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Article

Current Challenges of Cold Brew Coffee – Roasting, Extraction, Flavor Profile, Contamination, and Food Safety

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Abstract: Cold brew coffee has emerged as a new trend during the last decade. However, "cold brew" is an extraction style of ground roasted coffee with water at less than body temperature (typically 8°C or room temperature) rather than a beverage per se. Cold brew extraction poses several challenges including the need of specific optimization depending on the multivariate influences of coffee variety and processing, roast degree, grinding, dosage, water composition, turbulence, brew system (drip, immersion etc.), time and temperature. While cold brew is typically characterized by a floral sweetness, over-extraction may lead to abundant acidity and bitterness. To avoid this, an extraction degree of 70% was suggested using rather shorter times (i.e. 2 h at 15°C with 80 g/L coffee with optimized medium roast profiles). Due to the lack of sterilizing temperatures during preparation, cold brew is special in the coffee sector because hygiene and food safety aspects pose specific challenges for food industry. To avoid microbiological contamination and spoilage, cold brew should be as freshly prepared as possible and shelf-life should be minimized.

Keywords: coffee; cold brew; nitro cold brew; roasting; extraction; hygiene; risk assessment; product quality

1. Introduction

While the history of cold brew coffee may be traced back as far as the 1600s, with a major invention being the Toddy cold-brew coffee system in the 1960s [1], only recently cold-brew has become one of the latest uprising trends across the entire coffee industry [2]. For example, cold brew sales grew by a 580% in the US in the period between 2011 and 2016 [3]. Due to its novelty, there is an absence of in-depth research into this coffee extraction method. There is also currently an absence of internationally accepted standards or definitions about what cold brew is and under what conditions it is made [4]. The demand for high quality cold brew coffee may have been driven by the fact that the segment of iced coffee had been ruined in the past "by using old, bitter tasting brewed coffee as the base" or "even worse, many have used coffee extracts" [5].

In general, the term "cold brew" describes a method for preparing a beverage in the form of a certain extraction style. Cold brew is not necessarily a cold beverage (i.e. unlike iced coffee, cold brew may be served cold or hot). It is important to differentiate between cold brew and iced coffee (Table 1). Sometimes, mostly in industrial settings, hot brewed beverages are cooled (so-called "hot

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bloom" method [4]) and sold as some form of fake cold brew ("called brew"). Several cold brew methods such as drip filtration, full immersion, or cold press are available.

This article provides an overview about the current knowledge of cold brew coffee preparation along with practical aspects and pitfalls, specifically related to hygiene and food safety. Furthermore, open research questions are suggested and challenges for research are pointed out.

Table 1. Major differences between cold brew and iced coffee.

Cold brew	Iced coffee
Cold extracted	Hot extracted
Extraction method	Coffee beverage
Emphasizes water-soluble aromas	Emphasizes oil-soluble aromas

2. Materials and Methods

For the review part of the article (section 3), electronic searches of literature were conducted including the databases PubMed, Google Scholar and Food Science and Technology Abstracts (FSTA). Search terms used were "cold brew" or "nitro" and "coffee". The abstracts were screened for relevance regarding aspects of roasting, extraction, flavor profile, contamination and food safety. Relevant articles were obtained in full text. The searches were complemented by the literature collection of the authors. The major results of the review were discussed using several online training sessions with coffee experts hosted by the professional training centers of Earthlings Coffee Workshop (Malaysia) and Coffee Consulate (Germany) and research plans were derived from this (section 4). The feedback of the experts was also included in a section about open problems and challenges (section 5).

3. Cold brew extraction – what do we know?

3.1. Multivariate influences on cold brew extraction

The extraction of cold brew is typically conducted at temperatures below body temperature, but there is no universally accepted extraction temperature. The concept of "cold" is often culturally related relative to the natural or artificial environments, e.g. countries with cold winters vs. tropical countries, air conditioning, refrigeration. The authors, however, believe that temperatures near or above body temperature move away from the concept of cold brew, and should be critically assessed to avoid misleading food information.

Cold brew can be extracted by all the three methods used for hot coffee. It can be extracted (i) as "cold drip" (typically with iced water) like a filtration method, (ii) lixiviation or immersion (i.e. grounds in a pot sipping in the water, with or without stirring or other techniques such as ultrasonication), (iii) cold press (under or overpressure).

What is exactly cold? The temperature may be close to 0°C (i.e. melting ice in the drip method), at fridge temperature (4-8°C), or any temperature below body temperature. It is important to understand that there is a range of temperatures much larger than the one used for hot coffee extraction. The extraction time of cold brew will be much longer than for hot brews, but also largely depends on the actually selected temperature. The minimum would be 2 h (at 20°C). It is important to adjust the time/temperature equilibrium to not over or under extract the cold brew.

The extraction of cold brew coffee generally depends on several factors including the coffee, roasting, dosage (brew ratio), water temperature and composition (hardness, …), turbulence (i.e. increasing the water contact into the coffee grounds by stirring), grinding level (particle size and surface, dust) and time (Figure 1). From these parameters, the roasting profile is specifically important as it influences the acidity that may be extracted out of the beans. Grinding surface is also extremely important (e.g. extraction is influenced if the surface is irregular or round)

