

NO.	Compounds	molecular formula	RC[a] (%)		
			CE[b]	R-CE[c]	SFE[d]
50	*Trans-4-heptenal*	$C_7H_{12}O$	-	-	0.29±0.02
51	*Trans,trans-2,4-Heptadienal*	$C_7H_{10}O$	-	-	0.14±0.01
52	*Trans,trans-2,4-Decadien-1-al*	$C_{10}H_{16}O$	-	-	0.62±0.02
	Acids				
53	*2-methylbutyric acid*	$C_5H_{10}O_2$	2.00±0.10	-	1.27±0.04
54	*Octanoic acid*	$C_8H_{16}O_2$	2.34±0.04	-	-
55	*Valeric acid*	$C_5H_{10}O_2$	7.07±0.09	-	0.47±0.05
56	*2-methylidenecyclopropane-1-carboxylic acid*	$C_5H_6O_2$	-	1.46±0.02	-
57	Isovaleric acid	$C_5H_{10}O_2$	-	-	0.58±0.02
58	*Hexanoic acid*	$C_6H_{12}O_2$	-	-	3.82±0.02
59	*7-benzoylheptanoic acid*	$C_{14}H_{18}O_3$	-	-	0.44±0.07
60	*Heptanoic acid*	$C_7H_{14}O_2$	-	-	0.40±0.06
	Alcohols				
61	*(3S)-3-methylpentan-1-ol*	$C_6H_{14}O$	8.79±0.04	-	-
62	*1-butylcyclobutan-1-ol*	$C_8H_{16}O$	1.19±0.03	-	-
63	*Oct-1-en-3-ol*	$C_8H_{16}O$	2.15±0.05	-	-
64	*2-Ethylhexanol*	$C_8H_{18}O$	0.45±0.03	-	-
65	*2-Isopropyl-5-methylcyclohexanol*	$C_{10}H_{20}O$	0.23±0.01	-	-
66	*7-oxabicyclo[4.1.0]heptan-5-ol*	$C_6H_{10}O_2$	-	6.27±0.07	-
67	*Hexan-1-ol*	$C_6H_{14}O$	-	0.25±0.03	-
68	*(5-Methylfuran-2-yl)methanol*	$C_6H_8O_2$	-	0.36±0.01	-
69	*(S,S)-butane-2,3-diol*	$C_4H_{10}O_2$	-	-	1.00±0.10
70	*3-Methyl-1-pentyn-3-ol*	$C_6H_{10}O$	-	-	0.30±0.02
71	*(3S)-3-methylpentan-1-ol*	$C_6H_{14}O$	-	-	2.60±0.11
72	*Benzyl alcohol*	C_7H_8O	-	-	2.06±0.05
73	*2-phenylethanol*	$C_8H_{10}O$	-	-	1.62±0.06
74	*Nonan-1-ol*	$C_9H_{20}O$	-	-	0.48±0.03
75	*2,4-Diethylheptan-1-ol*	$C_{11}H_{24}O$	-	-	0.41±0.04
76	*Decan-1-ol*	$C_{10}H_{22}O$	-	-	0.12±0.03
	Ketones				
77	*1-hepten-3-one*	$C_7H_{12}O$	0.40±0.06	-	2.52±0.07
78	*2-octanone*	$C_8H_{16}O$	0.63±0.07	2.91±0.05	-
79	*Acetoxyacetone*	$C_5H_8O_3$	-	0.32±0.02	-
80	*Heptan-2-one*	$C_7H_{14}O$	-	1.52±0.12	-
81	*3,3,6-trimethylhepta-1,5-dien-4-one*	$C_{10}H_{16}O$	-	-	0.35±0.03
	Phenols				
82	*Guaiacol*	$C_7H_8O_2$	0.74±0.03	0.34±0.02	4.17±0.05
83	*Phenol*	C_6H_6O	-	0.25±0.03	1.09±0.11
	Pyridine				
84	*Pyridine*	C_5H_5N	4.90±0.13	0.60±0.06	-
85	2-Acetyl-3,4,5,6-tetrahydropyridine	$C_7H_{11}NO$	-	0.36±0.01	-
86	1-Acetyl-1,2,3,4-tetrahydro-pyridin;	$C_7H_{11}NO$	-	0.52±0.02	-
	Thiazoles				
87	*1,2-benzisothiazole*	C_7H_5NS	0.89±0.05		0.25±0.02
88	*2,4-Dimethylthiazole*	C_5H_7NS	-	0.65±0.02	-
89	*2,4-dimethyl-4,5-dihydro-1,3-thiazole*	C_5H_9NS	-	0.89±0.11	-
90	*2-Ethyl-4-methyl thiazole*	C_6H_9NS	-	0.32±0.02	-
91	*2-Isopropyl-4-methyl thiazole*	$C_7H_{11}NS$	-	0.32±0.02	-
92	*4-propyl-1,3-thiazole*	C_6H_9NS	-	0.28±0.01	-
93	Isothiazole	C_3H_3NS	-	-	0.16±0.04
	Furans				
94	*2-Pentylfuran*	$C_9H_{14}O$	2.92±0.07	-	-

