Cold Brew Coffee Extract, A Cradle to Grave Approach

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Research Article

Keywords: CBC extract, freeze dry, statistical evaluation, utilization of spend grounded coffee beans

Posted Date: August 13th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-799040/v1>

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Abstract

The research question related to this study was to produce various products from grounded-coffee beans such as cold-brew coffee extracts, firelighters, and soil fertilizer. The extraction of cold brew coffee (CBC) was investigated by brewing one particular sample of Rwanda coffee (medium roasted) using a cold and hot method, so that we could compare two brewing methodologies. The main parameter investigated was temperature. According to literature, particle size plays no significant role in the CBC extraction process. This work suggests that CBC can be extracted between 15 – 20 °C over 10 to 12 hours instead of 24 hours as outlined in typical cold brew extraction processes. The CBC can then be served with various flavors or diluted neatly in ice water or hot served if preferred or with milk. The spent GCB could be utilized in products such as firelighters or log firelighters for a log fire. This application has shown promising results and has longer burning times for the ignition of log fires and emits a pleasant soft coffee aroma.

Introduction

For most people, drinking coffee is part of a daily routine to start the day based on their mood and need. A caffeine kick to wake-up in the morning offers an on-the-go pick-me-up feeling.

A steady increase in coffee consumption from 29 760 tons in 2012/13 to 55 000 tones in 2016/17 was observed in South Africa. According to a survey from Masterton's coffee, consumers want to experience greater varieties of flavor and enjoy different experiences.

Cold brewed coffee could be a good alternative as a cold beverage for summer months bringing in a new experience from a different variety, still allowing the customers to enjoy the kick caffeine brings in a hot brewed coffee drink.

CBC is not iced coffee (which is hot brewed coffee over ice), (*Toddy instruction manual and guide.*, [2018](#)), CBC is prepared at room temperature over a 12 to 18-hour periods compared to traditional hot brewing methods. (*Garnier J.*, [2019](#), *Bodnaruic D.*, [2016](#), *Phung A. C.*, [2014](#), *Cordoba N., et al.*, [2019](#)) Brewing coffee is an extraction process that depends on several factors such as water to ground coffee bean ratio, the temperature of the water, the diameter of the ground coffee particles (coarse, medium or powder), and the brewing time. The temperature significantly influences the aqueous solubility of the compounds, therefore a significant difference in composition between hot brewing and cold brewing is observed in the literature. (*Fuller M. & Rao N.R.*, [2017](#)) Numerous literatures has been published detailing the chemistry of hot water brewing coffee, this includes quantification of the caffeine concentrations as a function of the hot water brewing method. (*Blumberg S., et al.*, [2010](#), *Bell L.N., et al.*, [1996](#), *Shibamoto, T. et al.*, [1981](#)). Coffee grounds contain a mixture of volatile (*Caporaso N., et. al.*, [2018](#)) and non-volatile components, such as various oils, acids, and other aromatic molecules. (*Phung A. C.*, [2014](#)) Collectively, these compounds are referred to as "coffee-soluble" and significantly contribute to coffee flavor.

A few unique characteristics gathered from literature define how coffee lovers can be hooked on cold-brew coffee: (*Cape coffee beans, 2017*)

1. It's cold – This is cold drink with the envisage on refreshing a person on a hot day.
2. The tart acids are lower in a cold brew coffee in comparison too hot extraction; therefore, the taste is bit more mellow.
3. The coffee provides a fuller body to the taste buds. It tends to be less acidic, cold brew is not less pleasant on body or mouthfeel; the long extraction times see to that.
4. It can be brewed in large quantities in advance especially for lazy coffee lovers would be pleased with this idea or for an entrepreneur that have his/her own coffee shop. You can store-up a couple of liters of cold brew and keep it in your fridge for a few days, rather than brewing a fresh batch each time.
5. The CBC could be bottled - This explains its commercial success as a ready to drink beverage.

