EFFECT OF COFFEE REDUCTION ON CONSTITUENT CONCENTRATION IN AN ENERGY-EFFICIENT PROCESS OF ULTRASONIC EXTRACTION

by

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Coffee is one of the popular beverage; its constituents include caffeine, oxidation resistant aromatic constituents, protein, tannin, and fat. It is indicated in literatures that a proper amount of coffee stimulates the brain and enhances memory, but excessive coffee causes negative results, such as coronary artery disease, high blood pressure, heart disease and kidney disease. This study used high-performance ultrasonic process to discuss the effect of pulverized coffee reduction on the constituent concentration. It further compared the constituent concentrations obtained in different extraction periods. The experimental results show that the coffee aroma constituents can be extracted effectively by ultrasonic process without any organic solvent, and the constituent concentration does not decrease with the addition of pulverized coffee. Therefore, the consumption of pulverized coffee can be reduced greatly by using the proposed. The time of extraction process can be shortened, so as to save energy. The most important point is to reduce the enterprises manufacturing cost and to increase the profit.

Key words: *energy-efficient, ultrasonic extraction, pulverized coffee reduction*

Introduction

The ultrasonic extraction is a method that uses the strong energy generated by the collapse of numerous micro vacuum bubbles resulted from the pressure variation of ultrasonic in liquid to accelerate the contact velocity of solvent and extract. This method is characterized by mixing the extract with solvent quickly and uniformly, extracting the active constituents of natural products from the matrix to the solvent without damaging the extract structure [1]. Therefore, the processing time and solvent consumption can be reduced, and the operation is available at low temperature, so as to reduce the heat loss resulted from temperature, and avoid the volatilization of low boiling materials. It is extensively used for food processing and storage in recent years [2].

The coffee constituents include caffeine, oxidation resistant aromatic constituents, protein, tannin, and fat. The caffeine concentration is a critical index inside human body. An amount

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of caffeine can stimulate the brain and enhance memory, eliminate sleepiness, and relieve fatigue. Excessive caffeine is likely to cause palpitation, headache, and insomnia, as well as negative effects on human body, such as coronary artery disease, high blood pressure, heart disease, and kidney disease [3, 4]. The peculiar aromatic constituents in coffee are mainly related to the contained aroma precursors (*e. g.* carbohydrates, saccharides, amino acid and oil, and fat), they are the interaction among various lysates generated by fire heating, and there is no additive. In coffee bean research report, Sarrazin *et al*. [5] used five different extraction methods to compare the coffee aroma, including supercritical carbon dioxide fluid extraction, oil aroma extraction method, vacuum steam extraction-hydrosolvent, and vacuum steam extraction-organic solvent. The vacuum steam extraction-hydrosolvent results in good aromatic constituents.

Experimental method

This experiment used ultrasonic at oscillation frequency of 28 kHz to extract coffee aroma constituents, the main aromatic constituents include 2-methoxy-3-methylpyrazine, 2-phenylethanol, capric acid and 4-tridecanone. The coffee aroma concentrations are compared by controlling the extraction temperature, oscillation frequency, and extraction time. The concentration of extraction liquid is analyzed by gas chromatography (GC). The experiment of this paper consists of two major parts:

(1) The amount of coffee powder is fixed at 25 g, and the amount of water is fixed at 250 cm^3 (reverse osmosis RO, water). The extraction temperature is 40 °C, 50 °C, and 85 °C, respectively. The ultrasonic oscillation frequency is 28 kHz. The effect of ultrasonic vibration and oscillation time (15 seconcs and 30 seconds) on the aroma content is analyzed.

(2) Pulverized coffee reduction experiment: The pulverized coffee with different decrements (12.5 g, 15 g, and 20 g) is extracted by ultrasonic at 85 °C, (amount of water is fixed at about 250 cm^3). A control group is planned for comparison, following the present drip coffee making mode with a fixed amount of pulverized coffee (25 g). (amount of water is fixed at about 250 cm^3, 85 °C hot water). The effect on coffee aroma concentration of experimental and control group is discussed.

Experimental structure

The extraction equipment consists of water chiller, water heater and ultrasonic extraction equipment and the structure is shown in fig. 1.

In terms of temperature control, normal temperature is 25 °C, if the extraction temperature is lower than the normal temperature, the water chiller cools the solvent from normal temperature to low temperature. When the temperature reaches the operating condition, the original material is put in the hydrosolvent, mixed uniformly by stirring device. The extraction process is carried out by ultrasonic extraction equipment and controlling the extraction time and temperature. The collection bottle 1 and collection bottle 2 collect extraction liquid generated in different extraction conditions.

Experimental procedure

Step 1. The coffee beans are powdered by pulverizer. The coarse powder is filtered by 40mesh screen mesh and the fine powder is collected in the zipper bag. The 250 ml RO water is poured into the 500 ml glass beaker. The beaker is put in the tank of ultrasonic extraction equipment. The extraction temperature is set according to experimental conditions. If the operating temperature is higher than 25 °C, the water heater heats the solvent to the required temperature.

