APPLICATION OF ULTRASOUND THERMAL PROCESS ON EXTRACTING FLAVOR AND CAFFEINE OF COFFEE

by

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In this research, our focus is the use of ultrasound thermal process to extract flavor and caffeine from coffee. The different operating conditions for extraction experiments are executed and the results are also compared. The results show that coffee flavor is not enhanced with the increase of temperature because the volatile degree of coffee flavor components is quick and easy to be reached at high temperatures. From the experimental results, it can be found that using low vibration frequency is better than using high vibration frequency. Also, caffeine will be reached into the saturated state at the 15th second of the extracting time and the quantity of caffeine augments with the increase of temperature.

Key words: *ultrasound, caffeine, flavor*

Introduction

Coffee is an extremely popular leisure drink throughout the world. It has a kind of very distinct aroma that is the result of a variety of constituents which include proteins, tannic acid, fats and of course caffeine and so on. A general survey of reference works indicates that ingesting a small amount of caffeine can be beneficial; it can stimulate the brain and enhance memory. If being ingested in excess, on the other hand, caffeine can exacerbate health issues such as heart problems, high blood pressure, kidney and coronary diseases.

The ingredients of coffee include caffeine, aroma, proteins, tannic acid fats, etc. When used in moderation, caffeine can stimulate the brain, enhance memory, inspire enthusiasm, clarify thoughts, and reduce fatigue and sleepiness. However, excessive amounts of caffeine can cause anxiety, uneasiness, heart palpitations, headaches, diarrhea and insomnia among other negative effects. Some literature indicates that caffeine can have a detrimental effect on human health. These negative effects include exacerbating coronary artery disease, raising blood pressure, and heightening the risk of heart attack and kidney disease [1, 2].

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The main ingredients of coffee include some flavor precursors (such as carbohydrates, sugars, amino acids, fats *etc*.). Today, at least 670 kinds of flavor compounds have been found [3]. In the research regarding the effects of extraction processes on aromatic constituents, Sarrazin *et al.* [4] compared the resultant aromatic oil extractions of five different extraction methods, including Press Oil Aroma Extraction (oil), Supercritical Fluid Extraction (SFE), Simultaneous Distillation-Extraction (SDE), Vacuum Steam-Stripping with water (VSS water) and Vacuum Steam-Stripping with methylene chloride (VSS CH_2Cl_2). Studies of Sarrazin concluded that the VSS water process produced the best results for extracting aromatic components of coffee.

Several kinds of experiments mentioned above are used for extracting flavor and caffeine; as long as the controlling factor increases, the results often lead to the increase of the experiments and the complexity of the process. Ultrasound thermal extraction is the way of using the powerful energy which is produced by the burst of the bubbles – produced by the change of the pressure when ultrasound is in the liquid – to accelerate the contact speed of the solvent and the extract. The main feature of the approach is that it can rapidly and evenly blend the extract and the solvent; in the process of extracting useful constituents from the natural substances, it can bring the extract from the matrix to the solvent without damaging the structure of the extract [5]. Ultrasound thermal extraction has been improved upon the shortcomings of traditional solvent extraction by reducing the processing time and procedures without the use of harmful solvents. In addition, this method produces higher yield rates than traditional extraction methods. Because this process operates at low temperature, it reduces heat loss and avoids losing or destroying volatile substances that have a low boiling point. This technique has become common in contemporary food processing and storage [6].

This paper applied ultrasound thermal process at a specific high-frequency that utilizes sound waves to extract flavor and caffeine. Our study also proposes a set of novel extraction equipment that is designed to optimize the consistency of the coffee powder and extraction liquid to allow for a highly efficient extraction process. The extraction equipment was executed under a wide spectrum of operating conditions and the obtained results are compared.

Experimental method

Experimental materials and equipment s

The materials used in the experiment are RO Water and Italian coffee powder, and the experimental equipment needed includes a grinding machine, a water bath, a refrigerated circulation bath, and a set of ultrasound thermal equipment that functions at 28 kHz and 42 kHz with gas chromatography (GC, fig. 1a) and high performance liquid chromatography (HPLC, fig. 1b).

As shown in fig. 2, this equipment is built from a refrigerated circulation bath, a water bath, and a piece of ultrasonic equipment. To ensure a consistent and accurate temperature for each experiment, the circulation bath is used to either raise or lower the temperature of the coffee/RO solution. If the required operating temperature is lower than 25 °C, the refrigerated circulation bath will cool the liquid mixture down from the room temperature to the desired temperature; if a temperature of more than 25 °C is required, the water bath will heat the liquid mixture from the room temperature to the desired temperature. When the correct temperature for the specific experiment is reached, the coffee powder will be mixed into the RO water. This mixture is then processed through one of the two separate ultrasonic machines. One ran at 28 kHz for the duration of 15 seconds and the other ran at 40 kHz for the duration of 15 seconds. The results of these extractions are then collected in collection tank 1 and collection tank 2, respectively. The process is then repeated for the duration of 30 seconds. This extraction is also added to the tanks. Each collection tank then holds a solution of the two extractions. One tank holds a solution of extracts that have been processed for 15 and 30 seconds using 28 kHz, and the other tank holds a solution of extracts that have been processed for 15 and 30 seconds using 40 kHz.