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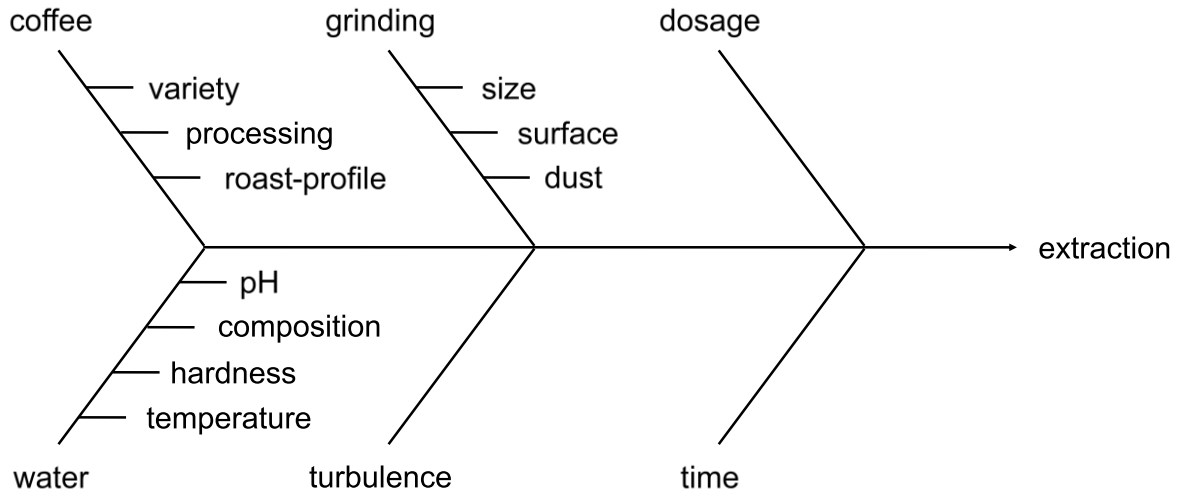

Figure 1. Ishikawa diagram of causal influences regarding cold brew coffee extraction.

3.2. Hazards during cold brew extraction

In the context of cold brew coffee, it is also important to think about contamination (Figure 2). Cold brew is one the few coffee beverages that includes some food safety hazards. Because normally, any risk is avoided by roasting of the beans, brewing hot and drinking the prepared beverage fresh and hot. With cold brew there are a lot of hazards: there is a long time for brewing, in which microbiological activity may occur. Cold brew makers should be aware of any signs of optical changes or of taste, which may be a first indication of microbial contamination. The risk of microbial growth is strongly related to the extraction temperature and is dramatically reduced at really cold temperatures.

Most common organisms that may spoil cold brew are yeasts (leading to alcoholic fermentation) and lactic or acetic acid bacteria (producing organic acids). For most small-scale producers (e.g. in their coffee shops), it is impossible to work sterile, so that the storage time of the product should be restricted. Besides spoilage, pathogenic microorganisms such as *Salmonella* or *Listeria* must be avoided.

When filling in cans, bottles or kegs, the use of additives such as ascorbic acid or preservatives may increase microbiological stability and shelf life, as well as heat sterilization or pasteurization (see [4]). However, all these methods are expected to negatively impact the flavor.

Heat-induced coffee contaminants formed during roasting such as furan or acrylamide [6] were found at similar levels in cold brew compared to hot brew [7].

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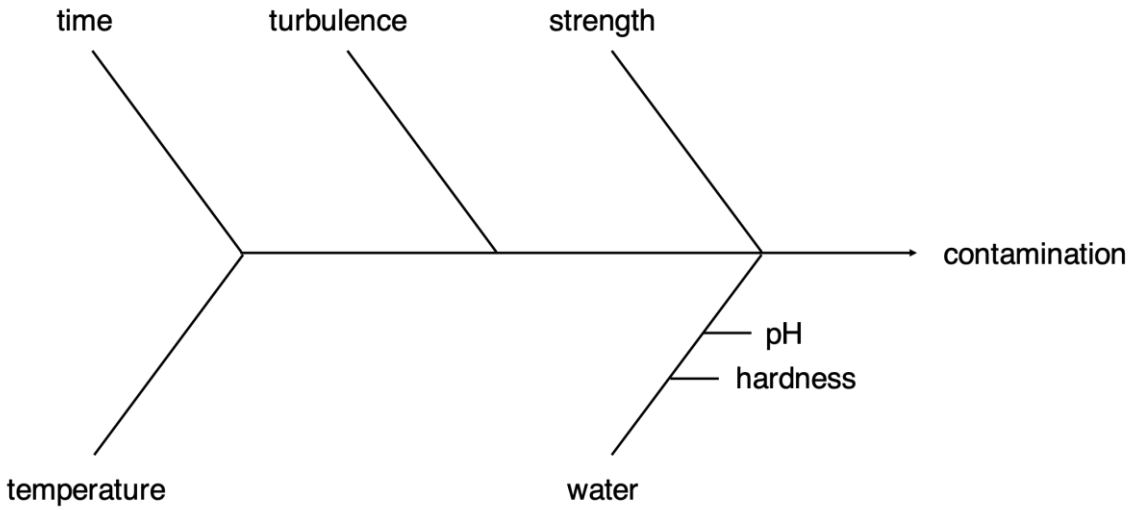

Figure 2. Ishikawa diagram of causal influences of extraction on cold brew coffee contamination.

3.3. Extraction degree

Considering the authors' experience, 70% extraction (i.e. 70% in relation to the total extractable/soluble amount) may be an optimal starting point for cold brew coffee recipe development to achieve a balanced product (Figure 3). This is not yet a number with scientific basis, but stems from experience considering all aspects, including the risk of contamination (i.e. avoidance of too long times), and the flavor. In other words, an extraction must be found which gets out the flavor while avoiding contamination. It will always depend on all the parameters and their interactions. Probably when measuring extraction value, there will be a certain corridor, where a good extraction is achieved. More agitation will be faster, cooler will be longer, and all these effects will add up. Not all the solubles should be extracted, but just enough to get a good taste but minimizing the risk for contamination. This is also known from hot extractions such as espresso, where an over-extraction also leads to unpreferable taste profiles.