Factors such as temperature affect the solubility and volatility of the coffee soluble. (*Phung A. C., 2014*). Solubility describes the number of solids dissolved out of the GCB into the water, volatility refers to their ability to evaporated into the air. Because of the increased volatility with higher temperatures the aromatics are easier released from coffee giving rise to that lovely scent of freshly brewed coffee. (*Phung A. C., 2014*)

On the other hand, where cold brewed coffee lacks in temperature, it makes up in time. (*Phung A. C., 2014*). By increasing the time of extraction from a few minutes to hours aims to maximize the extraction of the solutes from the grounded coffee beans. Other factors such as oxidation and degradation could still occur in cold brew water extraction methods, this happens much slower in comparison to hot water brewed coffee. A decrease in bitterness and acidity are also reported in literature (*Borack J., 2015*), especially if the CBC is kept cold. Therefore, CBC extracts might take on a much sweeter, and floral characteristic.

Large quantities of coffee are consumed worldwide every day which results in a large quantity of spent coffee grounds in countries across the globe. Part of this investigation is to develop downstream products that will utilize the spent coffee beans and therefore develop a higher commodity product that can be used by the end user. For example, traditionally, these residues would be dumped as fertilizer to condition soil. But what about other higher value products such as firelighters or burning bricks for heat generation. It might be utilized in the cosmetic industry as an exfoliant. Other examples: spent coffee grounds might be used in biofuel (*Blinova L., et.al., 2017*), and to as a source of extracted antioxidants (*Pettinato M, et.al., 2017, Seo H. S., & Park B.H., 2019*).

In this research, the authors focused on firelighters and log firelighters as a possible alternative product for the spent ground coffee beans in addition to a CGC beverage.

Results And Discussion

During these experiments, it was noted that the extraction proceeds very rapidly compared to the 18-hours literature suggested. (*Fuller M. & Rao N.R., 2017*). All the different ratios reach their end point just under 4 hours. This means time can be saved and more than one batch can be prepared in a single day.

To verify the results, two extractions were performed firstly at 2-hours and then at 4-hours extractions respectively. Table 1 summarizes the results. From these two extractions, a 100mL sample was taken and freeze-dried. The yield percentage was then calculated and compared to the TDS readings as well as previous 18-hour extractions that have been done.

Table 1: Results after 2 and 4 – hours of cold brew extractions

2- hour extraction	
Total extraction volume (mL)	300
Amount of coffee grounds (grams)	42,87
Freeze dry sample volume (mL)	100
Freeze dry mass (grams)	2,26
Calculated mass for overall extraction	6,78
Yield %	15,82
4 – hour extraction	
Total extraction volume (mL)	300
Amount of coffee grounds (grams)	42,95
Freeze dry sample volume (mL)	100
Freeze dry mass (grams)	2,67
Calculated mass for overall extraction	8,01
Yield %	18,65

Figure 1 shows the combined effect of pH results for the three water to coffee ratios at 1:7, 1:12 and 1:5 mixture ratios respectively. There was no significant difference observed between the three ratios and the coffee extracts gave a pH reading of about 4.5 – 5.5 which indicates the caffeinic acids present in the coffee extract. Figure 2 from the TDS, it can be noted that as the ratio between water and the coffee decreases, the amount of coffee particles in solution decreases, but becomes constant after about 1 – 1.5 hours of extraction.

The CBC extraction samples were subjected to various criteria to grade the CBC extract. A chart was constructed with the following criteria Aroma, Flavour, Acidity, Body, Aftertaste, and Balance.

The aroma was chosen because the CBC needs to have a good full body taste and not be flat or tasteless. Coffee aroma have several attributes that could enhance the coffee favour, other than the mouthfeel and sweet, salt, bitter, and sour taste attributes that are perceived by the tongue. (*Coffee Aroma Blog, 2017*)

Coffee aroma could be explained by two different mechanisms. It can either be sensed nasally via smelling the coffee or retro nasally. Retro nasal perception occurs when the coffee is either present in the mouth or has been swallowed and aromatic volatile compounds drift upward into the nasal passage. (*Patterson C.A., 2018*).

