An Investigation of the Kinetics and Equilibrium Chemistry of Cold-brew Coffee
Caffeine and Chlorogenic Acid Concentrations as a Function of Roasting Temperature and Grind Size

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Abstract

Recently both small and large commercial coffee brewers have begun offering cold-brew coffee drinks to customers with the claims that these water extractions contain fewer bitter acids due to brewing conditions (Toddy website, 2015) while still retaining the flavor profile. Dunkin Donuts’ website suggests that the cold water and long brewing times allow the coffee to reach “... its purest form.” With very little research existing on the chemistry of cold-brewed coffee consumers are left to the marketing strategies of Starbucks and other companies regarding the merits of cold-brew coffee. This research analyzes the caffeine and chlorogenic acid (CGA) content of cold-brew coffee as a function of brewing time, grind size, and roasting temperature of coffee beans sourced from the Kona region of Hawaii using high pressure liquid chromatography (HPLC). Coarse and medium grind sizes of both dark and medium roasts were analyzed by mixing 350mL of filtered water with 8mg of coffee grinds under constant stirring at 20°C. Sampling was performed every 15 minutes for the first hour, then every 30 minutes for the next ten to twelve hours, with a final sample being drawn at 24 hours. Equilibrium concentrations for both CGA and caffeine were reached following 600 minutes. The caffeine concentrations ranged from 88.5mg/L to 147mg/L. Variation was seen as a function of roasting method and was less so grind size. The CGA concentrations were found to range from 0.84mg/L to 4.74mg/L. In both cases, the medium roast grinds produced the lowest concentrations of caffeine and CGA. While our experiments agreed well with caffeine and CGA extraction concentrations in both dark roast coffees, showing very similar final concentrations. The medium roast coffees showed deviation from the hot brew coffees with respect to caffeine, indicating the need for additional experimentation to determine the role of water temperature in the availability of caffeine during extraction.

Why Cold Brewed Coffee?

Brewing coffee requires the extraction of compounds from coffee grounds. The suite of compounds gives coffee its flavor, pH, and aroma (as well as its potential antioxidant characteristics and its importance in lab). The concentration of compounds in coffee and the time it takes to extract them is controlled by an interplay between the solid particles (the coffee), the liquid solvent (the water), and the movement of the compound between the solid and liquid phases (diffusion). The movement is controlled by several factors, including (but not limited to) available surface area (grain/grind size), temperature (kinetic energy), and the solubility and interactions of components in the liquid medium.

Why Cold Brewed Coffee?

Cold brew coffee is said to have a more mild (less acidic) taste and less caffeine. Why Cold Brewed Coffee? (Huffington Post, “Is Cold Brew Coffee Better”, 2017) states that cold brew coffee’s acidity is removed during a longer brewing period, allowing it to be drunk immediately or stored in the fridge, thus preventing fermentation. While consumers are left to the marketing strategies of Starbucks and other companies regarding the merits of cold-brew coffee, this research analyzes the caffeine and chlorogenic acid (CGA) content of cold-brew coffee as a function of brewing time, grind size, and roasting temperature of coffee beans sourced from the Kona region of Hawaii using high pressure liquid chromatography (HPLC). Coarse and medium grind sizes of both dark and medium roasts were analyzed by mixing 350mL of filtered water with 8mg of coffee grinds under constant stirring at 20°C. Sampling was performed every 15 minutes for the first hour, then every 30 minutes for the next ten to twelve hours, with a final sample being drawn at 24 hours. Equilibrium concentrations for both CGA and caffeine were reached following 600 minutes. The caffeine concentrations ranged from 88.5mg/L to 147mg/L. Variation was seen as a function of roasting method and was less so grind size. The CGA concentrations were found to range from 0.84mg/L to 4.74mg/L. In both cases, the medium roast grinds produced the lowest concentrations of caffeine and CGA. While our experiments agreed well with caffeine and CGA extraction concentrations in both dark roast coffees, showing very similar final concentrations. The medium roast coffees showed deviation from the hot brew coffees with respect to caffeine, indicating the need for additional experimentation to determine the role of water temperature in the availability of caffeine during extraction.

