Technology innovation for production of specialty coffee

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Abstract. Coffee is one of the most important agricultural commodities in the world. Data from International Coffee Organization (ICO) indicate that total world production increased from 8.945 million metric tons in 2014 to 9.126 million metric tons in 2015, 9.462 million metric tons in 2016, and 9.580 million metric tons in 2017. Data from ICO also show that coffee is commercially cultivated in 56 countries and Indonesia with total production of about 720 thousand tons in 2017 was the fourth largest producer after Brazil (3.06 million tons), Vietnam (1.77 million tons), and Colombia (840 thousand tons). To increase the economic value of this commodity, the quality of coffee bean must be improved through both agronomic and postharvest aspects. This study was designed to develop a new ohmic-based fermentation technology for coffee cherry to improve flavor quality of coffee beans. Results of this study indicate that this technology can produce coffee with cup-test scores ranging from 84.38 to 86.88 with an average score of 85.713. This score is higher than the cup test score of Indonesia civet coffee (luwak coffee) reported by several researchers. Therefore, application of ohmic heating based technology for coffee fermentation can significantly improve flavor quality of coffee beans.

1. Introduction

Coffee is one of the most important agricultural commodity in the world due to the fact that it is traded globally. Data from FAO [1] indicate that total coffee exports every year in the last five years were about 7 million tons with an average value of about US$ 21 billion per year. Data from International Coffee Organization (ICO) [2] indicate that total world production increased from 8.945 million tons in 2014 to 9.126 million tons in 2015, 9.462 million tons in 2016, and 9.580 million tons in 2017. World coffee production mainly comes from two species namely Arabica (Coffea Arabica) and Robusta (Coffea canephora Pierre ex Froehn) and only about 1% comes from Coffea Liberica [3]. Several researchers reported that in the early 2000, about 75% of coffee production came from Arabica and about 25% came from robusta [4,5]. However, recent data from US Department of Agriculture [6] indicate that global coffee production in the last five years consisted of about 59% Coffea arabica and 41% Coffea canephora (robusta).

Economic value of coffee beans is determined by their flavor quality. Flavor profiles and cupping quality of the three coffee species are significantly different due to the difference in the types and quantity of chemical compounds contained in the respected beans [3]. The caffeine and chlorogenic acids in Arabica coffee beans are generally lower than those in Robusta beans [7,8]. In addition to the effects of variety, other factors affecting the aroma and flavor of coffee products include geographical and ecological conditions [9], shade [10-12], daily temperature [13, 14], and processing method [15-19]. Therefore, coffee aroma and flavor are not only affected by the genetic and the environment [20] but also by the processing method [17, 19, 21]. In order to obtain coffee beans with exceptional aroma and flavor quality, selection of coffee variety and origin and application of appropriate harvesting and postharvest technology are of paramount importance.
Processing is an important step in the production chain which can significantly affect the quality of green coffee produced and the flavor and aroma quality of the final products. Handling of coffee fruits after harvest must be done properly in order to avoid uncontrolled fermentation and contamination by fungi [16, 19]. Processing of coffee fruits can be done using three methods, namely dry or natural process, wet or washed process, and honey process. The dry process is commonly used for Robusta while the wet process is used for Arabica coffee [17, 22]. In the dry process, coffee cherries are dried directly without removing the pulp. This process can produce coffee with good body and distinctive flavor [19] and good sweetness, smoothness, and complexity [16]. The wet process is generally done by first removing the pulp of the coffee cherries and soaking the parchment in water for 12 – 72 hours. This process will allow yeast and bacteria to ferment the sugars contained in the mucilage and produce volatile compounds [17, 21] and metabolites that can impart additional flavor notes to the coffee beans [19]. Gonzalez-Rios et al. [17, 21] reported that the volatile compounds produced during fermentation process in water (wet process) imparted pleasant and fruity flavor notes that improve flavor quality of green and roasted coffee beans.

The fermentation process can be done without water (dry fermentation) or with water (wet fermentation). However, fermentation under water produced coffee with better flavor notes such as fruity, floral, and caramel [17, 21]. In addition, coffee fermentation can be done using natural fermentation where the fermentation process was done by enzymes or microbes naturally present in the coffee cherries or by artificially adding enzymes, yeast and/or bacteria into the soaking water. The purpose of adding certain yeasts and/or bacteria into the fermentation media is to accelerate the fermentation process and develop the desired aroma and flavor [23-27]. Even though fermentation is an essential process for producing high quality green coffee beans, over fermentation or fermentation at high pH can potentially develop undesired aroma [28]. The wet process can produce coffee with cleaner, brighter, fruitier, and more acidic flavor [16] or floral characteristics but less body than the dry process [19].

