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Effect of sterilization methods on the flavor of cold brew coffee

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Abstract

This research used ultra-fast E-nose, E-tongue and SCA analysis to explore the effects of different sterilization methods (pasteurization, back pressure sterilization, high temperature short-term sterilization, membrane filtration treatment and high pressure processing) on cold brew coffee. The results showed that non-heat sterilization can better maintain the sensory quality of coffee liquid. Back pressure sterilization could reduce the pH value of coffee liquid to 4.65, and decrease the aroma content significantly by 50.5% ($p < 0.05$), while the sourness and bitterness of coffee samples increased, which lowered the sensory quality of coffee. Among the heat sterilization treatments, high temperature short-term sterilization had relatively little effect on the sensory quality of the coffee beverage, and decreased the bitterness of the coffee. Taking sensory quality, nutrients and cost into consideration, it is suggested that high temperature short time sterilization is a prefered method. Thus, the results of this research provided a theoretical basis for the selection of sterilization method for cold brew coffee.

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INTRODUCTION

Arabica coffee (*Coffea arabica*), hereinafter referred to as coffee, is an evergreen tree or shrub belonging to the *Coffea* genus in the Rubiaceae family, and originated from Ethiopia. It was introduced to Europe from Arabia in the 17th century and is now one of the three most popular drinks in the world[1−2]. Coffee is welcomed by consumers for its pleasant flavor, but its sensory qualities are easily affected by the varieties, producing area, processing technology and other factors. Recent research on coffee sensory quality mainly focus on roasting and brewing technology, and there are relatively few research on sterilization methods. Yu et al.[3] found that the roasting speed could affect the aroma and flavor of coffee. Zhi et al.[4] found that the amount of coffee flavor substance was affected by the production area, and the coffee in Panama has a unique flavor. Zhu[5] discussed the influence of brew temperature on the aroma of Colombian coffee, and concluded that low temperature brew coffee had more fruity notes. Kulapichitr et al.[6] studied the fact that heat pump drying helping preserve the overall flavor of Arabica coffee.

Cold brew coffee, made by soaking coffee grind in unheated water for 12 h or more, had a sweeter taste and better flavor. The global cold brew coffee market size is expected to register a CAGR of 25.1% from 2019 to 2025 (valued at USD $339.7 million in 2018)[7]. The processing procedure inevitably causes loss of many flavor components of cold brew coffee[8−9]. Sterilization is a key step during the production of cold brew coffee, and different sterilization methods cause different influence on the flavor of beverages including coffee liquid[10]. Zhang et al.[11] found that ultra-high pressure sterilization can improve the flavor of fermented pear juice, and Cui et al.[12] found that ultrasonic sterilization can better maintain the taste of fruit and vegetable juice. By comparing sterilization methods, it is found that ultrasonic sterilization can better maintain the flavor of fruit and vegetable juice, with little damage to the nutrients. The sterilization methods commonly used can be divided into heat sterilization and non-heat sterilization. The usual heat sterilization technologies are pasteurization and ultra-high temperature sterilization. Pasteurization is commonly used for dairy products and ultra-high temperature sterilization is suitable for products that do not contain granular materials, due to its higher temperature requirements (130−150 °C). Non-heat sterilizations include ultrasonic sterilization, ultra-high pressure sterilization and ultraviolet sterilization[13−15].

This research used five methods to sterilize cold brew coffee, the sterilized coffee was then measured for pH value and concentration of organic acid. The sensory attributes were also analyzed through electronic nose (E-nose) and electronic tongue (E-tongue) combined with sensory evaluation. The results of the research can provide theoretical reference for the production and processing of coffee.

MATERIALS AND METHODS

Materials and reagents

The sun-dried green bean of Arabica coffee from Yirgacheffe, Ethiopia was used and was purchased from Kunshan Yiguo International Trade Co., Ltd (Kunshan Development Zone, Suzhou City, Jiangsu Province). Methanol and acetonitrile were HPLC grade solvents and were acquired from TEDIA Co., Ltd (USA). Ultrapure water was used in all experiments.

Methods

Cold-brewing

Green coffee beans were roasted to a medium-light degree with a PROBAT roaster and stored at room time for 72 h. The

equipment was adjusted to the 5th lever and the roast coffee bean were ground to a powder. Cold brew beverages were extracted by static immersion, using 0–10 °C water to brew for 8–10 h (powder : water = 1:5 – 1:6). The coffee liquid was collected when Brix reached 7.0 (± 0.2).

Sterilization

The coffee beverage was then sterilized. The methods used were pasteurization, back pressure sterilization, high pressure short-term sterilization, membrane filtration and high pressure processing. The sterilized coffee was the experimental sample used in this research. The specific process parameters of each sterilization method are shown in Table 1, and the acronyms of each sample will be used for convenience in the following paragraph. The control sample was cold brew beverage without sterilization and was hereinafter referred to as CK.

pH measurement

The coffee was mixed evenly and the pH was measured using a pH meter (FE28, METTLER TOLEDO Co., Switzerland).

Organic acid determination

Organic acids were detected by HPLC with a ultraviolet detector (1260, Agilent Technologies Co., Ltd, USA) and were separated using a C18 chromatographic column (4.6 mm × 250 mm, 5 μm, OSAKA SODA CO., Ltd).