Acknowledgement

This project is sponsored by the Philadelphia University Alumni Association ‘85 Fund for the Undergraduate Capstone Experience Grant. The authors would like to thank Dr. Joseph Alexander, M.S. for他的指导 and suggestions.

Method

Cold Brew

Course and medium grinds of both dark and medium roasts were analyzed by mixing 350mL of filtered water with 8mg of coffee grinds and constant stirring at 20°C. Sampling was performed every 15 minutes for the first hour, then every 30 minutes for the next ten to twelve hours, with a final sample being drawn at 24 hours. All samples were filtered and diluted before measurement.

Hot Brew

For the hot brew coffee we used both medium grinds of each roast were brewed using a traditional French press methodology maintaining the same ratio of grounds to water as was used in the cold brew experiments. A volume of 350mL filtered water was heated to 80°C and poured over 35g of grinds. The water maintained contact with the grinds for 5 minutes, after which time the press was depressed and the coffee was poured into a separate container for testing.

Caffeine and CGA quantification

Caffeine and CGA were measured using an Agilent 1200 series HPLC fitted with an AnaSorb C18 column (150mm x 4mm) and an isocratic mobile phase 75%:25% of 95% 2mM Phosphoric Acid and 9% methanol and 90% HPLC grade acetonitrile or ethanol (low flow of 1.0mL/min). Caffeine and CGA were detected at 280 and 255nm respectively using a Hewlett Packard 1100 diode array detector. Deviation from the hot brew coffee, indicating the need for additional experimentation to determine the role of water temperature in the availability of caffeine during extraction.

Kona Coffee

Kona coffee refers to coffee cultivated from the slopes of Mauna Kea and Makua Lea in the North and South Kona Districts of the Big Island of Hawaii. Kona and Kona Typica coffee plants must be of Kona Typica, a variety typical to the Kona region. We used 100% Kona coffee from the Kona region of the Big Island, purchased from Kona Joe Coffee. The coffee was ground in a Hobart® coffee grinder. The medium roast was roasted in between 435°F to 437°F and the dark roast was roasted in between 420°F to 423°F. The dark roast was roasted in between 420°F to 423°F. The dark roast was roasted in between 420°F to 423°F. The dark roast was roasted in between 420°F to 423°F.

Result and Conclusion

Brewing time - For all press and stove temperatures tested, all samples reached their peak concentration by 600 minutes for both cold and CGA. While brewing time is a matter of taste preference, time periods in excess of ten hours do not result in additional cold brew coffee.

Brewing temperature - Both dark roast coffees showed comparable CGA and caffeine concentrations for cold and hot brewing methods. Maximum extraction concentrations were identified using a pseudo-first order kinetic equation, which offered a superior fit than the second-order kinetic model. Only two brewing methods were employed in this study, but these preliminary results suggest that in dark roast coffees, these organics compounds are relatively stable, with comparable CGA extraction for cold and hot brewing methods, however there was deviation between cold and hot experiments with regards to caffeine. Furthermore, the concentrations of caffeine and CGA obtained in the cold brew experiments fall within the range published by Beswick et al., 2011 in their study of hot brew coffee extraction, with the exception of the medium roast coarse grind sample (T). This indicates, that contrary to previous studies that cold brew coffee may contain more CGA (and possibly other CGA isomers) than hot brew coffees. Additional brewing methods need to be tested to evaluate the role of brewing method in extraction efficiency and magnitude.

Roasting temperature - This research concludes that the medium roast grinds yield a coffee with higher concentrations of both caffeine and CGA (taken to be a proxy for other CGA isomers and therefore a proxy for antioxidant activity) than the dark roast coffee. There is general agreement that higher roasting temperatures result in lower caffeine concentration in coffee (1), however there is little agreement regarding the impact of roasting temperature on antioxidant capacities of coffee (1, 2, 8). This work is the first to quantitate CGA concentrations in cold brew coffee. Additional research is required in clarifying the antioxidant activity of cold brew coffee.

References