Acidity describes a coffee taste that refers to the fruity, tangy or wine-like flavour that characterize many Arabica coffees. (*Kalikoweo, 2018*) The acidity becomes more prominent in longer roasting times of the GCB. This term has nothing to do with the amount of acid present or the pH.

The term “body” describes the texture of the cold brew coffee, the full-bodied coffee taste refers to the strong, soft and enjoyable feel of the coffee in the mouth. A coffee's body (light, medium, or full) is depth of the aroma on the pallet due to the amount of dissolved and suspended solids and oils extracted from the coffee grounds. This may range in thickness from a thin and watery texture to a thick and creamy texture.

The aftertaste: the taste of brewed coffee vapours released after swallowing. Also called "finish", aftertastes can be burnt, chocolatey, spicy, etc.

A balanced coffee may be complex but does not have any overwhelming flavor or aroma characteristics.

Table 2 shows ten test samples, the first five samples were the freshly extracted CBC. This provides the judges with a benchmark on how the different CBC extract could taste at different coffee to water extract ratios and dilutions.

Table 2: Test samples for the analysis

Sample 1	1:14 Diluted 1:1
Sample 2	1:7 Diluted 1:3
Sample 3	1:14
Sample 4	1:7 Diluted 1:2
Sample 5	1:7 Diluted 1:1
Sample 6	1:14 Freeze dried, 2,6g/120ml
Sample 7	1:7 freeze-dried, 1,3g/90ml
Sample 8	1:7 freeze-dried 2,6g/90ml
Sample 9	1:14 After 1 week
Sample 10	1:7 Diluted 1:1 After 1 week

Table 3 summarizes the CBC extract results; the most favourable test sample proven seem to be the roasted coffee bean extract that was extracted in a 1:7 water ratio. Most of the judges liked the 1:7 freeze-dried sample. Most mixes were made up in a ratio of one teaspoon of coffee to a cup of water. Sample 4 consisted of the fresh extract CBC in a 1: 2 dilutions with cold water. It seems from this small population of 10 judges that the ground roasted coffee bean, coarse particle size in a 1:7 ratio to the water extract medium gave the best cold brew extract coffee according to taste parameters.

Table 3: Summary of cold brew extraction test results

	Aroma	Flavour	Acidity	Body	Aftertaste	Balance
s1	81	69	81	50	75	69
s2	75	56	64	39	67	61
s3	81	56	58	58	50	56
s4	89	56	58	47	58	64
s5	86	67	58	58	53	56
s6	78	67	58	56	61	64
s7	67	72	67	58	75	64
s8	75	58	58	61	42	56
s9	53	69	69	53	67	61
s10	58	64	61	58	64	64

The 3D surface model plots showed that when the sample has a good body the aroma and flavour improve compared to diluted samples or weaker extract coffee to water ratios. Figure 3(a) is the 3D surface plot for the Aroma, Flavour, and Body.

Figure 3(b) shows the 3D surface model plot for Aroma, Flavour and Acidity it is also clear that the almost all the judges like the acidity of the cold brew extract as the aroma becomes fuller in the body.

Figure 3(c) a 3D surface model plot for the comparison between Aroma, Body, and Aftertaste, when comparing these three parameters a mid-point is observed to give the most favourable CBC extract.

Figure 3 (d) shows a 3D surface model comparing Aroma, Acidity and Aftertaste from the plot it can be noted that the acidity does increase as the aroma increase with some improvements on the aftertaste of the coffee that was extracted in a 1:7 ratios.

Utilization of waste material such as the spend GCB can be used for fertilizer, or to be used to make firelighters. Below a discussion on the results obtained to produce firelighters from spent grounded coffee beans.

