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The effect of air flow in coffee roasting for antioxidant activity and total polyphenol content

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ABSTRACT

The objective of this study was to investigate the effect of air flow in coffee roasting for antioxidant activity and phenolic compound content. Roasting was conducted in various combinations of temperature (180–200 °C), time (13–17 min) and volume flow rate (VFR; −0.271–0.271 L/s) using Box-Behnken design. The results of DPPH, ORAC and total polyphenol content (TPC) were fitted to the response surface methodology models (R^2 = 0.9936–0.9869). Increasing temperature and time were negatively influenced for functional properties of roasted coffee with significances ($P < 0.05$). The quadratic effect of VFR was observed in DPPH and ORAC assays. Higher DPPH and ORAC values were shown in high or low VFR than the centre point of VFR at the same temperature or time. On the other hand, TPC was decreased from high to low VFR at the same temperature or time. The VFR was a significant parameter for antioxidant activity and TPC in coffee roasting. Manipulation of air flow by increasing or decreasing VFR can deliver higher antioxidants and phenolic compounds from the same amount of coffee beans to consumers.

1. Introduction

Coffee is one of the most widely consumed beverages in the world. Today, its consumption is increasing rapidly in the Asian region. Most coffee consumers do not drink coffee for their health. However, many functional materials such as caffeic, chlorogenic, ferulic, sinapic and other acids are in coffee (Gallardo, Jimenez, & Garcia-Conesa, 2006; Manach, Scalbert, Morand, Rémésy, & Jiménez, 2004; Parliment, 2000; Vignoli, Bassoli, & Benassi, 2011). In addition, previous studies showed coffee is a major source of antioxidants for Norwegian women (Qureshi et al. 2014) and in the Spanish diet (Pulido, Hernandez-Garcia, & Saura-Calixto, 2003). The functionality as well as the aroma, flavour and taste of coffee are heavily influenced by roasting (Del Castillo, Ames, & Gordon, 2002; Somporn, Kamtuo, Theerakulpisut, & Siriamornpun, 2011). Due to the significant amount of antioxidants in coffee how coffee industry roasting coffee beans is important in the aspect of nutrition.

In coffee roasting, temperature and time have been known as key parameters. Longer roasting of coffee beans generated higher intensities of bitter and burnt characteristics (Bicho, Leitão, Ramalho, de Alvarenga, & Lidon, 2013). Several studies were reported on the antioxidant activity of coffee beans roasted at different temperatures and for different roasting times. Arabica and Robusta coffee varieties were compared for antioxidant activity based on three roasting degrees (Hečimović, Belščak-Cvitanović, Horžić, & Komes, 2011). No consistent increasing or decreasing pattern in antioxidant activity by ABTS assay, total polyphenol content and individual polyphenolic compounds was observed. Sacchetti, Di Mattia, Pittia, and Mastrocola (2009) reported that radical scavenging activity was the highest in medium roasted condition, which had 26–29 L-values by the colorimeter, while Somporn et al. (2011) showed total polyphenol content and DPPH radical scavenging activity were decreased from light to dark roasting. However, these studies were performed at a certain time and/or at a certain temperature of coffee roasting conditions rather than covering a wide range of temperature and time consistently. In sensory evaluation, Mendes, de Menezes, Aparecida, and Da Silva

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(2001) assessed consumer acceptance of Robusta coffee beans roasted for various conditions of time and temperature conditions to determine the optimum roasting conditions using response surface methodology (RSM), and showed that optimum roasting conditions were a roasting time of 22–28 min and temperature of 225–230 °C.

Several studies assessed antioxidant activity of coffee beans roasted at various conditions of time and temperature using small lab roasters (10–1000 g) (Del Castillo et al., 2002; Hečimović et al., 2011; Nicoli, Anese, Manzocco, & Lerici, 1997; Somporn et al., 2011). There is one more handling parameter—air flow—for coffee roasting, especially in a commercial coffee roasting set-up. Many commercial coffee roasting machines have a damper to manipulate air flow during roasting (Kando, Katsuragi, & Kishimoto, 2010; Shin, 2011; Tidland & Welch, 1999). Coffee roasters consider the handling of the damper to influence coffee quality while roasting coffee beans (Mamoru, 2013; Shin, 2011). When a damper is on the neutral setting, the influx of air from the heater to the drum is the same as the efflux of air through the duct for emission based on the explanations by Shin (2011) and Mamoru (2013). If a damper is open, additional air goes through the gas heater, moves into the roasting drum, and then is emitted in the coffee roaster. On the other hand, if the damper is closed, a lower amount of air goes into the drum. Krysiak, Adamski, and Żyżelewicz (2013) showed 0.5 m/s and 1.0 m/s of air velocity in cacao roasting showed different response surfaces for the colour of the cocoa bean when roasting temperature and time were identical. Manipulation of a damper may have an effect on coffee roasting by adjusting the air flow. Effects of the damper in a commercial coffee roasting set-up were not proven scientifically to the authors' knowledge, although many coffee roasters mentioned its importance based on their technical experience. Therefore, the objective of this study is to investigate the influence of air flow in a commercial coffee roasting set-up for antioxidant activity and polyphenol contents with traditional roasting parameters (temperature and time) using RSM.