Some empirical research confirms the authors' suggestion of 70% extraction. Cordoba et al. [8] reported higher scores in their sensorial evaluation when cold brews were prepared using the shortest time (at 75-86% total dissolved solids compared to longer extraction time). More research is clearly necessary into this question.

To achieve the highest possible extraction, such as 100%, is specifically not desirable in the specialty coffee field. There is no need to spoil the beverage by getting "everything out". It is better to waste a little bit of coffee, especially the part with the bad flavors inside. There might be an ideal point, certainly below 100%, where all the "good" flavors are in and the "bad" flavors stay out. This point must be investigated individually in an iterative process considering the equipment and all the influencing factors mentioned. This will ultimately ensure a good and consistent product.

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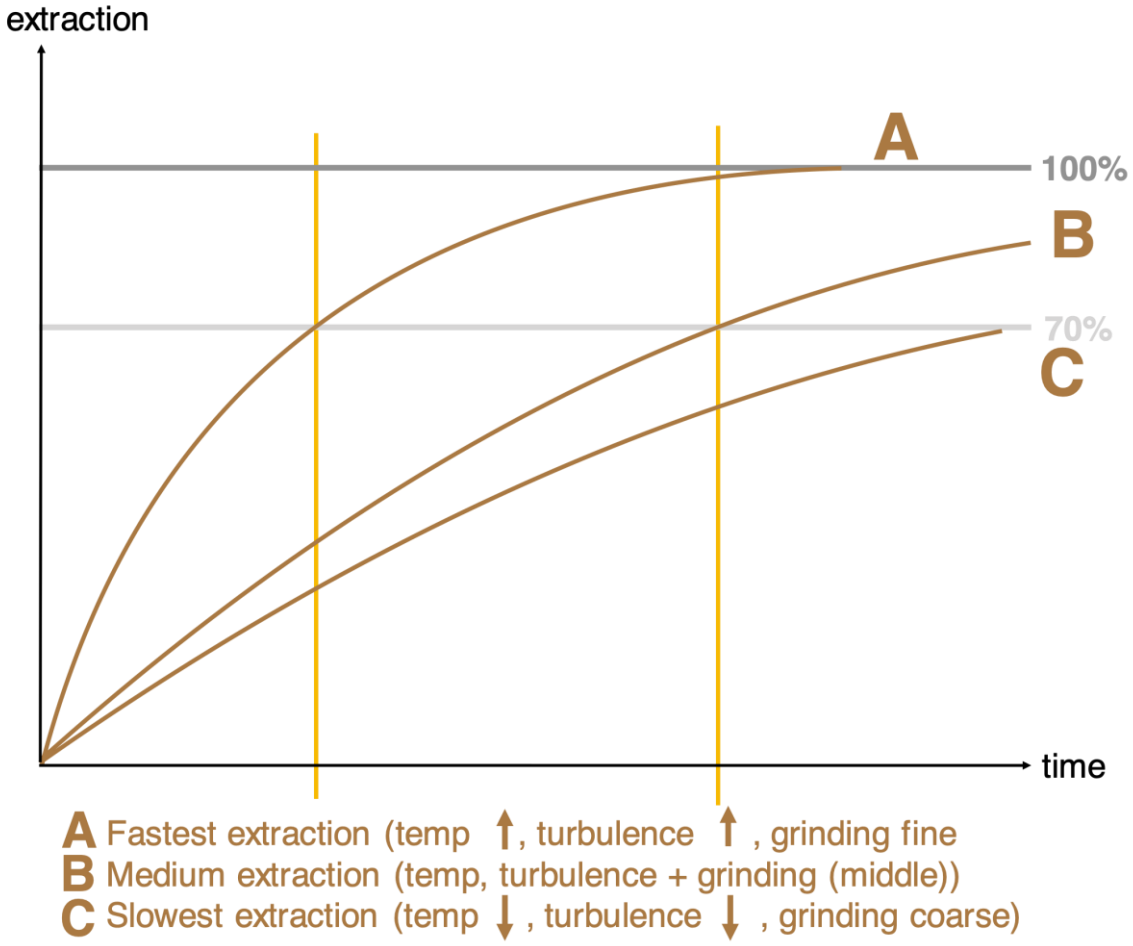

Figure 3. Model considerations about cold brew extraction.

3.4. Flavor and taste profile of cold brew coffee

Regarding the aroma of cold brew coffee, there are considerable differences compared to normal hot brew coffee. For example, the Coffee Consulate Aroma Wheel [9] shows some grayed out areas for cold brew (Figure 4). Those are the oil-bound aroma groups (i.e. herbs, spices, nuts), which are suppressed by extraction with cold water. With cold water fruit, floral and vegetal aromas but also light roast aromas, and some mineral and chemical aromas in case of very dark roasts contribute to the flavor profile. Especially in the drip method, with melting water just above 0°C, the product is predominated by the fine very fruity and floral aromas. It is also recommended to roast in a fashion to stay in the area of fruity and floral flavors. As a variation, some people may extract the cold brew with cold milk instead of with cold water, which may increase the lipophilic and more polar compounds and flavors.

Finally, the taste profile can be influenced by the serving, e.g. nitrogen-infused or so-called nitro cold brew, milk addition, sugar addition, use of ice or other ingredients such as alcoholic beverages. The nitro method is specifically interesting because it considerably changes the look and taste of the beverage. The nitrogen gas percolates through the glass like a Guinness beer, leaving a creamy head on the top [5]. The flavors are dispersed across the tongue because the bubbles dramatically increase the surface giving a smooth and creamy taste [5]. In our experience, the nitro method also intensifies the sweetness and takes the bitterness out of the product.

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Figure 4. Coffee Consulate Aroma Wheel. Aroma groups that are reduced due to cold brewing are grayed out.

