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Extraction technology and influencing factors of cold brew coffee

Zhi Li [1,*]

[1]College of Biological Sciences and Biotechnology, Beijing Forestry University, Beiing, China

[*]lizhi0806@bjfu.edu.cn

Abstract. Coffee especially cold brew coffee is widely popular around the world, so people have conducted deep research on how to make a cup of coffee. This paper studies the types of coffee beans, the chemical composition of coffee beans, the roasting degree of coffee beans and the extraction technology. Among them, there are a lot of biochemistry reactions such as Maillard and Caramel reaction. Moreover the extraction technology focuses on the cold extraction technology, which is compared with the hot extraction technology in the content of flavor substances. In addition, the flavoring substances are matched with their aroma to compare the flavor differences between hot brew and cold brew coffee. Finally, the adjustable influencing factors in the cold extraction technology were studied and summarized to provide theoretical reference and practical guidance for the flavor improvement and industrial production of cold brew coffee. Furthermore, there will emerge other problems of coffee producing which will be issues to solve in the future.

Keywords: cold brew coffee, extraction parameters, flavor substances, influence factors.

1. Introduction

Coffee is a plant of the genus Rubiaceae, which is native to the tropical regions of northern Africa, so coffee beans did not originate in China. However, coffee, especially cold brew coffee, is very popular in China and has become the second most consumed drink after water. So how to make a cup of high-quality boutique coffee is a question that baristas need to study. However, the extraction process of coffee and its chemical reactions are well understood, but the corresponding flavor and sensory descriptions of each substance produced are lacking, so further research is needed on the factors affecting coffee quality.

The quality of coffee is affected by many factors, such as the type of coffee beans, the degree of roasting, the extraction method and the extraction conditions. The chemical composition of Arabica and Robusta coffee beans is significantly different. Differences in the degree of roasting of the same coffee beans can also lead to differences in the flavor of subsequent products. The chemical substances produced by hot extraction and cold extraction are also different. In cold brew, drip filtration method and soaking method can be used, in which different choices of temperature, time, ratio of material to water, particle size and water quality will have significant effects on the product. The resulting chemicals are closely related to the flavor of coffee. Therefore, it is necessary to compare various influencing factors and the flavor performance of each coffee to determine the most suitable coffee for people's taste.

In order to industrialize coffee, especially cold brew coffee, it is important to understand the flavor profile of the product that corresponds to the chemical reactions in cold brew coffee. This will help to improve the taste of the coffee and extend the shelf life of the product in order to develop new, more popular and healthier coffees.

2. Types of coffee beans and differences in corresponding components

2.1. Category

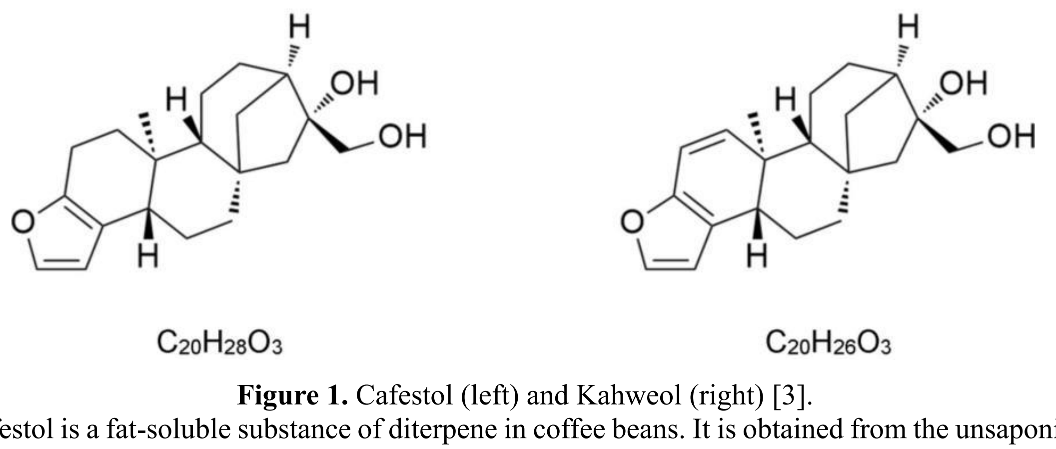
Coffee is the seed of coffee plant of Rubiaceae, which generally grows in shrubs and trees. The coffee beans which people use will be produced after a series of operations such as repeated baking. Coffee is the second largest trade product after oil. According to plant taxonomy, there are more than 100 types of coffee, of which Arabica and Robusta, two species native to tropical Africa, are often seen in coffee shops. These two varieties have different qualities and uses.