Various efforts have been done to improve the quality of green coffee beans through the development of on-farm processing methods which transform coffee cherry into green coffee beans. These efforts include studies on natural fermentation [29-32], fermentation with inoculated enzymes, yeasts and bacteria [24, 33-37], and fermentation using palm civets by feeding fresh coffee cherries to the civets [26,27,38,39]. The studies on the use of microorganisms from civet stomach in coffee fermentation were an effort to produce coffee with flavor characteristics which can mimic the flavor characteristics of natural luwak coffee; regarded as the most expensive coffee in the world. In addition, the development of fermentation technologies for de-pulped coffee cherries has also been done in an effort to control the fermentation process and improve flavor and cupping quality.

Aroma and flavor characteristics of fermented coffee beans are affected by the rate of fermentation. The fermentation process will proceed faster at high growth rate of microbes (yeasts and bacteria) which are involved in the fermentation process. On the other hand, the fermentation process can be slowed by creating a condition which is less than optimal for the growth and activity of the microbes. There are three environmental conditions that can affect yeast and bacterial activities, namely temperature, pH, and oxygen availability. Therefore, to create optimum flavor and aroma in coffee beans, fermentation condition can be optimized by controlling these three parameters. Therefore, the purpose of this research was to develop a technology for coffee fermentation which can be used to study the effect of fermentation temperature on the cup scores of coffee beans produced from the fermentation process. The technology developed in this study was based on ohmic heating technology which was used to provide uniform heating to the fermented coffee beans. The principle of heating used in this study was the same as that employed in other studies by the main author [40-43].

2. Material and Method
The fermentation process done in this study was carried out using an ohmic heating chamber made of PVC pipes (25.4 cm diameter and 150 cm length). Electric current was supplied to the ohmic heating chamber through electrodes fastened at the ends of the chamber. The flow of electric current to the ohmic heating chamber and the temperature inside the chamber were controlled by a PID thermo-controller.

The coffee cherries used in this experiment was Arabica harvested from a coffee farm in Tanah Toraja (about 1490 meters above sea level). The coffee cherries were harvested at full maturity and then transported to Teaching Industry at Hasanuddin University in Makassar (about 300 km from the coffee farm). The cherries were de-pulped and the parchment coffee beans were separated from the pulp (skin) and fermented in the ohmic heating chamber within 24 hours after harvest. For each experimental run, 50 kg of parchment coffee beans
were placed in the fermentation chamber and then the chamber was filled with water so as to the upper electrode was soaked in the water. Fermentation processes were conducted for 18 hours at 32°C. Following the fermentation process, the parchments were washed thoroughly to remove liquefied mucilage from the parchment and then sun dried for about 4 hours and hulled to remove the parchment skin. The green coffee beans were then sun dried to about 12 percent moisture content.

To assess the aroma and flavor characteristics of the coffee beans produced from the fermentation process, cup tests were done by certified coffee cuppers at the Indonesian Centre for Cocoa and Coffee Research in Jember, East Java. One hundred fifty grams of green coffee beans were roasted to light to medium roast using a small sample roaster. Green coffee beans were charged into the roaster when the temperature of the roaster’s drum reached 150°C and were discharged from the roaster when the temperature of the beans reached 180°C. The roasted coffee beans were cooled to room temperature rapidly and stored in an air tight glass jar for about 12 hours before grinding and sieving using 50 mesh sieve. Cup tests were done within 18 hours after roasting.

Cupping protocol used in this study followed the standard SCAA tasting protocol. About 12 grams of roasted coffee beans were placed in ceramic cups. The beans were then ground coarsely, return back to the cups and covered. The fragrance of the coffee samples was then assessed by certified coffee cuppers. For aroma and taste assessment, 10 grams of the ground samples was placed in ceramic mugs and added with 180 ml of hot water (about 93°C). The aroma and taste assessment procedure followed the SCAA protocol.

3. Results and discussion

The ohmic based technology for coffee fermentation developed in this study was able to ferment coffee beans at the desired temperature. The temperature of the coffee beans inside the ohmic heating chamber slowly increased from about 28°C at the start of fermentation to the setting fermentation temperature of 32°C. The acids in the mucilage dissolved into the water, turning the water into an electrolyte such that it can conduct electric current. In addition, the acids in the coffee beans also allow the beans to conduct electricity within the beans. The passage of electric current through the beans and the water inside the fermentation chamber would generate heat internally due to dissipation of electrical energy into heat. Therefore, uniform heating due to internal energy generation within the fermentation chamber can be achieved.