(1) Chlorogenic acids compounds

For sample pretreatment please refer to the method in Hu et al.[16]. One to two gram samples were weighed in a 50 mL brown volumetric flask. Thirty millilitres of 30 methanol-0.1% phosphoric acid (50:50, V/V) solution were added, followed by ultrasonic treatment for 20 min. Methanol-0.1% phosphoric acid (50:50, V/V) solution was then added to the volume scale, and filtered through 0.22 μm organic membrane. The samples were then stored at 4 °C in the dark.

The chlorogenic acid concentration was then measured by HPLC, and the parameters are shown in Table 2.

(2) Tartaric acid, malic acid, citric acid, succinic acid, fumaric acid

For sample pretreatment please refer to the method in GB5009.157-2016[17]. 1–2 g samples were weighed in a 50 mL volumetric flask. Thirty millilitres of 0.1% phosphoric acid solution was added, followed by ultrasonic treatment for 20 min. 0.1% phosphoric acid solution was added to the volume scale, then filtered through 0.22 μm organic membrane. The samples were stored at 4 °C in the dark.

The acid concentrations were then measured by HPLC, and the parameters are shown in Table 2.

Volatile Compound (VCs) determination

Two gram samples were weighed in a 20 mL headspace bottle, then determined by Ultra-fast E-nose (Heracles NEO, Alpha MOS Co., France)[18].

Taste determination

Ten millilitre samples were measured into sample cups, then assesed using the taste sensing system (E-tongue) (TS-5000Z, INSENT Co., Japan).

Sensory evaluation

Refered to the SCA coffee cup-testing in Hu et al.[19]. The samples were then assesed from six aspects, such as aroma, flavor, acidity, aftertaste, body, balance and overall taste. The score range of each aspect is between 6–10 points, and each score unit is 0.25 points. Thus, 16 degrees in total.

Statistic analysis

The samples for each experiment was measured in triplicate. Raw data was preliminary processed by Excel™. Statistical difference was performed at $p < 0.05$ with Duncan Test in an one-way ANOVA using SPASS 23. Graphs were drawn using Origin 2017 and Photoshop CS5.

RESULTS AND DISCUSSION

Effect of sterilization on the pH value and organic acid concentration of cold brew coffee

The results of pH value and organic acid concentration of the samples are shown in Table 3. In the quality evaluation of coffee, pH value is an important index[15]. Organic acids produced during coffee bean roasting, are the main compounds that affect the pH value[20]. The pH value quantifies the concentration of hydrogen ions and provides a metric description for deprotonated acid molecules in the sample. According to Table 3, BPS had lower pH value, and this may relate to the long time heat treatment.

The chromatogram of each organic acid compound standard is shown in Fig. 1a & b, which showed that each compound had

Table 1. Parameters of each sterilization method.

Category of treatment	No.	Method	Temperature	Pressure	Duration	Notes	Sample
Heat sterilization	1	Pasteurization	65 °C	/	30 min	/	PS
	2	Back pressure sterilization	121 °C	1.5 bar	30 min	/	BPS
	3	High pressure short-term sterilization	110 °C	/	5 s	/	HTS
Non-heat sterilization	4	Membrane filtration	25 °C	/	/	Ceramic membrane, 200 μm	MF
	5	High pressure processing	25 °C	5,000 bar	5 min	/	HPP

Table 2. Chromatographic parameters for organic acid measurement.

Parameters	Chlorogenic acids	Tartaric acid, Citric acid, Malic acid, Succinic acid, Fumaric acid
Speed	1.0 mL/min	0.3 mL/min
Column temperature	30 °C	40 °C
Wavelength	327 nm	210 nm
Moving phase	Methanol (A) -0.1% phosphoric acid solution (B)	Methanol (A) -0.1% phosphoric acid solution (B)
Elution program	0.00–20.00 min: 20%A–80%B 20.01–45.00 min: 35%A–65%B 45.01–55.00 min: 40%A–60%B 55.01–60.00 min: 20%A–80%B	0.00–20.00 min: 10%A–90%B 20.01–25.00 min: 100%A 25.01–35.00 min: 10%A–90%B

been well separated. The regression equation of sample concentration X to peak area Y, and the correlation coefficient R^2 (> 0.999) was obtained. CGA is an important nonvolatile substance in coffee, and significantly affects the taste and flavor of coffee. Chlorogenic acid can produce different derivatives and volatile components under different processing conditions, which can affect the sensory quality of coffee[21]. According to Table 3, chlorogenic acid, neochlorogenic acid and cryptochlorogenic acid were the main compounds in CK, and the concentration of isochlorogenic acid was relatively lower. Compared to CK, BPS had higher neochlorogenic acid and cryptochlorogenic acid concentration, but lower chlorogenic acid concentration. It might be that the conditions of back pressure sterilization were more likely to cause the degradation of chlorogenic acid and led to the conversion of chlorogenic acid compounds into isochlorogenic acid and cryptochlorogenic acid compounds. According to Table 3, the citric acid concentration was significantly decreased in BPS, while there was no significant difference in the concentrations of tartaric acid, malic acid, succinic acid and fumaric acid among all the samples.

Thus, compared to other sterilization method, back pressure sterilization influenced the pH value and the organic acid concentration of coffee more obviously, and may lower the quality of coffee.