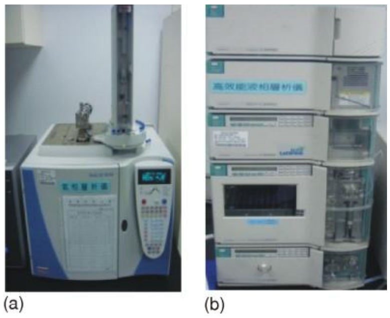

Figure 1. (a) GC, (b) HPLC

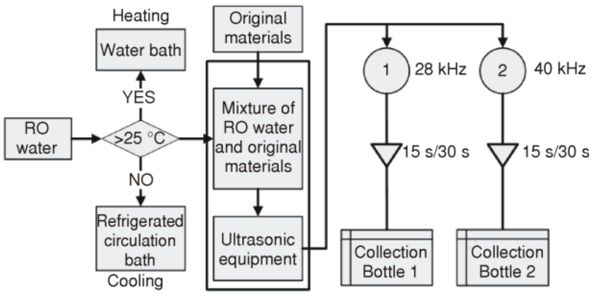

Figure 2. Description of experiment

Process of experiment

First, a grinder is employed to grind the coffee beans into fine grains and then filters them through a 40 mesh filter. When the temperature reaches the operating temperature, the mixture of coffee powder and RO water is placed into the ultrasonic equipment, and processed under various extraction conditions. The extraction liquid is initially filtered through a 40 mesh filter and collected. To achieve a ratio of extraction liquid to water of 1:9 for a final dilution of 10 times, the extraction liquid is further filtered by a 0.45 μm filter paper. And then, the coffee flavor concentration is used as the base for the comparative analysis of HPLC. The caffeine concentration, on the other hand, is used as the base for the comparative analysis of GC.

The integrity of the process and analysis is verified by using the known coffee flavor concentration of the standardized coffee. The results of the caffeine concentration of the standardized coffee are compared with the analyzed caffeine concentration of the sample provided by the issuing laboratory. If these results are not similar, the experiment will be repeated with adjustment to the operating conditions.

Finally, these results are tabulated and the comparisons indicate the optimum values for time/frequency and temperature would produce the greatest concentrations of caffeine.

Results and discussion

Analysis of caffeine concentration by operating frequency at 28 kHz and 40 kHz

The experimental data shows that caffeine concentration increases with the increase in temperature. When the operating temperature is 5 °C and the extraction time is 15 seconds, the caffeine concentration extracted from low operating frequency (28 kHz) is 1.8 times higher than using a high operating frequency (40 kHz) under the same conditions; when the extraction time is 30 seconds, the caffeine concentration is 1.1 times higher. As a result, in a low temperature and frequency state, a substantially better extraction result can be achieved more easily. The experimental data is as shown in figs. 3 and 4.

Figure 3 shows that the concentration values at the 15th ~~seconds~~ second and 30th second are not higher; the reason is that we do the experiments repeatedly for four times, and then, give up the largest diversity of concentration value. Therefore, the average values cause a slight amount of errors, and the error value is approximately within 5 ppm. Figure 6 shows that higher concentration will occur especially at the 30th second on the extraction time curves.

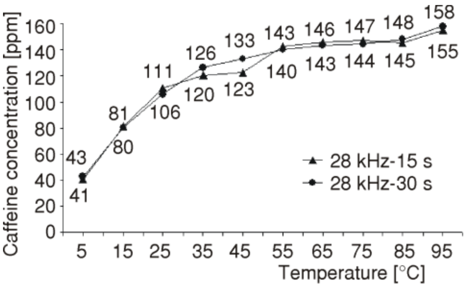

Figure 3. Influence of temperature on caffeine concentration with 15 seconds and 30 seconds of extraction time and 28 kHz operating frequency

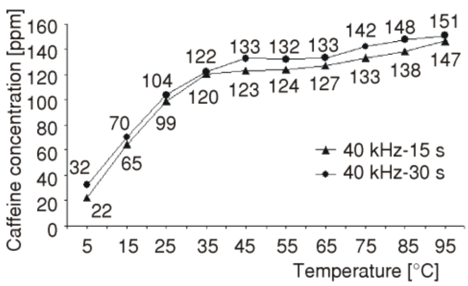

Figure 4. Influence of temperature on caffeine concentration with 15 seconds and 30 seconds of extraction time and 40 kHz operating frequency

The error values of caffeine concentration, at 80 °C and 95 °C and at the 15th second and 30th second of extraction time, are roughly in the range of 1%, and the error values are within the range of 3% to 6%. The result shows that if the temperature in the process of extraction is higher, the caffeine will be more concentrated. Moreover, it also proves that caffeine concentration is saturated at the 15th ~~seconds~~ second.