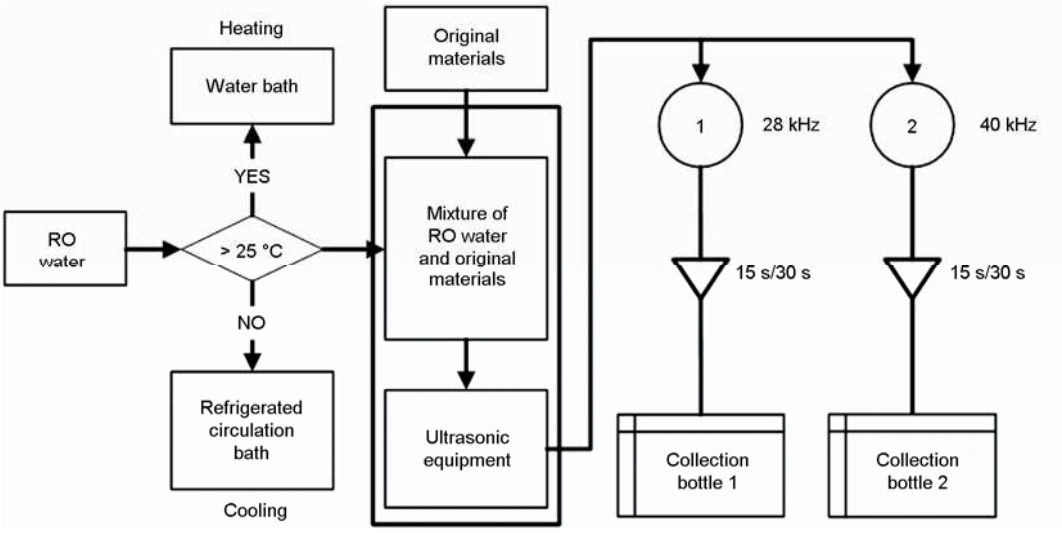

Figure 1. Experimental structure

Step 2. The extraction time of ultrasonic extraction equipment is set. When the tank temperature and the solvent temperature reach the required temperature, the pulverized coffee is dissolved in RO water and mixed uniformly by stirring device. The ultrasonic oscillation is switched on for extraction process. The oscillated extraction liquid is filtered by the 120mesh screen mesh twice and collected in the 300 ml plastic bottle. The sample is stored in the refrigerator.

Step 3. The extraction liquid is diluted 10 folds with pure water at 1:9. The dropper abstracts 3 ml extraction liquid to the centrifuge tube, centrifugated by micro tube centrifuge, so that the coffee powder in the extraction liquid is separated from the solution effectively. Then it is filtered by 0.45 μm syringe filter to minimize the residual fine particles in the collected extraction liquid. The extraction liquids obtained in different conditions are loaded in the test bottles for GC, respectively.

Step 4. The caffeine and aroma standards are analyzed by GC. When the data of standards are obtained, the composition of extraction liquid is analyzed. The analysis spectra are compared to check whether the required active constituents exist or not. The process is shown in fig. 2.

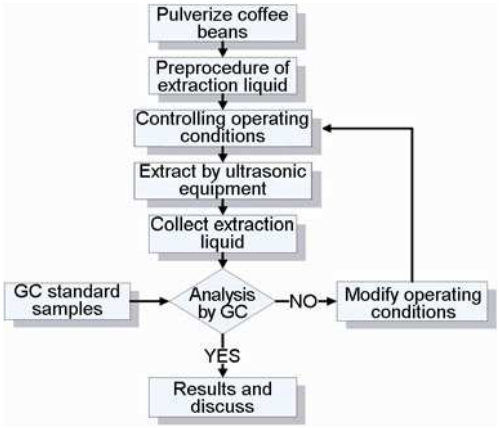

Figure 2. Experimental process

Results and discussions

Effect of oscillation time and extraction temperature on aromatic constituents. Figure 3 shows at any extraction temperature, the total aroma concentration of coffee is greater than that in standing (non-oscillating state is general drip coffee mode on the market) state when the extraction time is 15 seconds. Especially at 85 °C, the efficiency of ultrasonic extraction

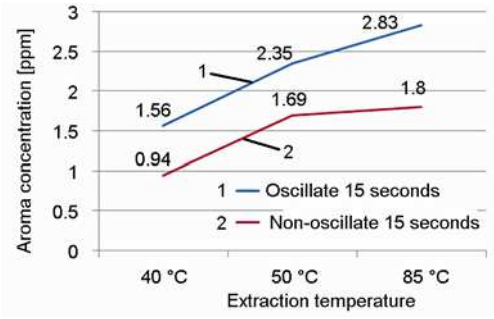

Figure 3. Effect of temperature on aroma concentration when oscillation frequency is 28 kHz and extraction time is 0 and 15 seconds, respectively