Effect of sterilization on VCs of cold brew coffee

Analysis on chromatograms

According to Fig. 2a, the retention time of each peak of the samples were similar, while the intensity of some peaks decreased, which indicated that different sterilization methods may not have a significant effect on the composition of VCs of coffee, but have a negative effect on the concentration of VCs. According to Fig. 2b, all the sterilization methods, except high pressure processing, had a negative influence on the total aroma amount of coffee, especially the back pressure sterilization and pasteurization (decreased by 50.5% and 12.5% respectively). The effect of high temperature sterilization on the total aroma amount of coffee was relatively low (decreased by 8.0%), which had no obvious difference from that of MF. Overall, non-heat sterilization had little effect, as its milder sterilization process conditions led to lower aroma loss.

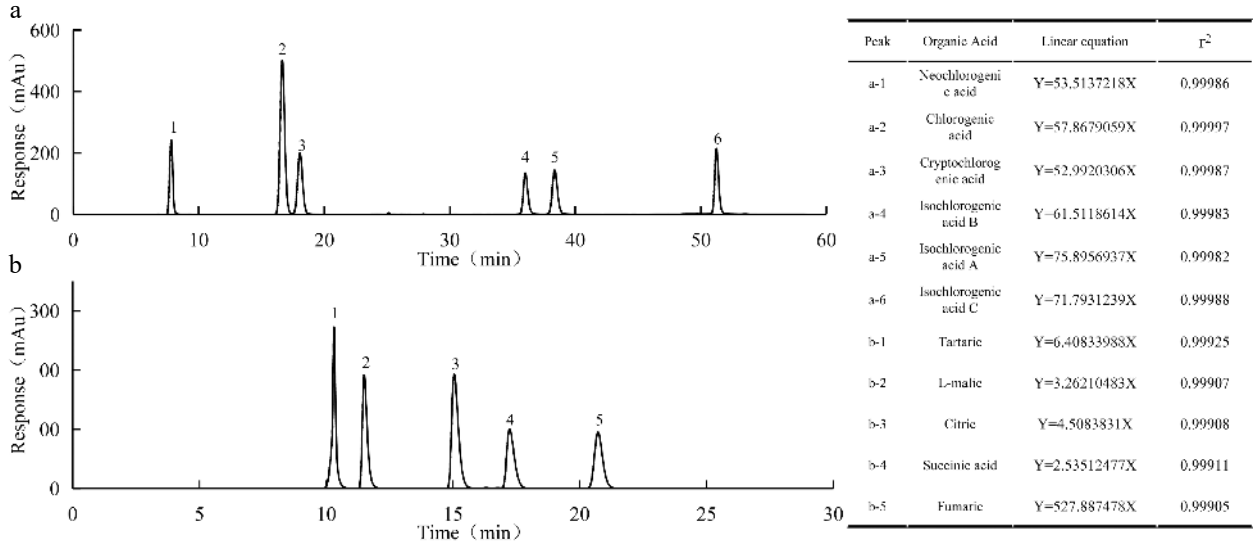
Analysis on VCs

Combined with the retention index of MXT-5 and MXT-1701 columns, the main VCs were retrieved by AroChemBase database of E-nose analysis software, and the possible compounds were obtained, as shown in Table 4. VCs were classified into

Table 3. pH value and organic acid concentration (g/kg) of each sample.

Sample	CK	PS	BPS	HTS	MF	HPP
pH value	4.92 ± 0.006^{cd}	4.89 ± 0^{b}	4.65 ± 0^{a}	4.91 ± 0.006^{bc}	4.93 ± 0.021^{d}	4.9 ± 0.006^{bc}
Neochlorogenic acid	1.45 ± 0.07^{a}	1.49 ± 0.02^{ab}	2.13 ± 0.02^{c}	1.47 ± 0.01^{ab}	1.47 ± 0.04^{ab}	1.53 ± 0.02^{b}
Chlorogenic acid	3.39 ± 0.18^{b}	3.46 ± 0.06^{b}	2.87 ± 0.04^{a}	3.42 ± 0.02^{b}	3.45 ± 0.09^{b}	3.48 ± 0.04^{b}
Cryptochlorogenic acid	1.8 ± 0.09^{a}	1.84 ± 0.03^{a}	2.12 ± 0.03^{b}	1.82 ± 0.01^{a}	1.83 ± 0.04^{a}	1.87 ± 0.02^{a}
Isochlorogenic acid A	0.04 ± 0^{a}	0.04 ± 0^{b}	0.04 ± 0^{b}	0.04 ± 0^{ab}	0.04 ± 0^{b}	0.04 ± 0^{b}
Isochlorogenic acid B	0 ± 0^{a}	0.01 ± 0.01^{ab}	0.02 ± 0.01^{ab}	0 ± 0^{ab}	0.01 ± 0.01^{a}	0.02 ± 0^{b}
Isochlorogenic acid C	0.04 ± 0^{ab}	0.04 ± 0^{c}	0.04 ± 0^{a}	0.04 ± 0^{bc}	0.05 ± 0^{c}	0.04 ± 0^{c}
Tartaric acid	6.71 ± 0.35^{a}	6.88 ± 0.11^{a}	7.21 ± 0.09^{b}	6.78 ± 0.04^{a}	6.85 ± 0.18^{a}	6.98 ± 0.08^{ab}
Malic acid	5.88 ± 0.56^{a}	5.85 ± 0.14^{a}	6.07 ± 0.33^{a}	5.88 ± 0.23^{a}	5.81 ± 0.09^{a}	5.85 ± 0.18^{a}
Citric acid	1.08 ± 0.48^{a}	1.26 ± 0.04^{a}	1.29 ± 0.09^{a}	1.22 ± 0.03^{a}	1.21 ± 0.03^{a}	1.39 ± 0.15^{a}
Succinic acid	4.26 ± 0.18^{a}	4.28 ± 0.46^{a}	7.57 ± 0.82^{b}	4.71 ± 0.12^{a}	4.6 ± 0.04^{a}	4.45 ± 0.18^{a}
Fumaric acid	0.19 ± 0.16^{a}	0.2 ± 0.18^{a}	0.29 ± 0.25^{a}	0.19 ± 0.17^{a}	0.21 ± 0.18^{a}	0.18 ± 0.16^{a}
Total	0.03 ± 0^{ab}	0.03 ± 0^{ab}	0.03 ± 0^{b}	0.03 ± 0^{a}	0.03 ± 0^{ab}	0.03 ± 0^{ab}