Arabica coffee, also known as small fruit coffee, is originally produced in the Ethiopian plateau region of the Great Rift Valley in East Africa. Since coffee became a delicious drink in the Arab region, coffee beans have gradually spread to other regions. (*lizhi0806@bjfu.edu.cn) At present, Arabica coffee beans are mainly produced in Brazil, Kenya, Colombia and other regions [1]. The caffeine content of Arabica coffee beans is relatively low, and the proportion is about 0.9% - 1.2%. The content of lipids and sugars is quite rich, with carbohydrates accounting for 5.3-8.6% and lipids accounting for 13% of dry weight. After brewing, the smell is soft and not irritating, and the taste is fresh and slightly sweet [2].

Robusta coffee, also known as medium fruit coffee, is larger than Arabica coffee. It was first found in the tropical jungle on the West Bank of the African continent. At present, the main producing areas are Indonesia, India and Vietnam. Compared with Arabica coffee, Robusta has better resistance to disease and insect pests. The content of caffeine is between 1.6-2.4%, and the content of fat and sugar is 50-60% less than Arabica coffee. After brewing, the taste is more stimulating, and the taste is bitter and strong.

2.2. Composition of different coffee beans

Coffee contains a variety of chemicals to provide a variety of flavors. The flavor difference between Arabica and Robusta is related to the content of chemicals. Stefano Mammi's team at the University of Padova, Italy, used nuclear magnetic resonance carbon spectroscopy (13C NMR) and high-performance liquid chromatography (HPLC) to conduct qualitative and quantitative analysis of Cafestol and Kahweol (as shown in Figure 1) in coffee oil of raw coffee beans [3]. The chemical structure of Cafestol and Kahweol is similar, and Kahweol has one more double bond than Cafestol, which has an antioxidant effect.



$C_{20}H_{28}O_3$ $C_{20}H_{26}O_3$

Figure 1. Cafestol (left) and Kahweol (right) [3].

Cafestol is a fat-soluble substance of diterpene in coffee beans. It is obtained from the unsaponifiable part of coffee oil. It is a substance that makes coffee bitter and oily and provides a strong smell. The content of cafestol in Robusta is very low, and it also has a unique chemical substance, 16-O-methylcaffeinol, which is not contained in Arabica coffee. By analyzing and determining the chemical composition of 16-O-methylcaffeinol, it can detect whether the high-price Arabica coffee products are mixed with low-price Robusta coffee (See Table 1).

Table 1. Determination of trace components in raw bean coffee oil by 13C NMR (determination of diterpenoids by DIN method) [3].

varieties	Place of Origin	Kahweol		Cafestol		16-O-Methylcafestol	
		DIN (g/kg oil)	NMR (g/kg oil)	DIN (g/kg oil)	NMR (g/kg oil)	DIN (g/kg oil)	NMR (g/kg oil)
Arabica	Brazil	26.9	29.5	35.3	28.9	0	0
	Columbia	10.0	25.6	17.7	28.4	0	0
Robusta	India	0.4	0.5	8.8	14.6	6.0	9.1

3. Baking degree of coffee beans and common flavor compounds in the roasting process

3.1. Baking degree of coffee beans

The roasting degree of coffee beans is closely related to the final quality of coffee. Less heat will make sour, and more heat will make old and tasteless. Barista need to balance the bitter and sour taste of coffee and find the most suitable roasting degree for different varieties of coffee. During roasting, the color of coffee beans will change from blue-green to beige and finally to brown as everyone know it, and the coffee beans will become larger with the quality reduction. Baking can effectively improve the extraction rate of lipids in coffee beans. Due to the microstructure transport of coffee beans after deep baking, the lipids wrapped in the structure by cellulose matrix are more easily adsorbed on the coffee bean wall. Viscosity and pH value of coffee beans will be affected. The content of chlorogen will be reduced by 50% with baking, resulting in the formation of aromatic phenolic compounds and bitter phenolic compounds. Chlorogenin also affects the calmness of coffee pigment. As the main source of coffee astringency, it affects the formation of coffee color by infiltrating the skeleton of protein melanin. The content of caffeine will sublimate with baking and cause loss [4].

