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Effect of preparation method and roasting temperature on total polyphenol content in coffee beverages

*Matúš Várady[1], Tatiana Hrušková[2], Peter Popelka[1]**

[1]*Institute of Meat Hygiene and Technology, University of Veterinary Medicine and Pharmacy, Košice, Slovak Republic*

[2]*Institute of Medical Chemistry, University of Veterinary Medicine and Pharmacy, Košice, Slovak Republic*

**Corresponding author: peter.popelka@uvlf.sk*

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Abstract: We evaluated the differences in total polyphenol content (TPC) of beverages prepared by three methods (Hario V60, espresso and pour-over coffee) using single-origin beans roasted at four temperatures. The beans were roasted based on the degree of roasting: the lightest roasting had a final temperature of 204 °C (first roasting), a slightly darker roasting had a final temperature of 205 °C (second roasting), a dark roasting had a final temperature of 215 °C (third roasting) and the darkest roasting had a final temperature of 220 °C (fourth roasting). TPC in the beverage was highest for the Hario V60 for all temperatures, ranging from 32.0 to 46.8 mg GAE g^{-1} (gallic acid equivalent per 1 g of ground beans). The third roasting had the highest TPC, ranging from 34.6 to 46.8 mg GAE g^{-1} for all methods of preparation, whereas the content for the fourth roasting ranged from 28.6 to 32.3 mg GAE g^{-1}. Our results indicated that the differences in TPC in the beverage depended on the preparation method ($P < 0.001$) and the degree of roasting ($P < 0.001$). The most nutritional coffee was prepared using the Hario V60 with the third roasting.

Keywords: coffee beans; coffee preparation methods; pH; roasting of coffee beans; total polyphenol content

The consumption or supplementation of polyphenols plays an important role in health by regulating metabolism, weight, chronic disease, and cell proliferation (Cory et al. 2018). The study of humans and some animals found that the antioxidant and anti-inflammatory properties of polyphenols could potentially prevent or treat many non-communicable diseases (Pérez-Jiménez et al. 2010). Various bioactive compounds such as phenolic acids (e.g. chlorogenic, caffeic, ferulic and *p*-coumaric acid) and especially polyphenols have been isolated from coffee beverages or coffee beans (Clifford et al. 2006; Jaiswal et al. 2010). Coffee beverages are the most popular commodities with antioxidant properties, but their antioxidant activities depend on the roasting of the beans, which affects the taste and aroma of the beverage (del Castillo et al. 2002). The beans are exposed to high temperatures during roasting, and chemical reactions between amino acids and reduced sugars lead to the formation of Maillard reaction products (Tamanna & Mahmood 2015). These products affect the organoleptic and antioxidant properties of the beverage. During roasting, products of the Maillard reaction become dominant antioxidant species (Liu & Kitts 2011), which may double the total antioxidant capacity (TAC) at darker roasts if TAC is measured by ABTS [*2,2'*-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)] or ORAC (oxygen radical absorbance capacity) assay (Opitz et al. 2014; Catelani et al. 2017). In particular, at the beginning of the roast, TAC increases from any assay or remains constant at least. During roasting the total antioxidant capacity of Robusta coffee decreases to about one half of the original level in the initial stages of roasting (Votavová et al. 2009). The total polyphenol content (TPC) depends on the degree of roast (Cotter & Hopfer 2018; Fikry et al. 2019).

The coffee plant belongs to the family Rubiaceae. Coffee beans contain a mixture of chemical substances that perform very important functions in the beverage. The antioxidant and anti-inflammatory effects responsible for the association between coffee consumption and lower incidence of various degenerative and

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non-degenerative diseases are mainly due to chlorogenic acids (Farah & de Paula Lima 2019). The antioxidant properties are maintained or increased during moderate roasting due to the release of phenolic compounds (Cämmerer & Kroh 2006; Sacchetti et al. 2009). The roasting temperature can influence the amount of TPC in the beverage (Hecimovic et al. 2011) by the degradation of chlorogenic acid, which decreases the amounts of malic and citric acid and affects the amount of quinic acid (Ginz et al. 2000). The amount of quinic acid in dark-roasted beans is very low, so the beverage loses some of its antioxidant and anti-inflammatory effects (Farah & de Paula Lima 2019). The degradation of chlorogenic acid can also produce chlorogenic acid lactones, which give the beverage its bitter taste (Kaiser et al. 2013). In addition, the pH of coffee depends on the strength of the acids (Flambeau & Yoon 2018).