The difference in flavor profile becomes evident when a cold brew and a standard hot filter coffee extraction of exactly the same coffee variety (oeiras) are compared using the Coffee Consulate flavor profile by a calibrated taste panel (n=3) (Figure 5) [10]. The cold brew profile is more intensive in orange/lemon/cucumber flavors, while filter coffee is more intensive in peach and in the spice and microbiological characteristics. Cold brew has a bit less body and is more refreshing. Clearly, much more emphasis is on the water-soluble, less polar compounds in the cup.

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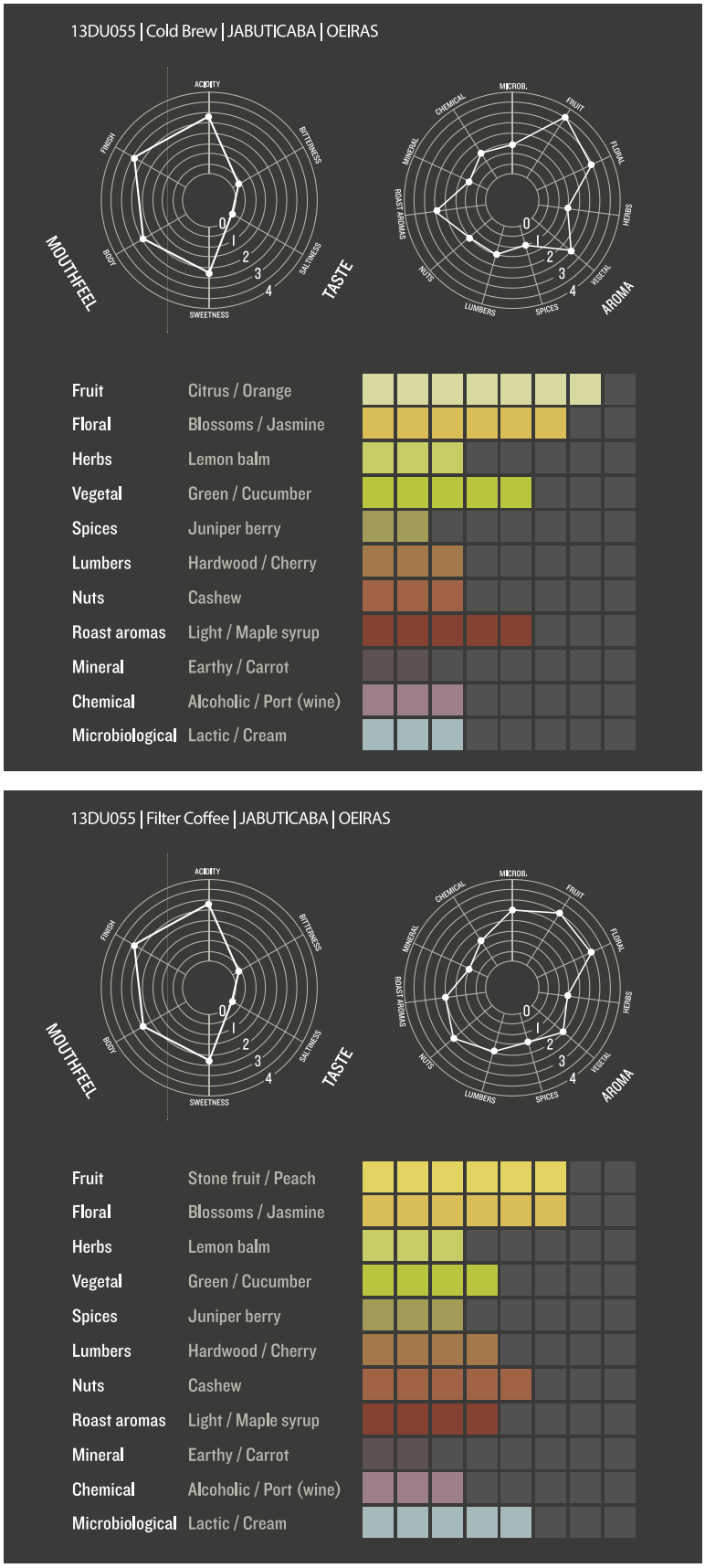

Figure 5. Flavor profiles of a cold brew (upper panel) compared to a filter coffee (lower panel) of the same coffee.

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3.5. Roasting for cold brew coffee

Roasting plays a big role in determining what flavors go into the cold brew as it is possible to retain or eliminate different aromas by manipulating different roast levels. In general, the authors suggest to avoid roasting too dark for cold brew to keep out unpleasant aromas. Typical roast profiles for cold brew, filter coffee and espresso are compared in Figure 6. The biggest difference is the espresso roast, while cold brew and filter coffee are more similar. The cold brew is basically the fastest roast of the three. It is faster arriving in the third phase. The first phase is more or less the same with all of them. The second phase (drying phase) is relevant for preserving the acids in the bean. The cold brew roast then is slowed down at the very end, to avoid excessive formation of Maillard-based aromas.