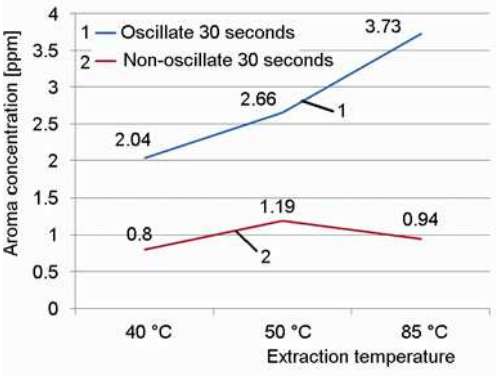

Figure 4. Effect of temperature on aroma concentration when oscillation frequency is 28 kHz and extraction time is 0 and 15 seconds, respectively

equipment is 57% higher than non-oscillation, the concentration is 2.83 ppm. When the extraction time increases to 30 seconds, in standing state, the aromatic constituents have been saturated, so the concentration does not increase anymore, as shown in fig. 4. The ultrasonic extraction mode not only improves this condition, the constituent concentration at different extraction temperatures is higher than that of 15 second extraction. The maximum concentration is 3.73 ppm, and the extraction efficiency is 4 times of that in standing state. Therefore, the proposed extraction equipment and method have excellent performance.

Effect of pulverized coffee reduction on constituent concentration. Figure 5 shows that the aroma concentration of drip coffee on the market is about 0.68 ppm. When the extraction time is 15 seconds, and the amount of pulverized coffee is reduced to 20, 15, or 12.5 g, the extracted aroma concentrations are higher than that of drip coffee. Therefore, the proposed extraction equipment and method proposed can reduce the consumption of pulverized coffee without influencing the content of coffee aroma. This equipment can be applied to mass extraction equipments to reduce the enterprises' operating cost effectively. However, when the extraction time increases to 30 seconds and the amount of pulverized coffee is reduced to 20, 15, and 12.5 g, respectively, the aroma concentration is still higher than that of drip coffee on the market. However, the effect is worse than 15 second extraction, as shown in fig. 6. This suggests that the extraction time is not required to be long in the experiment on reduction, otherwise the constituents are still saturated. The reduction of extraction time is very advantageous to the process and energy saving. Therefore, this result can be important reference for subsequent extraction of coffee aroma constituents.

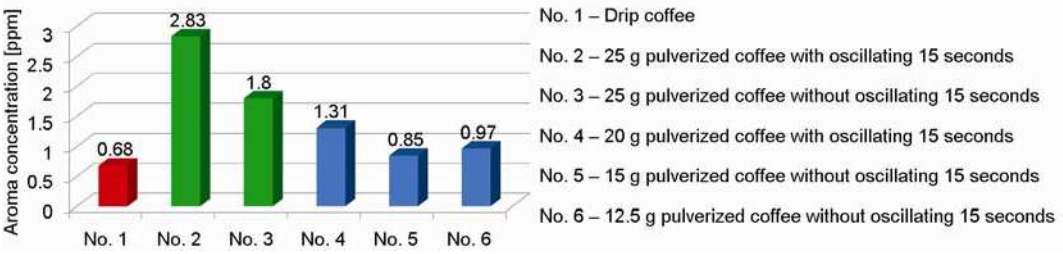

Figure 5. Effect of pulverized coffee reduction on aroma concentration when oscillation frequency is 28 kHz, and extraction time is 15 seconds

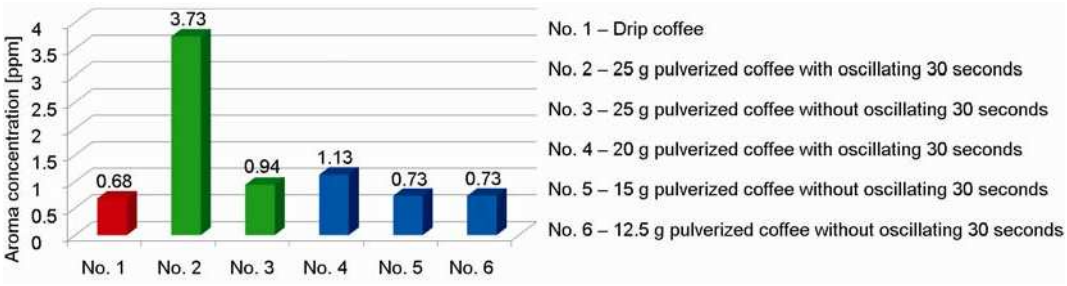

Figure 6. Effect of pulverized coffee reduction on aroma concentration when oscillation frequency is 28 kHz, and extraction time is 30 seconds

Conclusions

The ultrasonic extraction process proposed in this paper can increases the extraction yield of aromatic constituents in coffee. The effect is better especially at operating temperature of 85 °C. The control of extraction time is more important, compared with the drip coffee on the market in the same weight. The extraction efficiency is very good when the extraction time is 15 seconds to 30 seconds. In the experiment on coffee reduction, the proposed method can reduce the consumption of coffee without influencing the aromatic constituent concentration. Even half amount of pulverized coffee had more aromatic constituents than general drip coffee on the market. The process and experimental results proposed in this paper can be used as main reference frame for coffee aroma concentration control, and the extraction period can be shortened, so as to attain the goal for energy saving.

Acknowledgments

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