Polyphenol content in the beverage can depend on the degree of roasting and the origin and storage of the beans (Dybkowska et al. 2017; Król et al. 2020). Beans from multiple locations are usually roasted and mixed as a blend. Our experiment, however, used only beans harvested from the same farm within a single geographic origin. We hypothesized that the polyphenol content in the final beverage would be influenced by both the roasting temperature and the method of preparation. The aim of this study was therefore to evaluate differences in TPC in beverages prepared from single-origin beans using three methods of preparation (Hario V60, espresso and pour-over coffee) and roasted at four final temperatures (204, 205, 215, and 220 °C).

MATERIAL AND METHODS

Coffee samples. Samples of Ethiopia Bokasso Lot 5 coffee beans (100% Arabica) processed using the washed method (Diamonds Roastery, Dunajská Lužná, Slovakia) were used in our experiment. These beans were from Sidamo Province in the Ethiopian highlands at elevations of 1 500–2 200 m above the sea level. The beans were harvested in February 2017. Coffee is grown near settlements in small quantities of 1 000 to 1 800 plants per hectare. These garden coffee systems are widely practised in Bokasso. Most of the coffee plants were treated with organic nutrients. Fresh hand-picked cherries were sorted before the pulp was removed and the application of a wet treatment followed. The cherries were washed, naturally fermented, and dried to about 11.5% moisture while ensuring uniform drying. The dried material was stored until delivery to the central market in Addis Ababa.

Roasting. The roasting of the beans was based on the degree of roasting: the lightest roast was at a final temperature of 204 °C for 9 min (first roasting), a slightly darker roast was at a final temperature of 205 °C for 10 min (second roasting), a dark roast was at a final temperature of 215 °C for 13 min (third roasting) and the darkest roast was at a final temperature of 220 °C for 16 min (fourth roasting). Coffee batch size of 4 kg was roasted on a Probatone 12 commercial gas roaster (Probat, Emmerich am Rhein, Germany). The temperature was raised with time and it depended on the gas provided. The temperature was measured with a probe inside the roaster drum.

Grinding. The beans were ground in a Hario mini Mill Slim hand coffee grinder (Hario, Koga-Ibaraki, Japan). For Hario V60 we used the medium grind size with a final time of 2 min and 30 sec. For espresso, the fine grind size with extraction of 30 sec was used. The coarse grind size and extraction time of 9 min was used for the pour-over method.

Preparation methods. Three methods of beverage preparation were used: Hario V60, espresso, and pour-over coffee. For the Hario V60 method, Hario V01 filter paper (Hario, Koga-Ibaraki, Japan) was placed in a ceramic dripper and rinsed with hot water. Freshly ground beans (10 g) were added to the dripper and water at a temperature of 92 °C was poured over them. An initial infusion of 20 mL of distilled water (blooming) was used to start the release of CO_2 from the ground beans. More water up to 150 mL was gradually added after 30 sec. For the espresso method, freshly ground beans (10 g) were brewed in an espresso machine (De´longhi, Treviso, Italy) with the final volume of 30 mL. For the pour-over method, freshly ground beans (10 g) were weighed into a beaker and 150 mL of boiling distilled water were poured over them. After 9 min, the sample was filtered through a Falten paper filter 18.5 cm in diameter (Northwest Scientific, Inc., Billings, USA). Cooled samples from all three methods were transferred to volumetric flasks and diluted to final volumes of 150 mL with distilled water. Five replicates of all three brewing methods were prepared for each roast.