Different letters in the same row indicated significant difference ($p < 0.05$)



Peak	Organic Acid	Linear equation	r^2
a-1	Neochlorogenic acid	Y=53.5137218X	0.99986
a-2	Chlorogenic acid	Y=57.8679059X	0.99997
a-3	Cryptochlorogenic acid	Y=52.9920306X	0.99987
a-4	Isochlorogenic acid B	Y=61.5118614X	0.99983
a-5	Isochlorogenic acid A	Y=75.8956937X	0.99982
a-6	Isochlorogenic acid C	Y=71.7931239X	0.99988
b-1	Tartaric	Y=6.40833988X	0.99925
b-2	L-malic	Y=3.26210483X	0.99907
b-3	Citric	Y=4.5083831X	0.99908
b-4	Succinic acid	Y=2.53512477X	0.99911
b-5	Fumaric	Y=527.887478X	0.99905

Fig. 1 High Performance Liquid Chromatogram of organic acid concentration.

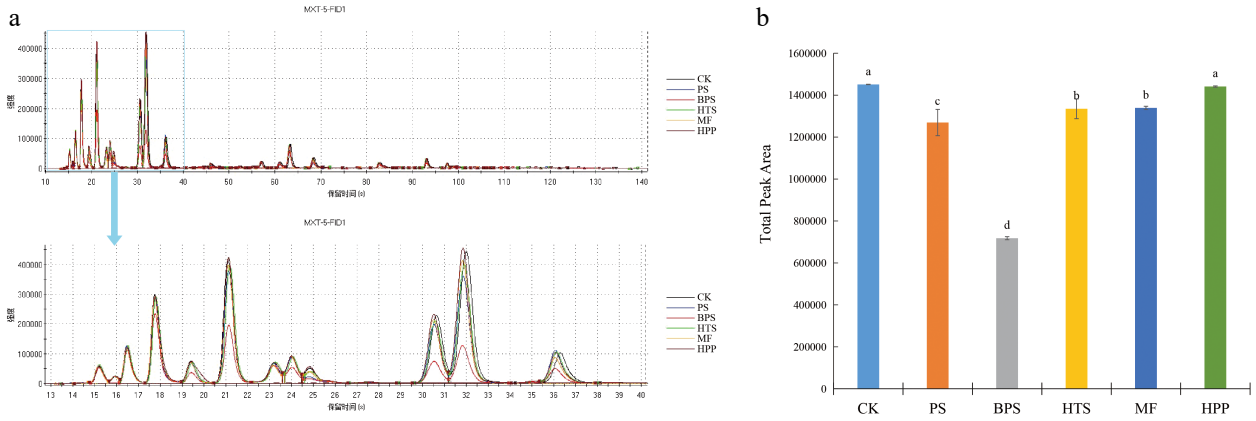


Fig. 2 (a) E-nose gas chromatogram; (b) total peak area.

Table 4. Information of main possible VCs.