3.2. Chemical reaction during baking

3.2.1. Maillard reaction. Maillard reaction, also known as carbonyl ammonia reaction, is a non-enzymatic browning widely used in food processing. It can be divided into three stages: (1) the carbonyl of sugar reacts with the amino group of protein or amino acid to generate water and unstable glycosamine (2) the glycosamine isomerization into Schiff base, converted into imine cation, enamine alcohol and other configurations, and then rearranged, Finally, a series of aminoketone compounds are produced (3) When aminoketone compounds undergo further rearrangement, transformation, addition and polymerization, many small molecular compounds with different flavor, aroma and color (such as pyrazine, pyridine, pyrrole, furan compounds, etc.) are produced [1].

In the roasting process of coffee beans, the Maillard reaction will be carried out rapidly at 140-170 ℃. After a series of complex reactions between the carbonyl of reducing sugars, amino acids and amino acids of proteins, melanin, a brown and black macromolecular substance, is finally produced and tastes delicious. Thousands of different flavor substances will also be produced during the process, including reducing ketones, aldehydes and heterocyclic compounds.

3.2.2. Caramel reaction. The caramelization reaction is the browning reaction of sugar because of dehydration polymerization reaction, which generates brown caramel anhydride, caramelene and caramelin. During the caramelization of coffee beans, volatile aldehydes and ketones are released by pyrolysis. Although the sugar is decomposed and the sweetness of the food is reduced, it provides a complex flavor.

3.2.3. Oxidation reaction. Enzymatic or non-enzymatic browning of food components is usually caused by oxidation reaction. The products of the Maillard reaction and caramel reaction may interact with each other to produce oxidation reaction and improve the coloring power of the products. However, if excessive oxidation occurs, melanoid will be generated and the product quality will be reduced.

3.3. Flavor substances

Coffee contains a variety of volatile flavor substances, including aldehydes, sulfur, ketones, esters, furans and other substances. Sulfur-containing compounds will have chocolate flavor, nut flavor, cocoa flavor and even wood flavor. The relative content of heterocyclic compounds increased significantly during the baking process. The pyrazine heterocyclic compounds produced by Maillard and caramel reaction are the source of chocolate flavor in coffee. The furan compounds are related to the caramel flavor and nutty flavor in the coffee aroma, and have the characteristics of rising into the nose during the baking process. Phenols are the main source of coffee bitterness. Coffee is rich in phenolic acids such as chlorogenic acid, caffeic acid and quinic acid. Although these phenolic acids are strong antioxidants, the degradation products after baking have a bitter taste.The sucrose content in coffee will also affect its flavor. The higher the sucrose content, the more acidic the coffee will be.

4. Coffee extraction technology

4.1. Cold and hot coffee extraction technology

There are two preparation methods of cold-brewed coffee: dropping and soaking. The drip method is to continuously drip cold water onto the coffee powder within a certain time, and obtain the coffee liquid in the form of cold extraction. The representative on the market is ZHONGFEI ice drop for 8h cold extraction of pure black coffee. The soaking method is to immerse the coffee powder in a container containing cold water for about 20 hours to obtain the cold-extracted coffee extract. This method is widely promoted in business. Starbucks uses the soaking method to make cold extract coffee.

Cold extract coffee needs to be drunk immediately after preparation or after short-term storage under cold storage conditions. However, its harsh taste period limits the consumption distance of cold extract coffee. Bellumori et al. evaluated the effects of high-pressure treatment, microfiltration, ultraviolet radiation, pasteurization and rapid cooling on the quality of cold-extracted coffee [5]. The results (Table 2) showed that high-pressure treatment and pasteurization had good performance in maintaining the content of caffeine and chlorogenic acid and microbial safety. However, the cold-extracted coffee samples treated by high pressure will reduce about 25% of the volatile compounds in the storage life of the pasteurized samples. Hot-extracted coffee can be extracted by using a mocha pot, using 82-95 ℃ hot water, and extracted within 5min.