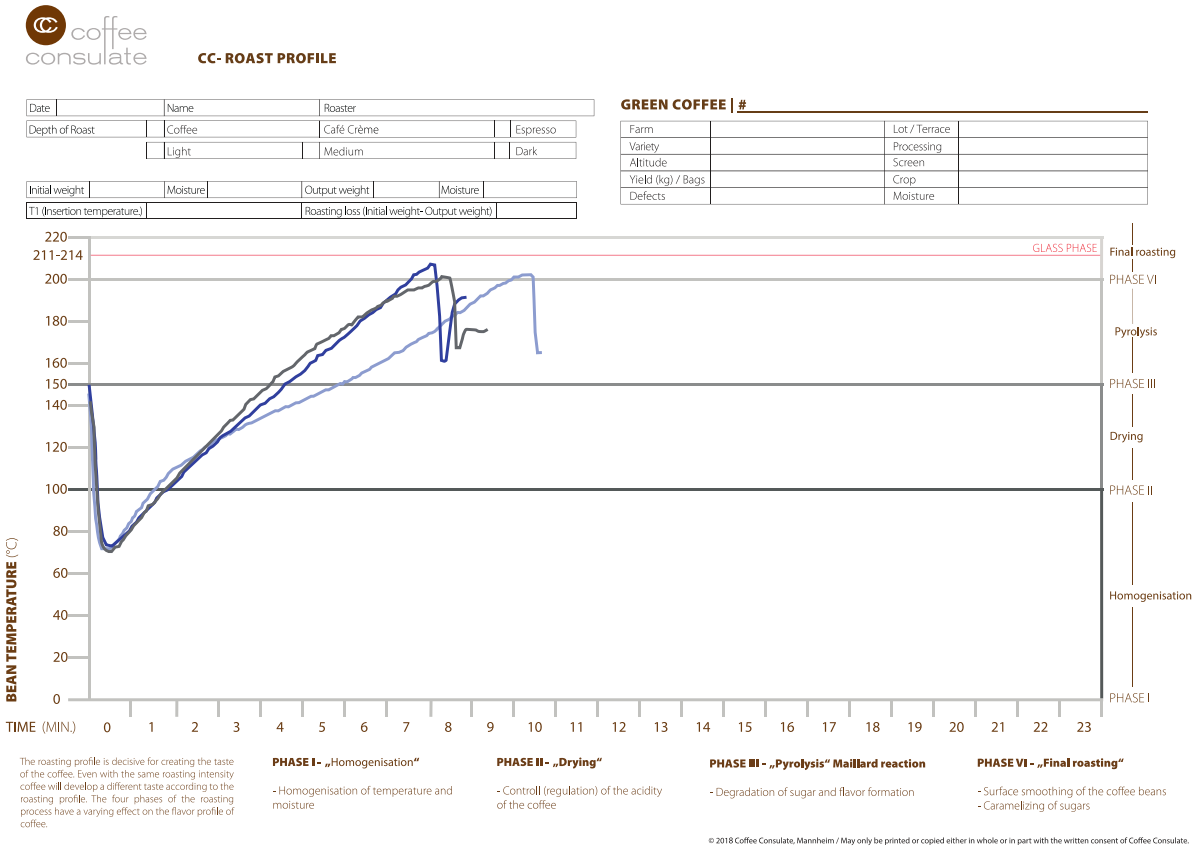

Figure 6. Exemplary roast profiles of cold brew compared to filter coffee and espresso (FZ-94 sample roaster, Coffee-Tech Engineering, Moshav Mazliach, Israel).

4. Cold brew – research plans

Some initial organoleptic experiments with cold brew were initiated during the Intergastra 2020 trade fair (15.-19. February 2020, Stuttgart, Germany), which includes the Stuttgart Coffee Summit, one of the largest professional coffee trade exhibitions worldwide. The visitors at the booth of Coffee Consulate were asked to participate in several ranking order and triangle tests according to ISO 8587 and ISO 4120 methodologies (n=60 for ranking order tests and n=25 for triangle tests). The statistical evaluation of the results is ongoing and will be published later this year, but some initial trends were that cold brew made with *Coffea arabica* beans was preferred over the one with *Coffea canephora*. There was also a tendency of pulped natural processed Arabica being preferred over fully washed Arabica, potentially due to the higher sweetness of the resulting brew. Another trial showed that consumers significantly preferred cold brew over hot brew (cooled down), when the same type of coffee beans was prepared in both fashions.

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There is not much literature about the question how cold brew is actually prepared in common practice. Therefore, a questionnaire has been developed [11]. Besides some demographic data and experience with cold brew, the questionnaire investigates the major parameters such as dosage, water composition, brewing temperature, brewing time, grinding degree, coffee variety, roasting degree as well as serving styles. The questionnaire was launched during an online training in April 2020 and sent to all participants, but also distributed on the Facebook pages of the affiliated institutions and other social network channels. The results will be finalized in July 2020. However, some initial interesting findings of the first 49 participants as of 22 April 2020, which mostly encompass the participants of several online training sessions, are shortly summarized in the following.

There was an almost equal distribution between the different cold brew systems (i.e., drip method, commercial systems, French press, mixing in various containers, etc.) with a slight preference (34%) of immersion in containers and filtration afterwards. The applied brew ratios were similarly diverse, with a majority of participants preferring 80-100 g/L. For water quality, soft or medium hard water is preferred. The most preferred extraction temperature is 8°C followed by 20°C (see Figure 7). The average brewing time was 16 h (standard deviation 10 h, maximum 49 h). Medium roast with coarse grinding degree is preferred. Following the brewing of the cold brew, the average storage time was 1 day (median 0.6 days, standard deviation 1.4 days, maximum 7 days).