Chemical analysis and measurements. TPC in the beverages was determined spectrophotometrically using Folin-Ciocalteau colorimetry (Blainski et al. 2013). We used a stock solution of gallic acid as a standard, prepared by dissolving 0.5 g of dry gallic acid in 10 mL of 96% ethanol and then diluted to 100 mL with distilled water. Briefly, 1 mL of 10% Folin-Ciocalteau reagent was

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added to 0.2 mL of sample, which was previously diluted to the appropriate concentration. The solution was kept in the dark for 5 min, and then 1 mL of a sodium carbonate solution (7.5% w/v) was added. This mixture was incubated in the dark for 60 min, and the absorbance was then measured at 765 nm using a UV-VIS spectrophotometer (UV-2550, Shimadzu, Kyoto, Japan) and compared with a gallic acid calibration curve. The results are expressed as milligrams of gallic acid equivalent (GAE) per g of dried sample. The pH of the samples was measured at room temperature (20–22 °C) using a pH meter (InoLab pH Level 1, Weilheim, Germany).

Statistical analysis. The data were analysed using GraphPad Prism version 8.3.0 (538) 2019 (GraphPad Software, Inc., San Diego, USA) by a two-way ANOVA (mixed model) with multiple *t*-tests using the Bonferroni-Dunn method. The model included effects for the preparation method (M), roasting temperature (R), and their interaction (M × R). The effects were determined to be significant at $P < 0.05$.

RESULTS AND DISCUSSION

The content of total polyphenols in the coffee beverages was significantly influenced by both the preparation method and the roasting temperature ($P < 0.001$, Figure 1). The polyphenol content of coffee decreases considerably as the degree of roasting increases (Sacchetti et al. 2009; Dybkowska et al. 2017; Król et al. 2020). Lightly roasted coffee has the best phenolic content and radical-scavenging activity (Somporn et al. 2011). Limited information is available in the literature on the direct comparison of roasting temperatures. Król et al. (2020) used the light roasting temperatures of 170–200 °C, moderate roasting of 200–220 °C and dark roasting of 220–240 °C. In contrast, we used four levels of roasting (i.e. final temperatures of 204, 205, 215, and 220 °C) which can be characterised by different colours of the coffee beans (i.e., light brown, medium brown, brown, and rich dark colour). The third roasting (215 °C) had the highest TPC, ranging from 34.6 to 46.8 mg GAE g^{-1} for all preparation methods. The content of total polyphenols for moderately roasted coffee (100% Arabica) ranges from 34.06 to 38.43 mg GAE g^{-1} (Dybkowska et al. 2017), similar to our results. The content of total polyphenols in the beverages in our study was highest using the Hario V60 method for all roasting temperatures, ranging from 32.0 to 46.8 mg GAE g^{-1}. The content of total polyphenols in the beverages differed significantly between the methods ($P < 0.05$), except for the fourth roasting using the Hario V60 and pour-over methods ($P > 0.05$). The content of total polyphenols depended on methods and was lowest for the pour-over method. This was also confirmed by Janda et al. (2020), who described that the content of polyphenols in coffee depends on the coffee extraction method and ranged from 133.90 g to 191.29 g of gallic acid L^{-1}.

The pH of the beverages did not differ significantly between the three preparation methods ($P > 0.05$), but the pH was significantly influenced by the roasting temperature ($P < 0.001$, Table 1). The pHs of the beverages prepared from the first and second roasting were comparable, ranging from 4.96 to 5.13, consistent with the pHs of lightly roasted coffees from Brazil and