Table 2. Effect of different shelf life extension techniques on cold brew coffee microbial reduction, shelf life and quality change.

Processing technology	Technological parameter	The reduction of total bacteria (FU/mL)	Storage life	The change of quality (t_0)
Rapid cooling	-18℃, 60min	881.7	After 7 days it shows microbial contamination	Compared with unprocessed species,Chlorogenic acid content was reduced by 11% and total volatile compound content was significantly reduced to 20.1mg/kg(246 mg/kg in untreated samples). Acetic acid, a key volatile substance with fruity aroma, was reduced by 25%. The senses show strong acidity and saltiness

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Table 2. (continued)

Processing technology	Technological parameter	The reduction of total bacteria (FU/mL)	Storage life	The change of quality (t_0)
Ultraviolet radiation	25±5°C, 1cm^3 coffee liquid is irradiated under 254nm a low pressure Mercury lamp	890.7	After 7 days it shows microbial contamination	pH4.98±0.02. The flavor perception of untreated and other treated samples was significantly higher than that of untreated samples
Microfiltration	1500g/m^2, fliter with standard of 5μm in rate of 600mL/min	990	After 30 days it shows high level of fungi which threat microbes	Compared to untreated samples. The content of 2-methylbutyral, a key volatile substance that has a malty aroma, was reduced by 20 percent, and the senses showed a strong bitter taste
Pasteurization	65°C, 30min	>995	4 months	There was no significant difference in pH, caffeine, chlorogenic acid and volatile flavor content between untreated and untreated samples, and the perception of phoenix flavor was similar to that of untreated samples
High pressure	Increasing pressure to 608MPa in 200s and sustain 6 mins	>995	4 months	There was no significant difference in pH, caffeine, chlorogenic acid and volatile flavor content between untreated and untreated samples, and the perception of phoenix flavor was similar to that of untreated samples

4.2. Comparison of cold extraction and hot extraction aroma

Chen et al. used the cold and hot extracts of Yunnan Arabica coffee as raw materials, extracted the aroma components by thermal desorption, analyzed the aroma components by gas chromatography (GC-MS), and compared the peak area and content by FID (See Figure 2-3) [6].

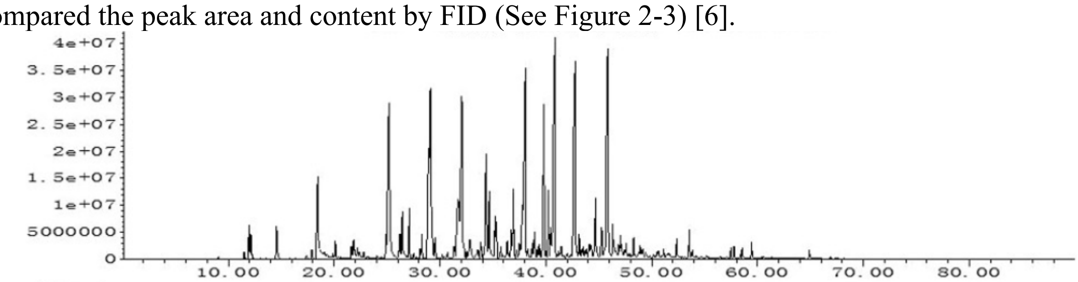

Figure 2. The aroma composition map of Yunnan Arabica coffee by cold extract (GC-MS, FID) (Horizontal axis is Time, Longitudinal axis is Abundance) [6].

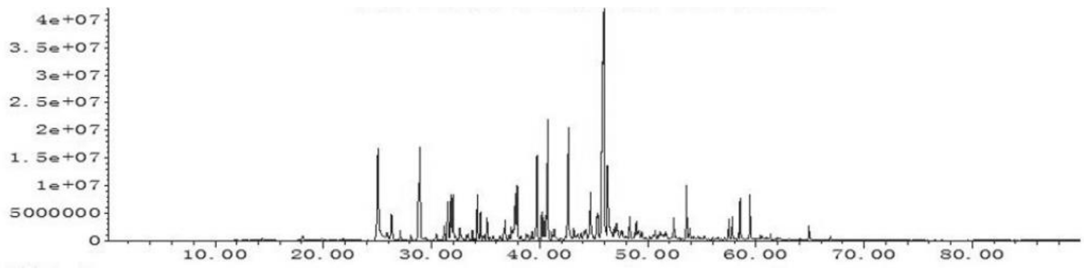

Figure 3. The aroma composition map of Yunnan Arabica coffee by hot extract (GC-MS, FID) (Horizontal axis is Time, Longitudinal axis is Abundance) [6].