2. Materials and methods

2.1. Chemicals

Folin-ciocalteu reagent, gallic acid, aluminum nitrate, potassium acetate, 1,1-diphenyl-2-picrylhydrazyl (DPPH), trolox, 2,2'-azobis (2-amidino-propane) dihydrochloride (AAPH), and fluorescein powder were purchased from Sigma Aldrich Co. LLC. (St. Louis, MO, USA). Sodium carbonate and sodium phosphate were purchased from Showa Chemical Industry Co. (Tokyo, Japan). Methanol and ethanol were supplied by Duksan Pure Chemical Co., Ltd. (Ansan-si, Korea). Dimethyl sulfoxide was purchased from Junsei Chemical Co. (Tokyo, Japan).

2.2. Coffee roasting and extraction

Arabica coffee (*Coffea arabica* L.) grown in Chiapas, Mexico was used for coffee roasting. Coffee roasting was conducted using a commercial coffee roaster. A coffee-roasting specialist pre-heated the roaster (Type R-105, Fuji Royal Co., Kobe, Japan) for 20 min and manipulated the emission temperature to the target temperature. Coffee (2000 g) was put in when the target temperature was reached. Coffee roasting was conducted with 1 kPa gas pressure until the exhaust gas temperature reached the target temperature again. After the temperature surpassed the target temperature, the roasting specialist manipulated the gas pressure to maintain the target temperature until the roasting was finished. The roasted coffee beans were then cooled at room temperature for 10 min. The coffee beans were kept at room temperature for one day and then moved to the refrigerator (4 °C) for three days for degassing.

Roasted coffee beans were ground using the 'fine' option of an electronic coffee grinder (KG79, De'Longhi Group, Treviso, Italy). The ground coffee was sieved using a 710 × 710 μm standard sieve to screen large particles. Leftover ground coffee on the sieve was thrown away. The extraction was slightly modified from the methods of Hečimović et al. (2011) and Sacchetti et al. (2009). The 1:10 (w/v) ratio of ground coffee and 98 °C distilled water were put into a flask and extracted in a 98 °C water bath at 120 rpm for 10 min. Then, the extracted coffee was cooled down to room temperature in another water bath filled with tap water, and then centrifuged at 6485×*g* force at 4 °C for 15 min. The supernatant was vacuum-filtered using Advantech #2 filter paper (pore size: 6 μm, Advantech MFS, Inc., Dublin, CA, USA) for analyses.

2.3. Antioxidant activity by DPPH assay

The DPPH assay for antioxidant activity was conducted by the method of Nebesny and Budryn (2003) with some modifications. Coffee extract was diluted with distilled water (1:100 v/v). The diluted coffee extract (40 μL) was mixed with 1.4 × 10^{-4} M DPPH methanol solution (160 μL). The mixture was then kept in a dark room for 30 min at room temperature. After incubation, the mixture was transferred to a 96-well microplate and absorbance was measured at 517 nm (Spectra max M2, Molecular Devices, LLC. Sunnyvale, CA, USA). A blank was prepared by substituting the coffee extract with distilled water. DPPH radical scavenging activity was calculated based on the following formula

$$\text{DPPH radical scavenging activity } (\%) = \left[1 - \frac{ASample}{ABlank}\right] \times 100 \quad (1)$$

where A_{Sample} and A_{Blank} are the absorbance of the sample and the blank, respectively.

2.4. Antioxidant activity by ORAC assay

The Oxygen Radical Absorbance Capacity (ORAC) was measured using the method of Ou, Hampsch-Woodill, and Prior (2001) with some modifications. Phosphate buffer (75 mM, pH 7.0) was used as a solvent. A volume of 50 μL fluorescein solution (78 mM) and coffee extract (50 μL) were mixed, and then incubated for 15 min at 37 °C. A volume of 25 μL of 221 mM AAPH was added and then vortexed. The samples were put in a 96-well plated, and fluorescence was measured by the microplate reader (Spectra max M2, Molecular Devices, LLC.). Measurements were taken every minute for 2 h (excitation wavelength: 485 nm, emission wavelength: 535 nm). The ORAC values were calculated by the following formula and presented as μM trolox equivalent/g of coffee (μM TE/g)

$$ORAC\ (\mu M\ TE/g) = \frac{CTrolox \times (AUCSample - AUCBlank) \times k}{(AUCTrolox - AUCBlank)} \quad (2)$$

where C_{Trolox}, k, and AUC were the concentration of trolox (5 μM), the sample dilution factor, and the area under the curve, respectively. AUC was calculated based on the following formula

$$AUC = \sum_{n=1}^{120} fn \quad (3)$$

where f_n is the fluorescence at time n (min).