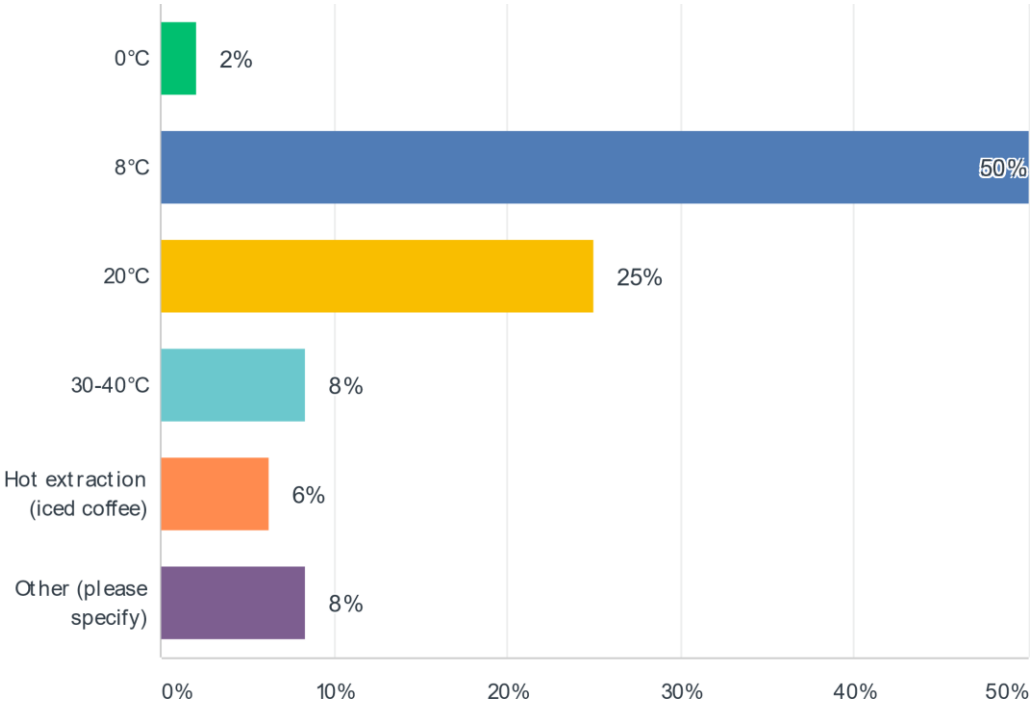

Figure 7. Survey result of cold brew extraction temperatures (https://www.surveymonkey.com/r/cold-brew-research).

5. Open problems and challenges about cold brew coffee

5.1. Should cold brew be served with ice?

The ice will lower the temperature and may also dilute the aromas. Cold temperature will also suppress optimal taste perception. Therefore, a good cold brew does not need ice. But obviously, if consumers like ice such as in whisky-like cocktails, there is nothing speaking against it.

5.2. Is cold brew extracted at room temperature still a "cold brew"?

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There is no definition or regulatory standard on cold brew coffee available. According to the authors' own judgement, every brew made at temperatures below body temperature may be considered as "cold" brew. Cold does not necessarily imply "ice cold". We, however, do not consider hot brewed (>65°C) coffees, which are just cooled down, as cold brew anymore. If cold brews are brewed at room temperature (which could reach levels above 30°C in some regions of the world), it must obviously be considered that the extraction is much faster. This could even be advantageous regarding contamination problems (e.g. comparing 18 h at 8°C vs. 2 h at 20°C), however, systematic research into this issue is lacking so far. Shelf life should be longer at fridge temperature than at room temperature.

5.3. What would be your suggestion for cold brew extraction conditions?

Based on the experience at Coffee Consulate, an amount of 80 g/L coffee is suggested for 2 h at initially 15°C (tap water temperature in Europe) then stored in a fridge. We use a 5 L food-grade plastic container with the aliquot of medium fine coffee (Catuai, pulped natural or natural) and water (4.8 °dH German hardness) , then we stir once after 1 h of lixiviation. Finally, the product is filtered using a standard paper filter. We believe that this method is simple and stable, making a consistent product also over various coffee shops that use this recipe.

From a sensorical standpoint, nothing may be gained by prolonging the extraction time to 4 h or even longer. Increasing the extraction time may only increase the bitterness of the beverage. Some empirical evidence confirms this opinion: caffeine and 3-chlorogenic acid reached equilibrium (i.e. 100% extraction, compare Figure 3) between 6 and 7 h, instead of 10 to 24 h outlined in some typical cold brew methods [12]. We are currently in the process of adjusting our coffee analytical methods [13-15] to cold brews aiming to studying and optimizing the multivariate influences and their interactions on cold extraction.

5.4. Is it possible to make cold brew with beans from Asia-Pacific?

These beans are often underrated. The advantage of the Indonesian and South-East Asian (e.g. Myanmar, Thailand, Philippines, and Malaysia) beans is the uniqueness in very floral and spicy coffees. To make a cold brew out of these beans really needs consideration of roast profile and extraction method. Cold brew prepared with beans from Indonesia (Arabica Bali Kintamani coffee) showed a fruity flavor with intense sweetness [16]. Otherwise, no reports on sensorial data of South East Asian (SEA) coffees in cold brew are currently available.

5.5. What would be the optimum shelf life of a cold brew coffee?

Optimally, the cold brew would sell on the same day of preparation. The authors are of the strong belief that cold brew should be made fresh everyday (this actually appears to be in divergence of current practices, see survey result above). When stored longer, there are some changes of product quality to be expected, such as rises in acidity and ethanol content, and decreases in sugar content/sweetness due to yeast or bacteria activity. For example, So et al. [17] have shown that pH declines and total acidity increases during cold brew storage for 8 weeks, with larger effects for storage at 20°C than at 4°C.

In addition to microbiological changes, the product will also go rancid and stale due to oxidative processes. This oxidative process will not be as fast as for hot brewed coffee, which has much higher lipid content. Anecdotally, if the cold brew is stored under nitrogen pressure (e.g. in kegs), oxidation may be avoided and shelf life be extended [18,19]. Some studies claim that the shelf life of cold brew is limited not by microbial stability, but rather by deterioration in sensory attributes [20].

Currently, for artisanal producers we would suggest a maximum storage time of 2 days. Taste is currently the only guidance available on site to determine how long a cold brew may be stored. Otherwise, microbiological laboratory testing for shelf life analyses might be conducted.