According to the Fig 2 and 3, there are 145 aroma compounds in the coffee extract. 109 kinds of aroma compounds were analyzed from the cold extraction solution, 107 kinds of aroma compounds were analyzed from the hot extraction solution, such as furfuryl alcohol, 2,3-pentanedione, furfural, and conyl acetate, and the relative content of aroma compounds was more than that of furfuryl alcohol, acetoxy-2-propanone, isovaleric acid, pyridine, etc.

Among pyrazine compounds, cold extraction has more pyrazine, 2, 3-diethylpyrazine and other flavor compounds than hot extraction. These compounds have the most important chocolate and cocoa aroma in coffee, making the cold extraction nuttier and more pure baking flavor. The hot extract has a stronger sense of scorching and more flavor.

Among furan compounds, 2,5-dimethylfuran and 2-n-butyl furan, which are extracted from cold, can provide beef flavor and chicken flavor. The hot extracted 2-ethyl-5-methylfuran has a strong sweet, nutty and musty fragrance.

Among the olefinic compounds, 2-pentene is more in the cold extraction than in the hot extraction solution, which makes the cold extraction more abundant in the citrus head fragrance than in the hot extraction.

Among the alcohol compounds, the cold extract contains more n-hexanol, terpinol, 2-methyl-1-butanol, and isoprenol than the hot extract. These compounds provide the cold extract with the terpene sense of fructus and fructus and citrus. However, the hot extraction solution has more 3-penten-2-ol, 3-ethyl-3-buten-2-ol and 2-methyl-3-buten-2-ol than the cold extraction solution, adding soil aroma, mushroom aroma and wood aroma to the hot extraction solution. In addition, the content of furfuryl alcohol in cold extraction is much less than that in hot extraction. Furfuryl alcohol will provide a similar sweet taste to bread and rice bran, which also makes hot extraction have a stronger woody aroma, while cold extraction has a heavier fruit aroma.

Among ketone compounds, cold extraction has more flavor than hot extraction, such as 2,3-pentanedione, 2,3-hexanedione, cyclopentanone, etc., providing the aroma of biscuits, cheese and fermented dairy products. On the contrary, the thermal extraction has more hydroxyacetone, 2-cyclopentenone, etc., which can provide milk flavor and honey flavor. These also make the cold extraction prefer the sweet flavor of malt biscuits, and the hot extraction prefer the creamy fermentation flavor. Among the aldehydes, the cold extract contains more isovaleraldehyde and 3,4-dihydroxybenzaldehyde, which can provide the aroma of cocoa beans and nuts than the hot extract. Compared with cold extraction, hot extraction has more p-methylbenzaldehyde and 2,5-dihydroxybenzaldehyde, which have strong fragrance, pungent taste and bitter taste of almond. Among the acid compounds, the relative content percentage of isovaleric acid in hot extraction is more than that in cold extraction, which makes the sour flavor of cold extraction incline to cream cheese acid, and the hot extraction acid has more stimulating aroma. In general, pyrazines, furans, aldehydes and ketones have a key impact on the aroma of coffee. The citrus head fragrance, sweet fragrance and biscuit fragrance in cold extraction make it more advantageous in flavor than in hot extraction. Because sweetness and baking aroma are easy to volatilize and lose when the water temperature is relatively high, and coffee beans produce chemical reactions at high temperatures, making these substances less.

5. Influencing factors of cold extraction

5.1. Effect of temperature on the quality of cold-extracted coffee

Relatively high cold brew temperatures can extract more caffeine. Coffee prepared at 22 ℃ may contain more total dissolved solids, caffeine and chlorogenic acid than coffee prepared at 5 ℃. The content of bioactive compounds, antioxidant activity, total dissolved solids and total titratable acidity of cold-extracted coffee with water temperature controlled at about 15 ℃ are higher than those obtained at 5 ℃. Angeloni et al. extracted coffee caffeine at room temperature for 6h and obtained a concentration of 0.97 ± 0.12mg/mL [7].