-: not detected. [a]RC: relative content. [b]CE: cold extrusion. [c]R-CE: roasting followed by CE. [d]SFE: supercritical fluid extraction.

Table 3. Continued...-

NO.	Compounds	molecular formula	RC[a] (%)		
			CE[b]	R-CE[c]	SFE[d]
95	*2-heptylfuran*	$C_{11}H_{18}O$	-	-	0.14±0.02
	Pyrimidines				
96	*2-Hydroxypyrimidine*	$C_4H_4N_2O$	-	0.59±0.06	-
97	*4,5-dimethylpyrimidine*	$C_6H_8N_2$	-	1.38±0.05	-
	Pyrroles				
98	*2-acetylpyrrole*	C_6H_7NO	-	0.32±0.01	-
	Hydrocarbons				
	Alkanes		0.73±0.03	0.54±0.01	24.79±2.00
	Alkenes		0.26±0.05	-	1.21±0.10
	Others		20.58±0.44	3.02±0.12	13.00±0.36

-: not detected. [a]RC: relative content. [b]CE: cold extrusion. [c]R-CE: roasting followed by CE. [d]SFE: supercritical fluid extraction.

grassy/fatty flavor. Meanwhile, SFE-FMSO also had a higher level of hydrocarbons (26.00 ± 2.10%) and some other components such as esters (10.75 ± 1.07%), alcohols (8.59 ± 0.44%), and acids (6.89 ± 0.26%). Additionally, some phenols (5.26 ± 0.16%) and ketones (2.87 ± 0.10%) made a significant contribution to the flavor of SFE-FMSO.

Comparison of different extraction processes for volatile components in FMSO

The volatile components of FMSO prepared by three different processes are compared in a column chart shown in Figure 7. In terms of the identified compounds, the maximum volatile flavor compounds were identified in SFE-FMSO. Notably, the types of volatile components extracted by different processes showed no obvious variation, however, the amount of characteristic volatile flavor substances such as pyrazines, hydrocarbons, and esters showed great variation. Volatile components such as aldehydes, alcohols, acids, esters, ketones, phenols, and thiazoles were detected in all three processes. Pyrazines were mainly found in R-CE-FMSO and CE-FMSO. Pyrazines content was significantly higher in R-CE-FMSO (51.51 ± 3.15%) than in CE-FMSO (7.77 ± 0.39%). Meanwhile, GC-MS analysis highlighted the abundance of aldehydes (26.00 ± 2.78%) and hydrocarbons (26.00 ± 2.10%) in the SFE-FMSO. The amount of aldehydes (22.53 ± 0.58%) in the CE-FMSO was close to that in SFE-FMSO. Aldehydes were identified as the predominant compound in the CE extracted oil, followed by esters accounting for 13.43 ± 0.60%. The ester compounds impart fruity notes to FMSO and making the odor diffusive.