No.	Retention time (s)	Retention index	Possible VCs	Sensory description	Category
1	15.2	415	Acetaldehyde	Fruit, pleasant, spicy	Aldehydes
2	15.9	430	Methanol	Alcohol, spicy, strong	Alcohols
3	16.5	441	Ethanol	Alcohol, spicy, strong	Alcohols
4	17.7	468	Propionaldehyde	Cocoa, nut, plastic, spicy	Aldehyde
5	19.4	502	Ethyl formate	Fruit, green, spicy, rose	Esters
6	21.1	537	2-methylpropionaldehyde	Baked potatoes, fruit, malt, roasted	Aldehyde
7	23.1	580	N-butyraldehyde	Cocoa, chocolate, green, malt, musty	Aldehyde
8	24.0	597	2-butanone	Butter, cheese, chocolate, pleasant	Ketones
9	24.8	605	2-methylfuran	Charred, chocolate, metal	Other
10	27.5	627	Isobutanol	Alcohol, bitter, licorice, sweet	Alcohols
11	29.3	641	Isopropyl acetate	Bananas, fruit, sweet	Esters
12	30.5	650	3-Methylbutyraldehyde	Almonds, cheese, chocolate, malt, peach, roasted	Aldehyde
13	31.8	661	2-ethylfuran	Burnt, acidic, sweet, rubber, malt	Other
14	35.1	686	2-pentanone	Bananas, fruit, sweet	Ketones
15	36.1	694	2,3-pentanedione	Almond, apple, cream candy, caramel, cheese, cream, fruit, malt, nut	Ketones
16	38.5	709	3-pentanol	Fruit, green, nutty, greasy, sweet	Alcohols
17	41.5	726	Glutaraldehyde	Almonds, berries, fruits, green, nutty, malt, herbal	Aldehyde
18	43.6	737	Pyrazine	Bitter, corn, hazelnut, nutty, sweet, spicy, strong	Pyrazine
19	44.8	744	Isoamyl alcohol	Alcohol, sesame oil, bitterness, cheese, fruit, malt, spicy, whisky, charred	Alcohols
20	46.0	750	pyridine	Burnt, amine, spicy	Pyridine
21	48.1	762	2-methylglutaraldehyde	Cheese, fruit	Aldehyde
22	49.6	771	N-pentanol	Alcohol, fruit, sesame oil, fennel, sweet, spicy	Alcohols
23	50.8	777	1-hexene-3-alcohol	Freshly cut grass, rum	Alcohols
24	52.2	784	2-hexanone	Fruit, cinnamon, fungi, meat, spicy	Ketones
25	54.0	794	N-hexanal	Herbal, dense, sweet, oak, butter	Aldehyde
26	55.0	800	2-Hexanol	Broccoli, fruit, wine	Alcohols
27	56.9	808	Propyl propionate	Apple, fruit, pineapple, fruity (sweet)	Esters
28	58.7	815	Bread ketone	Nuts, coffee, bread	Ketones
29	59.5	819	2-hydroxy-3-pentanone	Butter, nuts, peanuts, truffles	Ketones
30	60.9	824	Ethyl isovalerate	Fennel, apple, fruit, sweet	Esters
31	63.1	833	Furan formaldehyde	Almond, aromatic, roasted, sweet, woody	Aldehyde
32	68.2	855	Isovaleric acid	Cheese, fruit, sour	Acids
33	70.8	865	N-hexanol	Medicinal, plant, branch, sweet, woody, barbecue	Alcohols
34	76.3	888	2,4-dimethylthiazole	Cocoa, coffee, meat, beef flavor	Other
35	79.9	904	2-methoxypyrazine	Chocolate, cocoa, nuts, sweet	Pyrazine
36	82.7	919	Valeric acid	Sour, sweet, spicy, rotten	Acids
37	86.0	936	4,5-dimethylthiazole	Roasted, smoked, nutty, earthy	Other
38	86.8	940	Isovaleraldehyde propylene glycol acetal	Caramel, fruit, sweet, sour	Aldehyde
39	88.3	948	Propyl isovalerate	Apple, fruit, sweet	Esters
40	89.7	956	2-ethoxythiazole	Nut (roasted), coffee, burning	Other

(to be continued)

Table 4. (continued)

No.	Retention time (s)	Retention index	Possible VCs	Sensory description	Category
41	91.0	963	Tetrahydrothiophene-3-one	Roasted, garlic, onion flavored	Ketones
42	93.0	973	Filbertone	Hazelnut, nut	Ketones
43	97.5	997	2-Acetylthiazole	Bread, burnt, caramel, grain, peanuts, hazelnuts, popcorn, roasted	Other
44	99.0	1007	Caproic acid	Cheese, goat, sour, sweet, rotten	Acids
45	100.0	1015	Heptadiene aldehyde	Cinnamon, greasy, nutty, rancid	Aldehyde
46	101.7	1028	2-acylpyrrole	Popcorn, roasted	Pyrrole
47	103.2	1040	2-acetylpyridine	Biscuits, bread, greasy, popcorn, tobacco	Pyridine
48	105.1	1055	Furanone methyl ether	Caramel, fruit, mushroom, burning	Other
49	105.8	1061	2-methyl-5-vinyl pyrazine	Roasted, sweet, coffee, nut	Pyrazine
50	106.3	1065	2-acetylpyrrole	Nuts, walnuts, caramel, fennel, licorice	Pyrrole
51	107.1	1071	3-methylcyclopentane-1,2-dione	Caramel, coffee, sweet, maple	Ketones
52	109.1	1086	2-acetylpyrazine	Cocoa, coffee, popcorn	Pyrazine
53	111.2	1104	2-Nonanol	Apple, banana (ripe), cherry, orange, fruity	Alcohols
54	122.7	1194	Ethyl octanoate	Fennel, roasted fruit, fruit	Esters
55	132.4	1269	Nonanoic acid	Cheese, dairy products, sour	Acids

different categories (aldehydes, pyrazines, ketones, alcohols, esters, acids, pyrrole, pyridine and other), then the total peak area of each category was summed up, as shown in Fig. 3. Among CK, PS, HTS, MF and HPP, there was no obvious difference among the distribution of each VCs category, and aldehydes, pyrazines, ketones and alcohols were the main compounds. In BPS, the content of aldehydes and pyrazines are obviously lower. Compared to that of CK, they were decreased by 43.7% and 50.9% respectively.

Analysis on aroma type

Based on the sensory description in Table 4, the aroma of coffee can be classified to corny odor, sour/fermented odor, fruit/floral odor, caramel odor, nutty/cocoa odor and toasty odor. The main odors of CK were caramel odor, nutty/cocoa odor, toasty odor and corny odor. Compared to CK, BPS had a more sour/fermented odor but lower corny odor. Other samples were similar with CK, showing a little decrease in caramel odor and nutty/cocoa odor (Fig. 4).