Analysis of coffee flavor ingredients by the operating frequency of 28 kHz

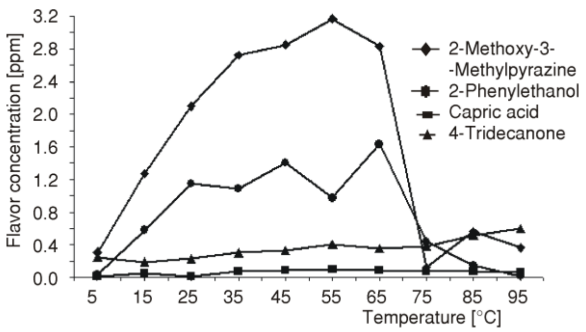

Figure 5. Influence of temperature on coffee flavor concentration with 15 seconds of extraction time and 28 kHz operating frequency

Figure 5 shows that at the 15th second of the extraction time, the ingredients of 2-Methoxy-3-Methyl-pyrazine and 2-Phenylethanol of the coffee flavor are in higher concentration at the temperature ranging from 35 °C to 65 °C, and the highest concentration is up to 3.17 ppm; if the temperature, on the other hand, is over 65 °C, the coffee flavor concentration decreases signifycantly, and it is about 0.56 ppm. The curve of flavor concentration for Capric Acid and 4-Tridecanone does not rise and fall significantly. When being extracted for 30 seconds, all the coffee flavor concentrations descend, and the highest concentration is not over 1ppm. This shows that if the extracting process lasts longer, there will be a stronger volatility, as shown in fig. 6.

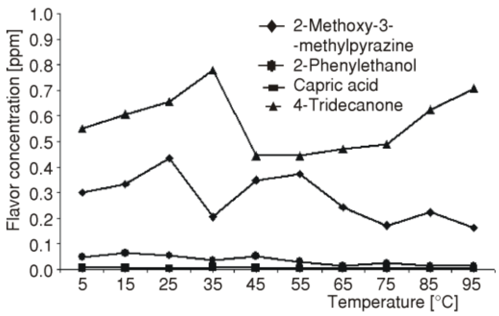

Figure 6. Influence of temperature on coffee flavor concentration with 30 seconds of extraction time and 28 kHz operating frequency

Analysis of coffee flavor ingredients by the operating frequency of 40 kHz

As shown in fig. 7, at the 15th second of the extraction time, the ingredients of 4-Tridecanone and 2-Methoxy-3-Methyl-pyrazine of the coffee flavor are in higher concentration, and the highest concentration is up to 1.07 ppm; the curve of flavor concentration for 2-Phenylethanol and Capric Acid does not rise and fall significantly. When the extraction time is at the 30th second, on the other hand, the ingredients of 4-Tridecanone and 2-Methoxy-3-Methylpyrazine are in higher concentration as well, but the concentration of 2-Methoxy-3-Methylpyrazine decreases along with the increment of the temperature. There is no obvious influence of temperature on the other three sets of flavor concentration, as shown in fig. 8.

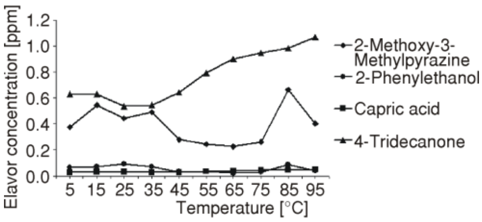

Figure 7. Influence of temperature on coffee flavor concentration with 15 seconds of extraction time and 40 kHz operating frequency

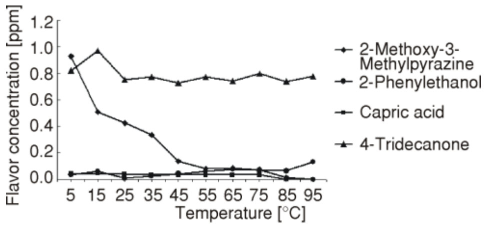

Figure 8. Influence of temperature on coffee flavor concentration with 30 seconds of extraction time and 40 kHz operating frequency

Conclusions

From the results of these experiments, it can be concluded that the influence of temperature is the most important factor in determining caffeine concentration of an extraction. Specifically, an increase in temperature results in a higher concentration of caffeine. Furthermore, the specific extraction time for specific coffee varieties also has a different saturating temperature. In particular, the caffeine concentrations that are produced by an extraction time of 15 seconds and 30 seconds are similar. The curves of the graphed results nearly overlap. The results indicate that the caffeine concentration after a 15-second process is near the saturation point. The ultrasonic vibration frequency in the low operating frequency can be used to obtain much better extraction effects. It is not significant in high operating frequency.

There will be a better extraction of coffee flavor concentration when it is in the lower frequency (28 kHz); the extraction time lasts for 15 seconds and the temperature ranges from 35~65 °C. However, when the temperature is over 65 °C, coffee flavor concentration will decrease significantly. The 4-Tridecanone and 2-Methoxy-3-Methylpyrazine of the coffee ingredients can be extracted more easily and efficiently when the extraction time lasts for 30 seconds with a lower frequency; the other two flavor ingredients are in a stable state.

Acknowledgments

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