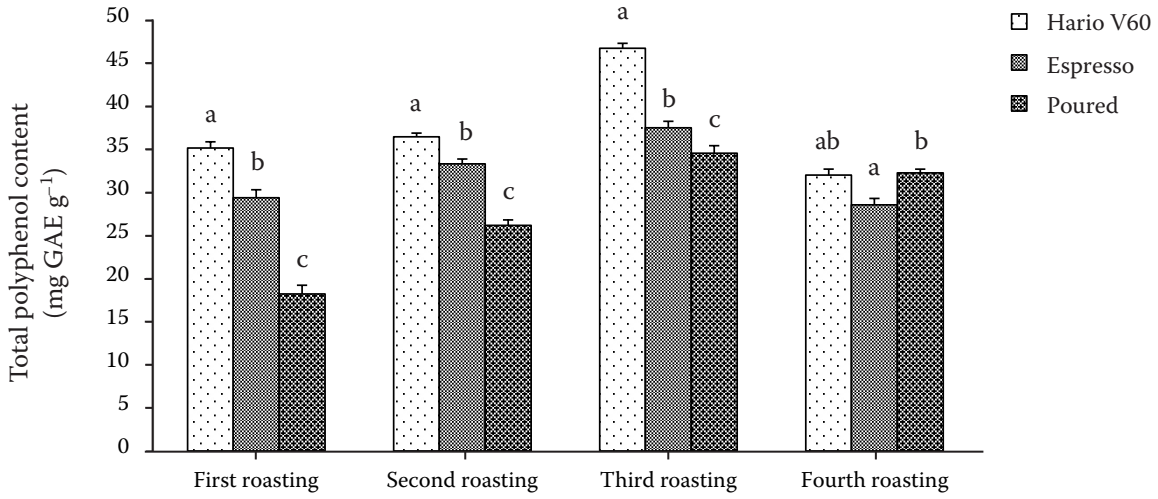

Figure 1. Total polyphenol content in the coffee beverages for the three preparation methods and four roasting temperatures ($P < 0.001$)

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Table 1. pH of the coffee beverage for the three preparation methods and four roasting temperatures (means ± SEM)

Roasting (R)	Method (M)			*P*-value		
	Hario V60	Espresso	Pour-over	R	M	R × M
First	5.09 ± 0.016	5.13 ± 0.030	5.07 ± 0.021	0.001	0.881	0.206
Second	5.01 ± 0.021	4.96 ± 0.022	4.99 ± 0.032			
Third	5.31 ± 0.028	5.28 ± 0.031	5.27 ± 0.019			
Fourth	5.57 ± 0.020	5.61 ± 0.024	5.62 ± 0.022			

SEM – the standard error of the mean; $P < 0.001$

Ethiopia, which ranged from 4.85 to 5.10 (Rao & Fuller 2018). The samples from the third roasting in our study were less acidic, with a pH of 5.27–5.31, whereas the samples from the fourth roasting were the least acidic, with a pH of 5.57–5.62. These differences in pH were probably due to the presence of isomers of caffeoylquinic acid (CQA), lower concentrations of which are correlated with higher pHs (Rao & Fuller 2018). In addition to CQA, quinic acid and aliphatic organic acids such as acetic, citric, lactic, and malic acids are responsible for coffee acidity and are degraded during roasting (Wei et al. 2012). The measurement of total titratable acidity of the beverage to pHs of 6 and 8 could be useful because it is probably better correlated with sourness than is pH (Bähre & Maier 1996). Recent data reported by Rao & Fuller (2018) indicated a weak correlation between pH and titratable acidity titrated to pHs of 6 and 8. Neither pH nor titratable acidity, however, were correlated with the sensory aspect of acidity in a comparative study of nine of the most common extraction methods for preparing coffee beverages (Gloess et al. 2013). An optimal pH of coffee extraction, however, is very important for obtaining more undissociated acids, which are responsible for the higher antioxidant activities of polyphenols in the beverage (Rao & Fuller 2018).

Polyphenol content and antioxidant activity depend on methods used and also on the region of cultivation (Sacchetti et al. 2009; Dybkowska et al. 2017). Antioxidant activity depends on the balance between the formation and degradation of compounds during roasting. The presence of melanoidins in the final product partially compensates the loss of phenolic compounds with roasting, however both phenolic compounds and melanoidins contribute to the antioxidant activity of roasted coffee (Vignoli et al. 2011, 2014). Mainly biological activities, such as antioxidant, antimicrobial, anticarcinogenic, anti-inflammatory, antihypertensive, and antiglycative activities, have been attributed to coffee melanoidins (Moreira et al. 2012).