Firelighters

This experiment demonstrates the development of firelighters from SGCB, molasses, and wax. The idea behind this was to use the SGCB as the filler, with wax as the fuel and the molasses as the binder. Two ratios were used for the firelighters as well as one of each having molasses added as a binder to see if it changes the way it burns. The ratios used were a ratio of 2:1 and 1:1, SGCB to wax. With each ratio, one sample had the addition of molasses, so in total 2 samples of each ratio were prepared. The sample size

is relatively big and will be made smaller when compared to commercial firelighters. The size of testing the firelighters manufactured from the SGCB and the commercial ones was roughly between 20-25grams. The firelighters with a 1:1 ratio stay alight for 9.45 minutes on 20 grams compared to 2:1 SGCB: wax ratio of 16.05 minutes per 20 grams compare to a commercial product that stay alight for about 10.45 minutes.

Freeze dry

From these results, it was noted that a 4-hour brew yields 18% freeze dry solid mass, compared to 16% during a 2-hour cold brew extraction. It was observed that the optimum cold brew extraction is in the region of about 4 hours compares to the 12 – 18 hours suggested through other authors in literature. (*Fuller M. & Rao N.R., 2017*).

Temperature Determination:

By analysing the results of the experiments at 10, 15 and 20 °C we can conclude as to how the temperature affects the cold brewing of coffee. By keeping all factors constant except the temperature changes, we can compare the yields of these experiments. From the results, we can conclude that the temperature at which coffee is cold brewed, does not affect the product. By keeping all factors constant, except for the temperature changes, we can compare the yields of these experiments. From these results, it can be concluded that the temperature at which coffee is cold brewed does not affect the product yield. This means we can save energy costs by not needing to cool the setup to 10 or 15 °C, but rather brewing at 20° C. The cold extraction technique was compared to hot extraction at 95°C. In each study, it can be observed that a lesser amount of TDS (TDS) were extracted hot, compared to extracts from the cold-water extraction. The amount TDS extracted ranged between 1021 – 1050 ppm compared to over 2000 ppm for the cold brew extraction. The pH remains the same for all the extractions at 4.88 which is an indication of the caffeinic acid been extracted from the ground coffee beans. The amount of coffee is extracted from the ground coffee beans during the cold brew extraction process gave a yield percentage of 19% compared to the hot extraction method that results only in a 6% freeze dry solid mass percentage.

Cold brew extraction

From Table 2 summarized, 7 CBC dilutions and 3 freeze-dried CBC granular to water ratio were prepared for analysis. The importance of this was to establish which product would be best marketed and in what format. Most commercial coffee sellers prepare the CBC in advance and store it in a keg, in a cool place in order to achieve could brew of the CBC and then filter the CBC through before serving. The authors suggests, in order to achieve a longer shelf life, one way would be to freeze dry the CBC extract, this will remove caffeinic compounds out of the coffee and provide a better healthier option rich in caffeine but without the caffeinic aromatics.

The CBC extract was rated in these various mixture ratios as per Table 2 into the following categories Aroma, Flavour, Acidity, Body, Aftertaste and Balance have been discussed in section 3. Results. From

Table 3 it can be noted that the CBC extract in most cases appears to be flat in comparison to hot brew (traditional way) coffee and score a 61% for the 1:7 freeze dried product (2.6g / 90mL). The best overall was the CBC extract dilution of 1:14 and further diluted 1:1 with water. This was scored overall as 71%, followed by sample 7, the 1:7 freeze-dried products with a score of 67%. The best score on average was 62% with the best aroma of most of the sample mixture ratios these results also indicated that there were only a few products that have an aftertaste when compared to the lingering aftertaste of hot brew coffee.

Uses of spent ground coffee beans

Since the aim of this research was to utilize the entire granular coffee bean it was important to study one case where they could be used as firelighters. There are other uses like applying the spent beans as a fertilizer for soil conditioning or a meat rub before BBQ and so on. However, from some entrepreneurs point of view we chose to investigate firelighters and log fire fighters. The method was discussed under "Materials and Methods" and the results are given in the section "Results". These firelighters burning time was compared to commercial firelighters and we found that on average they burn for about 9.45 minutes compared to the commercial firelighters which burn for 10.45 minutes per 20 grams.

Conclusions

In conclusion, the ground coffee bean extract that was extracted in a 1:7 water ratio had the best aroma and acidity resulting in a fuller body texture.