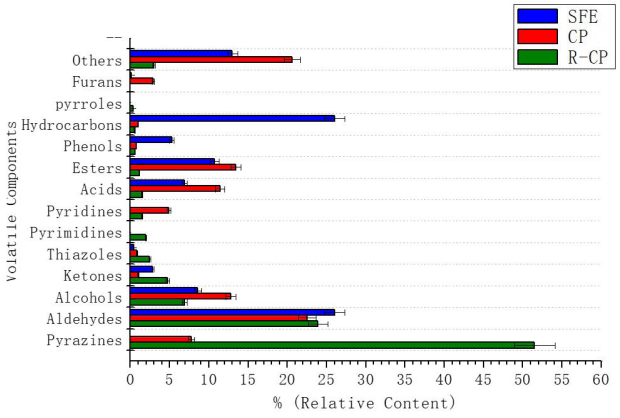

Figure 7. The relative content of volatile components in FMSO extracted by different processes.

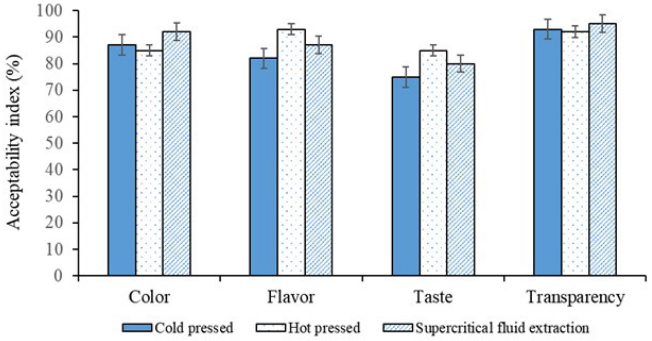

Figure 8. Acceptability index of three test objects. Means + standard deviation (n = 30).

3.4 Sensory characteristics

With respect to taste, all quality sensory attributes in three test objects showed values above 78% (Figure 8). Looking at the color and transparency, it can be noted that hot pressed presented less acceptability

Although the field muskmelon seed oil is little known, an acceptability index of over 75% was obtained for practically all technologies and properties tested suggesting the possibility of commercialization of the formulated products.When evaluating the purchase intention of test objects, We observed a higher proportion of people who definitely would buy cold pressed oil, more than 55% of tasters said they probably would buy the product hot pressed oil and supercritical fluid extraction oil (Figure 9).

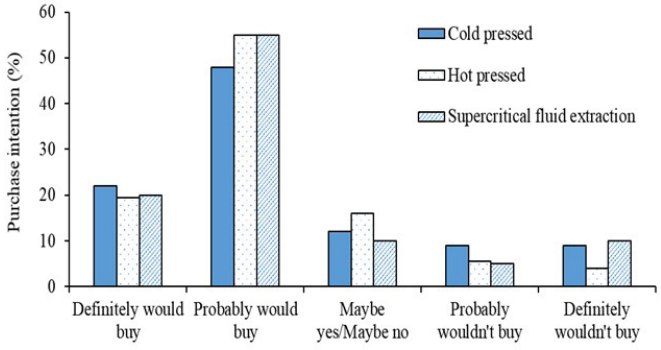

Figure 9. Purchase intention of three test objects (n = 30).

4 Conclusion

This study analyzed the quality characteristics of FMSO to investigate its potential nutritional value and provide a theoretical basis for its development and application. The results showed that FMSO contained favorable fatty acids compositions; *i.e.*, low level of SFA and high level of UFA. CE-FMSO exhibited the highest content of UFA, followed by SFE-FMSO, and the lowest was seen for R-CE-FMSO. The types of volatile components extracted by different processes showed no obvious variation. However, the content of characteristic volatile flavor substances such as pyrazines, hydrocarbons, and esters changed significantly. The R-CE-FMSO was abundant in pyrazines that majorly contribute to nutty and roasted odor. Aldehydes in CE-FMSO and SFE-FMSO contributed to grassy/fatty flavor.

The present study confirmed the potential nutritional value of the FMSO with high content of UFA and a pleasant aroma. The oil can be considered as a potential natural source for functional vegetable oil in the near future.

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