5.2. Effect of particle size on the quality of cold-extracted coffee

The degree of grinding has an important influence on the extraction rate, total dissolved solids content, total phenol content, pH and titratable acid of coffee. A relatively fine grinding degree, namely, small-size coffee, can increase the extractability of volatile and non-volatile compounds in the extraction process. Cordoba et al [8]. Finding that the extraction effect of moderately ground coffee powder is worse than that of coarsely ground coffee in terms of total dissolved solids and extraction rate. It is speculated that filter bag extraction is used instead of direct extraction, and the moderately ground coffee powder is easy to agglomerate in the bag. It is also related to the type of coffee. At 15 ℃, the cold extraction rate of Arabica beans is not significantly related to the degree of grinding, while the finer robusta beans will increase the cold extraction rate [9].

5.3. Effect of feed-water ratio on the quality of cold-extracted coffee

The ratio of material to water is one of the key factors affecting the quality of coffee compound extraction. In the process of preparation, the excessive ratio of material to water will lead to insufficient expansion and compaction of coffee powder, thus affecting permeability. The little material-water ratio will lead to over-extraction and a more bitter taste. Yu studied the total sugar, reducing sugar, viscosity and other indicators of coffee obtained by cold extraction of coffee beans with the same baking degree and crushing degree under different feed water ratios [4]. The composition of total sugar and reducing sugar is the highest at the ratio of 1:12, which is because the appropriate dilution of the ratio of material to water will help the effective separation of sugar components in coffee beans, while the excessive ratio of material to water will dilute the total sugar content. The viscosity is negatively correlated with the ratio of material to water. The viscosity decreases with the increase in the ratio of material to water and the difference is obvious.

5.4. Effect of roasting degree of coffee beans on the quality of cold-extracted coffee

After the coffee beans are properly roasted, the polysaccharides, proteins, fats and other substances have undergone the Maillard reaction and caramelization reaction in varying degrees. After deep baking, the total acid content, pH value, total phenol content, viscosity, total sugar content and sour and bitter taste of the final cold-extracted coffee products will increase [4].

5.5. Effect of water quality on the quality of cold-extracted coffee

In recent years, the use of water has become more and more important in the coffee industry, because nearly 98% of the substances in coffee are water, and the quality of water has an important impact on the quality of coffee. There are corresponding recommended standards for coffee water in the coffee industry, focusing on the trace components in water, such as potassium, calcium, sodium, magnesium, aluminum, etc. Because these ingredients have a certain impact on the taste of coffee. And will affect the extraction of coffee by affecting the dissolution promotion or inhibition of specific ingredients. Jiang obtained the result that the extraction concentration, extraction rate and pH value of coffee gradually increased with the increase of ion concentration and physical and chemical indicators through experimental analysis of water samples with different ion concentrations and physical and chemical properties [10]. For non-volatile components, cucurbitacin, chlorogenic acid and caffeic acid will gradually increase, while titratable acid and total phenol content will gradually decrease. These factors have more influence on hot extraction than cold extraction.

6. Conclusion

Different kinds of coffee beans have obvious differences in appearance, chemical substances and extraction effects in the face of different conditions in subsequent extraction. In the roasting process of coffee beans, Maillard reaction, caramelization reaction and oxidation reaction have some preliminary processing on the chemical substances contained in coffee beans, laying a good foundation for subsequent extraction. In the extraction technology of coffee, cold extraction technology is also more popular than hot extraction. The flavor substances in the process of cold extraction and hot extraction, and the factors affecting the effect of cold extraction under different conditions were extracted and analyzed. At present, people's demand for coffee is increasing. However, whether in chain coffee shops or bottled coffee, the quality of coffee still needs to be improved, which can be achieved by adjusting the roasting degree of coffee beans and improving the extraction methods and conditions. There is still no clear and rigid standard for water quality, and deeper research should be carried out to produce better-quality coffee. Cold extract coffee is also becoming more and more popular in coffee, among which there are more suitable flavors for Chinese people. However, its storage and transportation are still lacking, and further research is needed.

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