The constant temperature of 32°C within the fermentation chamber will allow yeasts and bacteria that are naturally present in the coffee beans to grow faster so that they can degrade the coffee mucilage faster. Visual observations indicate that all the mucilage has been liquefied during the 18-hour fermentation process. This result suggests that ohmic heating at 32°C can effectively assist the fermentation process. However, further experiments at other temperature and duration need to be done to find the optimal conditions for ohmic assisted coffee fermentation.

Results of cup test of the coffee beans produced from the fermentation experiments conducted in this study indicate that in general the overall quality of the coffee beans produced can be classified as specialty coffee beans. Based on the criteria set forth in the Specialty Coffee Association of America (SCAA) manual, coffee samples that give scores in the range of 80-84 are classified as premium coffee beans and samples that give scores in the range of 85-89 are classified as specialty coffee beans. The results from this study indicate that the ohmic heating assisted fermentation of parchment coffee beans can consistently produce coffee beans with good quality. In addition, these results also suggest that this technology produce coffee beans with higher cup score compared to the fermentation using microbial isolated from civet intestines as reported by several researchers [26,27]. The results reported by these researchers showed that the coffee beans produced from their studies (artificial luwak coffee) gave cup scores of less than 85. It is also interesting to note that the cup scores of luwak coffee tested by Towaha and Rubiyo [26] as benchmarks only received cup score of 79.25 and the coffee luwak sample used by Hadiernata and Nugraha [27] gave cup score of 84.875. Therefore, the cup scores (Figure 1) of the coffee beans produced from the technology developed in this study gave higher cup scores compared to the cup scores of both original luwak coffee and artificial luwak coffee reported by the researchers mentioned above.

Careful examination of all the aspects assessed in the SCAA protocols indicate that the samples tested have “very good” to “excellent” cupping scores on all the aspects. It is important to note that the cupping score scales used by judges at the Indonesian Center for Coffee and Cacao Research were based on the SCAA scales. The quality descriptors used by the judges were as follows: scores 6 – 6.75 is categorized as Good, 7 – 7.75 is very good, 8 – 8.75 is excellent, and 9 – 9.75 is outstanding. Sample 3 scored “excellent” on all aspects, Sample 1 scored “excellent” on 8 aspects and scored “very good” on 2 aspects, while Sample 2 scored excellent on 4
aspects and 6 aspects scored very good on 6 aspects. Based on the final score of each sample, all the coffee beans produce from this technology can be classified as specialty coffee (final score > 80). Based on the SCAA protocol, two of the samples can be classified as “Excellent” (final score > 85) and one sample can be classified as “very good” (final score > 80). These results indicate that the ohmic heating assisted fermentation of coffee beans is able to consistently produce coffee beans with high quality.

The results obtained in this study may indicate that the temperature employed during fermentation (32°C) was suitable for the growth of yeasts and bacteria involved in the fermentation process. The fermentation duration of 18 hours at 32°C was enough to completely degrade the mucilage and produce coffee beans which can produce brewed coffee with good flavor and taste. In addition to the positive effect of the temperature employed in this experiment on the growth and activities of yeasts and bacteria, there could be an effect of electric field on the structure of coffee beans which facilitate diffusion and chemical interaction within the coffee beans. As have been reported in previous studies on the effect of ohmic heating on biomaterials, there might occur electro poration (pore formation) of the cell membranes of biomaterials during ohmic heating as shown by the increase in drying rates [42,44] and extraction yields [41,45], enhanced diffusion [46,47], leaching of soluble solids [48], and the decrease in oil absorption of potato slices during frying and subsequent cooling [49].

**Overall Cupping Score:**

Sample 1 = 85.88  
Sample 2 = 84.38  
Sample 3 = 86.88

![Figure 1. Cup scores of coffee beans fermented using ohmic heating assisted fermentation technology.](image-url)
4. Conclusions
Ohmic heating assisted coffee fermentation technology has a great potential to be used commercially in coffee production to produce specialty coffee. Overall results from this study indicate that this technology can consistently produce coffee beans with quality attribute “very good” or “excellent” based on the SCAA cup score. This technology can produce coffee with cup-test scores ranging from 84.38 to 86.88 with an average score of 85.713. This score is higher than the cup test score of Indonesian civet coffee (luwak coffee) reported by several researchers. Therefore, application of ohmic heating based technology for coffee fermentation can significantly improve flavor quality of coffee beans.

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