Future recommendations would be to continue with the 1:7 CBC extract in the water at room temperature but on a slightly bigger scale of about 5 – 10L with and without agitation under air and nitrogen atmosphere. This could provide good evidence about the feasibility of the project. Further studies will also be done on freeze-drying the CBC extracted as well as to investigate suitable packaging materials by making use of sachets under dry conditions or concentrates.

Materials And Methods

To test these variables, we will establish fixed values in each experiment with the same batch of coffee beans to compare them to a control sample of a normal cup of hot brewed coffee. The roasted coffee chosen will be a lightly roasted ground coffee bean from Rwanda ground to coarse particle size. Rwanda coffee purchased from Masterton coffees, Gqeberha (Port Elizabeth), South Africa.

Temperature Determination:

The goal of this experiment was to determine the optimum temperature at which CBC should be brewed to yield the most product. During this experiment the ratio of water to coffee was held constant at 5.62:1

which translates to 720mL DI water with 128grams of coffee added. The weight of the coffee was recorded accurately to determine the yield of the product. The time of extraction was also held constant at 18 hours with agitation speed on low. After the cold extraction, a hot extraction was performed at 95°C for 5 minutes to determine the amount of hot brewed coffee left behind after the cold brew extraction has been completed.

As a method to determine the overall extraction of the total dissolved solids (TDS) were measured of the cold extractions at various temperatures as well as the subsequent hot extraction. The cold extraction had to be volumetrically diluted to 50% to acquire a ppm reading as it was more than 2000ppm. These readings could then be compared at the different temperatures of extraction.

For each extraction, hot and cold, a 200mL aliquot was placed in the freezer to solidify and then freeze-dried. This freeze-dried sample could then be accurately weighed and from there, a yield could be obtained. These yields could then be compared to see if there is a difference in yield based on the various temperatures of cold extraction and to see if these yields correlate to a change in the yield of the subsequent hot extractions.

Endpoint Determination:

The goal of this experiment is to determine when the cold brew extraction reaches its endpoint by means of taking a TDS reading every hour for 10 hours. This experiment was performed at three different ratios of coffee to water.

These ratios are (coffee to water):

- 1:5
- 1:7
- 1:12

From the TDS reading we take hourly we can then construct a graph of TDS versus time and visually see at what point the extraction ends with these various ratios. These results will help us optimize the process by not wasting time on trying to extract for longer periods of time, if all the compounds have already been removed. We will also be able to see if it is more efficient to extract a concentrated solution with a higher coffee to water ratio than extracting it with a diluted ratio that is ready to drink.

Pilot-scale demonstration of the CBC extract.

A small-scale pilot demonstration was performed at a sister Technology Station – Agrifoods at Cape Town University of Technology. A reactor was charged with coarse ground Rwanda coffee beans (720g)

and water (5L) was added. The mixture was agitated at a slow rpm (150) for 12 hours at 20°C, and then filtered to remove the spent coffee beans.

The CBC extract was then freeze dried.

Declarations

Acknowledgments

The authors would like to thank all from InnoVenton that provide valuable insight into this project and provide financial support towards the internship of MM. The authors would like to thank Hybre' van Blerk (Stellenbosch University, Agrifood Technology Station) for freeze-drying the pilot study CBC extract. Melissa Gouws for proofreading the manuscript. Peter Grant's input in the statistical analysis of CBC.

Author Contributions: CRediT roles

SG: Conceptualization, Methodology, Software, Writing- Original draft preparation, Reviewing and Editing: SG Supervision, Conceptualization, Methodology: MM: Data curation, Validation.

Competing interests

The author(s) declare no competing interests.

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Figures

Figure 1

Effect of pH on the CBC extract

Figure 2

TDS effect over time

Figure 3

3D surface model plot for the comparison of a) Aroma, Body, and Flavour, b) Comparing Aroma, Flavour, and Acidity c) comparing Aroma, Body, and Aftertaste, and d) comparing Aroma, Acidity, and Aftertaste