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To give the example of filter coffee in analogy, this product would turn stale and be thrown away after 1-2 h. We do not believe that there is a reason to demand week-long storage times for cold brew, which basically has the same underlying costs (similar brewing ratio) than filter coffee. We know from experience that this also greatly increases customer satisfaction. It is a shame that the segment of cold brew, at least in Central Europe, appears currently dominated on industrial level by "called brews" (i.e. hot extracted fakes) and on the artisanal level by over-extracted and over-stored products, which are sometimes extremely acidic and bitter, which is adverse to the goal to achieve a loyal, returning customer.

5.6. Is it possible to prepare cold brew as concentrate and dilute before serving?

If a high-quality coffee is used to prepare a concentrate, there should be no reason why it should taste bad. This would be the equivalent to high gravity mashing on beer brewing. Increasing the ground coffee to water ratio may simplify the extraction and storage of the brew, that can be diluted just before consumption. Most commercially available concentrates, however, appear to be based on lesser grade coffees and bad roasts as well as on hot extraction, using advanced equipment such as evaporation systems. Currently, we would not advise to make concentrates in smaller coffee shops. There is also no research available how concentration influences flavor.

5.7. What are typical customer's complaints against cold brew?

Too bitter, because bitterness is the sign that something is turning toxic. The next complaint would be too sour, to acidic (meaning that it tastes rotten). The acidity may arise from over-extraction and microbiological spoilage (lactic characteristics). These defects can be avoided when over-extraction and over-storage is avoided

5.8. What are the risks of handling cold brew coffee?

Cold brew has a pH value greater than 4.6 (typically 4.9-6.0 [12,21,22]), which is a low acidity and does not effectively suppress microbial growth [4]. Therefore, foodborne pathogens (i.e. human illness causing microorganisms) or spoilage organisms, which mainly affect flavor, may develop in cold brew [4].

Some initial experiments showed that growth of pathogens may be inhibited by compounds in the coffee, but this must be confirmed for each individual preparation [4]. Contrarily, spoilage organisms such as molds and yeasts appear not to be inhibited and may increase fast during storage leading to fermentation [4]. Most sensitive products are ready-to-drink beverages, especially those under anaerobic conditions (for example when filled under pressure with nitrogen [21]). These products must be closely controlled to mitigate the risk of *Clostridium botulinum* (botulism), by either pH control or thermal processing [23]. In fact, the product "Death Wish" nitro cold brew was recalled from the market in September 2017, because it was determined that its production process could lead to the growth and production of botulinum toxin in this low acid food commercialized in reduced oxygen packaging [24,25].

We currently would compare the risk of cold brew coffee to other alcohol-free beverages, for which considerably more experience exists. As cold-brew is slightly sugar containing, and unlike beer does not contain alcohol which inhibits bacterial growth, the risk would be similar to, e.g., other alcohol-free beverages with pH>5. Hence, special care and diligence need to be conducted regarding handling and cleaning of dispensing equipment and coffee lines (e.g., for nitro cold brew "on tap"). For example, the German norm DIN 6650-6 suggests a cleaning and disinfecting interval of at least once a day for alcohol-free beverages [26].

Special care is also required when cold brew is filled in kegs needing careful study of the shelf life [5]. Most commercial cold brews in the market also require refrigeration for both storage and dispensing [27]. We recommend to specifically consider cold brew in the Hazard Analysis Critical Control Points (HACCP) system, which is mandatorily implemented in many countries including

the European Union. To avoid contamination with pathogenic microorganisms, maximum storage times based on microbiological shelf-life testing should be implemented (including labelling of maximum duration and compliance controls that the product is removed before this date). Visual controls for clouding and organoleptic testing at least once a day before service starts should be conducted.

Some further guidelines are specified in the "Cold brew coffee toolkit for industry" published by the National Coffee Association of U.S.A. [23]. The toolkit includes information on challenge studies to avoid risk from spore-forming bacteria such as *Clostridium* and guidance on shelf-life testing, storage and handling [23]. The British Columbia Centre for Disease Control suggests a maximum refrigerated storage of less than 10 days for products stored at 4°C and below, if no other controls are present [21]. The Centre also suggests the following options to control the hazards of spore-forming bacteria for products intended for longer term storage: i. heating and pasteurization, ii. reducing the pH to 4.6 or below, iii. ensuring aseptic processing, iv. addition of preservatives, and v. a combination of these controls [21].

5.9. What are the advantages of the cold drip method?

Based on the experience at Earthlings Coffee Workshop, customers like the concentrated, punchy flavor from the ice drip coffee. It is usually served straight or with ice cubes, dependent on the customers' preference. The ratio is usually 1:5. 300 g of blend and about 1450 g of ice cubes plus 50 g of filtered water. The time is about 8-12 h. The use of ice cubes is extremely important for the flavor.

6. Conclusion

We are at the very beginning of scientifically understanding what cold brew coffee is. It is important not to have a pre mindset into any direction and be really open to experience the entire spectrum of possibilities we have with this extraction technology. The cold brew extraction is a highly multivariate process, and additional chemical, microbiological and sensory studies are needed to increase our understanding.

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References

1. Le Compte, C. *Cold brew wasn't invented yesterday, so here's some historical perspective;* Daily Coffee News: https://dailycoffeenews.com/2015/07/15/cold-brewing-wasnt-invented-yesterday-so-heres-some-historical-perspective/ [accessed on 24 April 2020], 2015
2. Patel, D. Cold coffee revolution in Southeast Asia. *Asia Pacific Food Ind.* **2017,** *April/May*, 72-73.
3. Anon. Niche and ultra-niche segments set to expand rapidly in diversifying US market. *Coffee Cocoa Int.* **2019,** *46*, 20-23.
4. Puro, E. Cold brew with caution. Food safety and quality concerns for the growing market. *Roast* **2016,** *July-Augus*, 36-49.