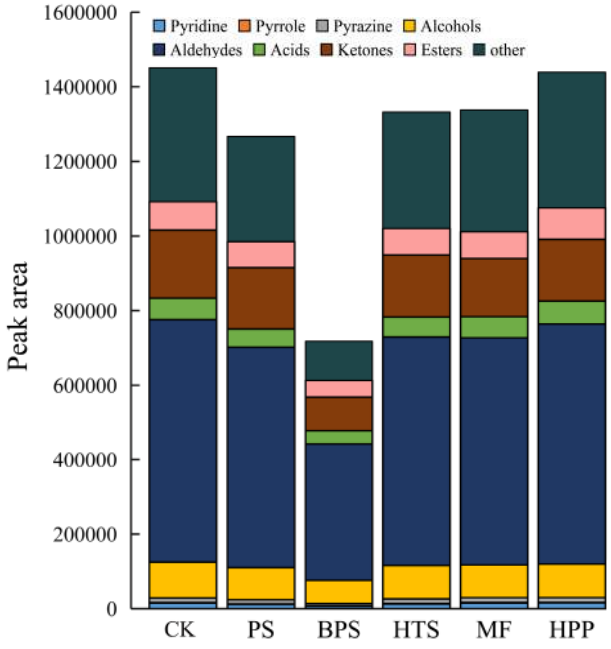


Fig. 3 Comparison of total peak area of different category VCs.

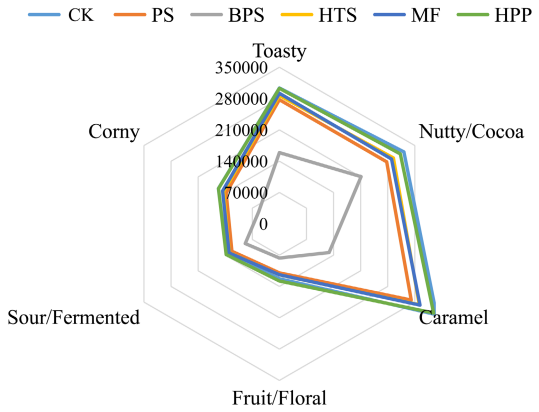


Fig. 4 Radar chart of coffee aroma.

Effect of sterilization on taste of cold brew coffee

E-tongue simulates the taste perception mechanism of living organisms. Sourness, sweetness, bitterness, saltiness, umami, astringency and aftertaste of cold brew coffee were evaluated by detecting the change of membrane potential caused by electrostatic interaction or hydrophobic interaction between various flavor substances and artificial lipid film[22]. The data of CK was set as the reference (zero point), then other samples were compared with it, and shown in Fig. 5.

Bitterness and astringency are important taste indicators of coffee. From Fig. 5a, different sterilization methods had different degrees of influence on the bitterness of coffee. BPS and PS had higher bitterness and astringency values than other samples. HTS, MF and HPP had lower bitterness, astringency and aftertaste values, among which HTS had the lowest.

Coffee samples also performed a significant response to saltiness, umami and richness (also known as umami aftertaste), and these three taste indicators were compared as shown in Fig. 5b. Back pressure processing had obvious negative influence on performance of the umami, saltiness and richness, while other methods had little influence on umami. Pasteurization and high pressure processing led to an increase in the richness value of coffee. For saltiness value, pasteurization increased it, while high temperature sterilization, membrane filtration and high pressure processing decreased it, and high temperature short-term sterilization decreased it the most.

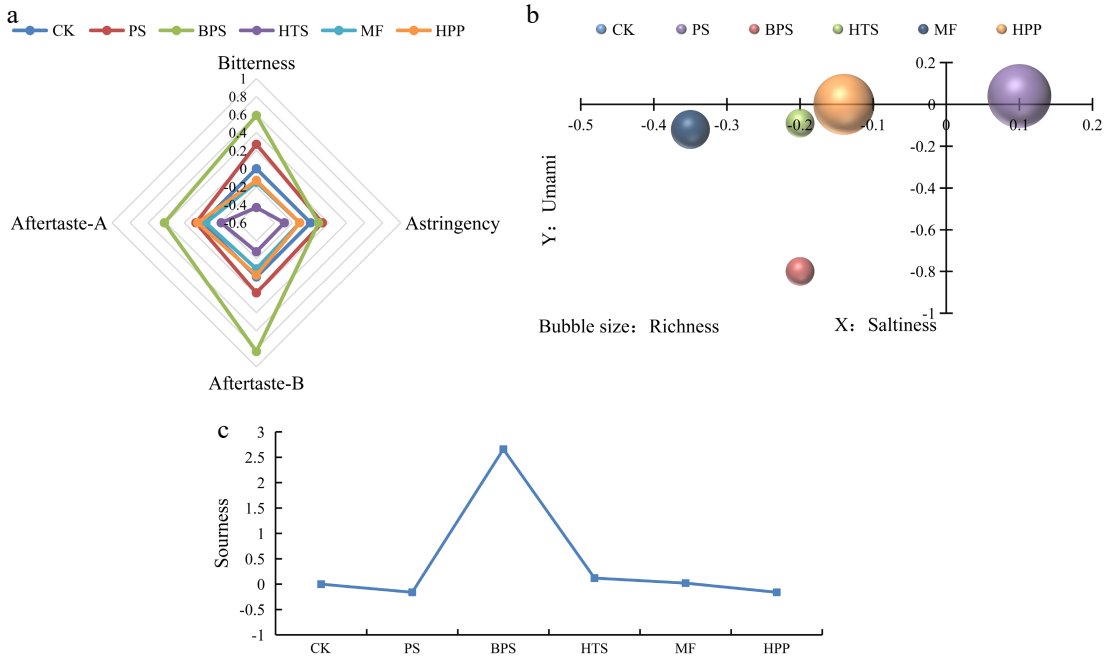


Fig. 5 Comparison of coffee taste. (a) bitterness, astringency and the aftertaste of the two; (b) saltiness, umami and richness; (c) sourness.