CONCLUSION

This study describes the influence of the method of coffee preparation and the temperature of roasting on the content of total polyphenols in coffee beverages based on single-origin coffee. The differences in the content of total polyphenols in the beverages depended on both the preparation method and the degree of roasting. The most nutritional beverages were prepared using the Hario V60 method with the third roasting at a final temperature of 215 °C.

REFERENCES

Bähre F., Maier H.G. (1996): Electrophoretic clean-up of organic acids from coffee for the GC/MS analysis. Fresenius Journal of Analytical Chemistry, 355: 190–193.

Blainski A., Lopes G.C., Palazzo de Mello J.C. (2013): Application and analysis of the Folin Ciocalteu method for the determination of the total phenolic content from *Limonium Brasiliense* L. Molecules, 18: 6852–6865.

Cämmerer B., Kroh L.W. (2006): Antioxidant activity of coffee brews. European Food Research and Technology, 223: 469–474.

Catelani T.A., Páscoa R.N.M.J., Santos J.R., Pezza L., Pezza H.R., Lima J.L.F.C., Lopes J.A. (2017): A non-invasive real-time methodology for the quantification of antioxidant properties in coffee during the roasting process based on near-infrared spectroscopy. Food and Bioprocess Technology, 10: 630–638.

Clifford M.N., Marks S., Knight S., Kuhnert N. (2006): Characterization by LC-MS(n) of four new classes of p-coumaric acid-containing diacyl chlorogenic acids in green coffee beans. Journal of Agricultural and Food Chemistry, 54: 4095–4101.

Cory H., Passarelli S., Szeto J., Tamez M., Mattei J. (2018): The role of polyphenols in human health and food systems: A mini-review. Frontiers in Nutrition, 5: 87.

Cotter A.R., Hopfer H. (2018): The effects of storage temperature on the aroma of whole bean Arabica coffee evaluated by coffee consumers and HS-SPME-GC-MS. Beverages, 4: 68.

https://doi.org/10.17221/122/2020-CJFS

del Castillo M.D., Ames J.M., Gordon M.H. (2002): Effect of roasting on the antioxidant activity of coffee brews. Journal of Agricultural and Food Chemistry, 50: 3698–3703.

Dybkowska E., Sadowska A., Rakowska R., Dębowska M., Świderski F., Świąder K. (2017): Assessing polyphenols content and antioxidant activity in coffee beans according to origin and the degree of roasting. Roczniki Państwowego Zakładu Higieny, 68: 347–353.

Farah A., de Paula Lima J. (2019): Consumption of chlorogenic acids through coffee and health implications. Beverages, 5: 11.

Fikry M., Yusof Y.A., Al-Awaadh A.M., Rahman R.A., Chin N.L., Mousa E., Chang L.S. (2019): Effect of the roasting conditions on the physicochemical, quality and sensory attributes of coffee-like powder and brew from defatted palm date seeds. Foods, 8: 61.

Flambeau K.J., Yoon J. (2018): Characterization of raw and roasted fully washed specialty bourbon cultivar of *Coffea arabica* from major coffee growing areas in Rwanda. Food Engineering Progress, 22: 89–99.

Ginz M., Balzer H.H., Bradbury A.G.W., Maier H.G. (2000): Formation of aliphatic acids by carbohydrate degradation during roasting of coffee. European Food Research and Technology, 211: 404–410.

Gloess A. N., Schonbachler B., Klopprogge B., D'Ambrosio L., Chatelain K., Bongartz A., Strittmatter A., Rast M., Yeretzian C. (2013): Comparison of nine common coffee extraction methods: Instrumental and sensory analysis. European Food Research and Technology, 236: 607–627.