5. Mendez, D.W. What's so hot, about cold brew coffee? *Total Food Serv.* **2016,** *26*, 46, 106.
6. Lachenmeier, D.W.; Schwarz, S.; Teipel, J.; Hegmanns, M.; Kuballa, T.; Walch, S.G.; Breitling-Utzmann, C.M. Potential antagonistic effects of acrylamide mitigation during coffee roasting on furfuryl alcohol, furan and 5-hydroxymethylfurfural. *Toxics* **2018,** *7*, 1. doi:10.3390/toxics7010001
7. Kang, D.E.; Lee, H.U.; Davaatseren, M.; Chung, M.S. Comparison of acrylamide and furan concentrations, antioxidant activities, and volatile profiles in cold or hot brew coffees. *Food Sci. Biotechnol.* **2020,** *29*, 141-148. doi:10.1007/s10068-019-00644-2
8. Cordoba, N.; Pataquiva, L.; Osorio, C.; Moreno, F.L.M.; Ruiz, R.Y. Effect of grinding, extraction time and type of coffee on the physicochemical and flavour characteristics of cold brew coffee. *Sci. Rep.* **2019,** *9*, 8440. doi:10.1038/s41598-019-44886-w
9. Coffee Consulate. *CoffeeBasics AromaWheel;* Coffee Consulate, Mannheim, Germany: https://coffee-consulate.com/en/produkt/coffeebasicsaromarad/ [accessed 24 April 2020], 2020
10. Coffee Consulate. *CC-Flavour Profile for Coffee*; Coffee Consulate, Mannheim, Germany: https://coffee-consulate.com/en/wp-content/uploads/2019/04/cc-flavour-profile_english-1.pdf [accessed 14 June 2020], 2020
11. Claaßen, L.; Schwarz, S.; Winkler, G.; Lachenmeier, D.W. Cold-Brew Coffee Preparation Survey. Research Gate, 2020. doi:10.13140/RG.2.2.19212.67206
12. Fuller, M.; Rao, N.Z. The effect of time, roasting temperature, and grind size on caffeine and chlorogenic acid concentrations in cold brew coffee. *Sci. Rep.* **2017,** *7*, 17979. doi:10.1038/s41598-017-18247-4
13. Lachenmeier, D.W.; Teipel, J.; Scharinger, A.; Kuballa, T.; Walch, S.G.; Grosch, F.; Bunzel, M.; Okaru, A.O.; Schwarz, S. Fully automated identification of coffee species and simultaneous quantification of furfuryl alcohol using NMR spectroscopy. *J. AOAC Int.* **2020,** *103*, 306-314. doi:10.1093/jaocint/qsz020
14. Okaru, A.O.; Scharinger, A.; Rajcic de, R.T.; Teipel, J.; Kuballa, T.; Walch, S.G.; Lachenmeier, D.W. Validation of a quantitative proton nuclear magnetic resonance spectroscopic screening method for coffee quality and authenticity (NMR Coffee Screener). *Foods* **2020,** *9*, 47. doi:10.3390/foods9010047
15. Monakhova, Y.B.; Ruge, W.; Kuballa, T.; Ilse, M.; Winkelmann, O.; Diehl, B.; Thomas, F.; Lachenmeier, D.W. Rapid approach to identify the presence of Arabica and Robusta species in coffee using ^{1}H NMR spectroscopy. *Food Chem.* **2015,** *182*, 178-184. doi:10.1016/j.foodchem.2015.02.132
16. Fibrianto, K.; Umam, K.; Shinta Wulandari, E. Effect of roasting profiles and brewing methods on the characteristics of Bali Kintamani coffee. *Adv. Eng. Res.* **2018,** *172*, 194-197.
17. So, Y.J.; Lee, M.W.; Yoo, K.M.; Kang, H.J.; Hwang, I.K. Physicochemical characteristics and antioxidant activity of Dutch coffee depending on different extraction conditions and storage. *Korean J. Food Sci. Technol.* **2014,** *46*, 671-676. doi:10.9721/KJFST.2014.46.6.671
18. Jarvis, L.M.; Morrison, J. What's nitro cold brew, and why is it so damn delicious? *Chem. Eng. News* **2015,** *93*, 37.
19. Northrop, R. Manufacturing food safe cold brew. *Tea Coffee Trade J.* **2018,** *190*, 46-47.
20. Northrop, R. Cold brew and nitro coffee on tap for growth. *Tea Coffee Trade J.* **2019,** *191*, 16-19.
21. British Columbia Centre for Disease Control. *Nitro cold brew coffee food safety risks;* BC Centre for Disease Control: Vancouver, BC , Canada, 2017
22. Rao, N.Z.; Fuller, M. Acidity and antioxidant activity of cold brew coffee. *Sci. Rep.* **2018,** *8*, 16030. doi:10.1038/s41598-018-34392-w
23. NCA. *Cold brew coffee toolkit for industry;* National Coffee Association of U.S.A., Inc.: New York, NY, USA, 2019
24. U.S. FDA. *Death Wish Coffee Co. announces recall of nitro cold brew cans from retailers, online sales;* U.S. Food and Drug Administration: https://www.fda.gov/safety/recalls/ucm576809.htm [accessed on 24 April 2020], 2017
25. Rossman, S. *'Death Wish' coffee recalled because it can literally kill you;* USA Today: https://eu.usatoday.com/story/news/nation-now/2017/09/22/death-wish-coffee-recalled-because-can-literally-kill-you/692417001/ [accessed 24 April 2020], 2017
26. DIN. *DIN 6650-6:2014-12 Dispense systems for draught beverages - Part 6: Requirements for cleaning and disinfection;* Deutsches Institut für Normung: Berlin, Germany, 2014 doi:10.31030/2250528
27. Anon. Cold brew coffee - on tap! The future of coffee and how to serve it. *Total Food Serv.* **2018,** *28*, 12, 110.