Sourness is a basic flavor of coffee. Compared to CK, BPS had higher sourness value, indicating that back pressure processing could lead to the increase in sourness, which corresponds to the results in pH value and organic acid concentration. Pasteurization and high pressure processing could decrease the sourness value of coffee while membrane filtration increased it.

Effect of sterilization on the sensory attributes of cold brew coffee

Coffee cup-testing is an important method to evaluate the sensory attributes of coffee. Recently, coffee cup-testing has been gradually applied in scientific research[23]. In order to obtain accurate results, professional testers were invited to participate in the evaluation, the results are shown in Figs. 6 and 7. The scores of each sensory attribute of samples ranged from 6.75 to 8.15. There was no significant difference in the score of flavor, aftertaste, acidity and body among the samples. Slight differences were shown in aroma, balance and overall scores, and the scores of BPS were significantly lower than that of CK.

CONCLUSIONS

In this research, five sterilization methods were used to sterilize cold brew coffee, then E-nose, E-tongue and coffee cup-testing were used to analyze the difference of coffee sensory quality before, and after sterilization. The results indicated that, compared to heat sterilization, non-heat sterilization was more favorable to the sensory attributes of coffee, as they had less negative influence on the aroma and taste of coffee. Among heat sterilization, back pressure sterilization showed significant negative effect on coffee sensory quality, as total aroma decreased, and sourness, bitterness and astringency increased. While the coffee treated with high temperature short-term

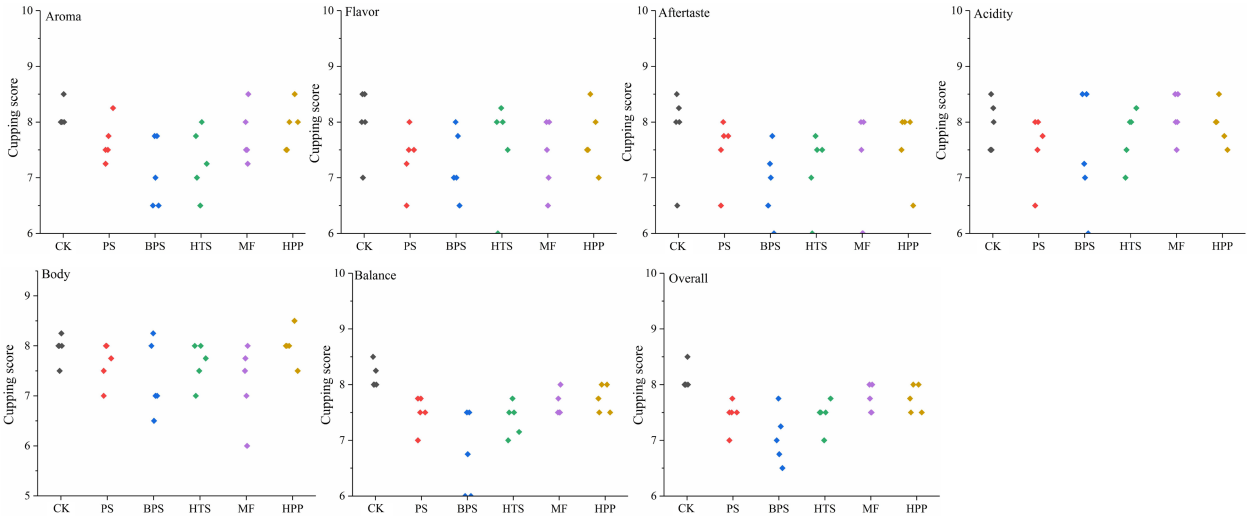


Fig. 6 Analysis of coffee cup-testing.

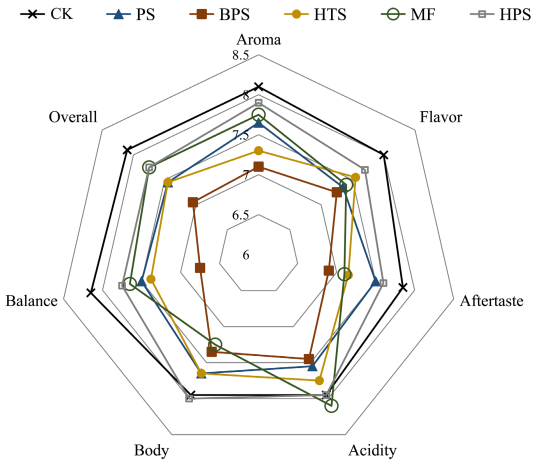


Fig. 7 Radar chart of coffee sensory results.

sterlization was relatively good overall, as the decrease of total aroma was not significant, and the bitterness of coffee decreased comparatively.