Hecimovic I., Belscak-Cvitanovic A., Horzic D., Komes D. (2011): Comparative study of polyphenols and caffeine in different coffee varieties affected by the degree of roasting. Food Chemistry, 129: 991–1000.

Jaiswal R., Patras M.A., Eravuchira P.J., Kuhnert N. (2010): Profile and characterization of the chlorogenic acids in green Robusta coffee beans by LC-MS(n): Identification of seven new classes of compounds. Journal of Agricultural and Food Chemistry, 58: 8722–8737.

Janda K., Jakubczyk K., Baranowska-Bosiacka I., Kapczuk P., Kochman J., Rebacz-Maron E., Gutowska I. (2020): mineral composition and antioxidant potential of coffee beverages depending on the brewing method. Foods, 9: 121.

Kaiser N., Birkholz D., Colomban S., Navarini L., Engelhardt U.H. (2013): A new method for the preparative isolation of chlorogenic acid lactones from coffee and model roasts of 5-caffeoylquinic acid. Journal of Agricultural and Food Chemistry, 61: 6937–6694.

Król K., Gantner M., Tatarak A., Hallmann E. (2020): The content of polyphenols in coffee beans as roasting, origin and storage effect. European Food Research and Technology, 246: 33–39.

Liu Y., Kitts D.D. (2011): Confirmation that the Maillard reaction is the principle contributor to the antioxidant capacity of coffee brews. Food Research International, 44: 2418–2424.

Moreira A.S., Nunes F.M., Domingues M.R., Coimbra M.A. (2012): Coffee melanoidins: Structures, mechanisms of formation and potential health impacts. Food & Function, 3: 903–915.

Opitz S.E.W., Smrke S., Goodman B.A., Keller M., Schenker S., Yeretzian C. (2014): Antioxidant generation during coffee roasting: A comparison and interpretation from three complementary assays. Foods, 3: 586–604.

Pérez-Jiménez J., Neveu V., Vos F., Scalber A. (2010): Identification of the 100 richest dietary sources of polyphenols: an application of the Phenol-Explorer database. European Journal of Clinical Nutrition, 64: 112–120.

Rao N.Z., Fuller M. (2018): Acidity and antioxidant activity of cold brew coffee. Scientific Reports, 8: 16030.

Sacchetti G., Mattia C.D., Pittia P., Mastrocola D. (2009): Effect of roasting degree, equivalent thermal effect and coffee type on the radical scavenging activity of coffee brews and their phenolic fraction. Journal of Food Engineering, 90: 74–80.

Somporn C., Kamtuo A., Theerakulpisut P., Siriamornpun S. (2011): Effects of roasting degree on radical scavenging activity, phenolics and volatile compounds of Arabica coffee beans (*Coffea arabica* L. cv. Catimor). International Journal of Food Science & Technology, 46: 2287–2296.

Tamanna N., Mahmood N. (2015): Food processing and Maillard reaction products: Effect on human health and nutrition. International Journal of Food Science, 2015: 526762.

Vignoli J.A., Bassoli D.G., Benassi M.T. (2011): Antioxidant activity, polyphenols, caffeine and melanoidins in soluble coffee: The influence of processing conditions and raw material. Food Chemistry, 124: 863–868.

Vignoli J.A., Viegas M.C., Bassoli D.G., Benassi M.T. (2014): Roasting process affects differently the bioactive compounds and the antioxidant activity of Arabica and Robusta coffees. Food Research International, 61: 279–285.

Votavová L., Voldřich M., Ševčík R., Čížková H., Mlejnecká J., Stolař M., Fleišman T. (2009): Changes of antioxidant capacity of Robusta coffee during roasting. Czech Journal of Food Sciences, 27: S50–S52.

Wei F., Furihata K., Koda M., Hu F., Miyakawa T., Tanokura M. (2012): Roasting process of coffee beans as studied by nuclear magnetic resonance: Time course of changes in composition. Journal of Agricultural and Food Chemistry, 60: 1005–1012.

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