According to this research, non-heat sterilization can better retain the aroma and taste of cold brew coffee, but due to its high cost and limited application, it is not as widely used as heat sterilization in coffee and other beverage products. Among heat sterilization, high temperature short-time sterilization is more suitable for the processing and production of cold brew coffee, as its cost is reasonable, and the sensory quality and nutrients of coffee can be better maintained. This research conclusion provides theoretical support for the selection of sterilization methods for cold brew coffee processing, but the optimization of sterilization procedures and the influence of processing conditions on the sensory quality of cold brew coffee requires further investigation.

Conflict of interest

The authors declare that they have no conflict of interest.

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REFERENCES

1. NCA National Coffee Association USA. The History of Coffee. www.ncausa.org/About-Coffee/History-of-Coffee
2. ICO – International Coffee Organization. 2021. Coffee prices underwent further increases in September 2021 but volatility lessened substantially while the market continues to be driven by weather in Brazil and by covid-related disruption affecting trade in Asia. *Coffee Market Report – Setember 2021*. www.ico.org/documents/cy2020-21/cmr-0921-e.pdf
3. Yu F, Dong W, Hu R, Long Y, Chen Z, et al. 2021. Effects of different roasting speeds on the volatile components of Xinglong coffee beans. *Chinese Journal of Tropical Agriculture* 42:3316−26
4. Zhi M, Xu W, Wu L, Pan H, Huang W, et al. 2021. Detection and evaluation of flavor substances of roasted coffee beans in different regions. *Quality and Safety of Agro-Products* 3:84−90
5. Zhu X. 2021. Analysis of Colombia coffee extracts' aromas at different extraction temperatures. *Beverage Industry* 24:12−20
6. Kulapichitr F, Borompichaichartkul C, Suppavorasatit I, Cadwallader KR. 2019. Impact of Drying Process on Chemical Composition and Key Aroma Components of Arabica Coffee. *Food Chemistry* 291:49−58
7. Grand View Research. 2019. Cold brew coffee market size (2019–2025) – by distribution channel (supermarkets & hypermarkets, company owned outlets, convenience stores, online), by region, and segment forexasts. *Share & trends analysis report. GVR-2-68038-937-1*, Grand View Research. https://www.grandviewresearch.com/industry-analysis/cold-brew-coffee-market
8. Xing Y, Weng J, Wu Y, Li M, Li N. 2021. Aroma analysis of cold brew coffee liquor with different extaction times. *Beverage Industry* 24:36−42
9. Seninde DR, Chambers E IV, Chambers D. 2020. Determining the impact of roasting degree, coffee to water ratio and brewing method on the sensory characteristics of cold brew Ugandan coffee. *Food Research International* 137:109667
10. Bellumori M, Angeloni G, Guerrini L, Masella P, Calamai L, et al. 2021. Effects of different stabilization techniques on the shelf life of the Cold Brew coffee: chemical composition, flavor profile and microbiological analysis. *LWT- Food Science and Technology* 142:111043
11. Zhang P, Ruan Z, Li B. 2021. The flavor quality of pear juice fermented with Lactobacillus plantarum improved by ultra-high pressure pretreatment. *Modern Food Science and Technology* 37:230−239+300
12. Cui S, Yan B, Lou Y, Ye T. 2019. Ultrasound sterilization on fruit and vegetable juice and quality change. *Beverage Industry* 22:15−20
13. Huang X, Wang Y, Liao X, Zhao L. 2021. Effects of Ultra-high pressure and high temperature short-time sterilization on the quality of NFC orange juice. *Science and Technology of Food Industry* 42:1−8+14
14. Guerrini L, Zanoni B, Breschi C, Angeloni G, Masella P, et al. 2020. Understanding olive oil stability using filtration and high hydrostatic pressure. *Molecules* 25:420
15. Gloess AN, Schönbächler B, Klopprogge B, D'Ambrosio L, Chatelain K, et al. 2013. Comparison of nine common coffee extraction methods: instrumental and sensory analysis. *European Food Research and Technology* 236:607−27
16. Hu H, Song H, Wang J, Lin T, Liu X, et al. 2018. Determination of six kinds of chlorogenic acid by high performance liquid chromatography. *Journal of Food Safety & Quality* 9:1634−43
17. GB5009.157-2016 National food safety standards, Determination of organic acids in foods.
18. Wang W, Jin L, Cheng C, Zhang J, Xing Z. 2020. Analysis of aroma changes during the processing of coffee freeze-dried powder by heracles NEO Ultra-fasted gas chromatography. *Beverage Industry* 23:12−16
19. Hu R, Kuang Q, Wang X, Solano W, Long Y, et al. 2021. Sensory characteristics of dry aroma and cupping quality of coffee from pu' er producing area. *Chinese Journal of Tropical Crops* 42:535−45
20. Duan L, Qiu B, Dai L, Zhang S, Mei L, et al. 2018. Seven Organic Acids Contents in Catimor Coffee DEtected by HPLC. *Chinese Journal of Tropical Agriculture* 42:7−14
21. Liu X, Chen X, Du L, Lin T, Yin B, et al. 2021. The Interaction of Multi-Factor Leads to Chlorogenic Acid Rapid Degradation in Roasted Coffee. *Food Science* 42:7−14
22. He J, Geng L, Chen Q, Hu Z, Xiao Z. 2021. An initial research on quantifying coffee taste evaluation. *Science and Technology of Food Industry* 35:307−11
23. Hu R, Kuang Q, Qang X, William S, Long Y, et al. 2021. Sensory characteristics of dry aroma and cupping quality of coffee from Pu'er producing area. *Chinese Journal of Tropical Agriculture* 42:535−45