

Impact of consumption temperature and additions (milk and/or sugar) on sensory properties of
hot brewed coffee

by

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Abstract

The sensory properties of coffee are impacted by various factors such as coffee origin, degree of roasting and ways of consumption. This study analyzed impact of ways of consumption (1. consumption temperatures and 2. milk and/or sugar additions) on 38 flavor attributes of hot brewed coffee by descriptive sensory analysis. Different type of coffee samples (2 Arabica, 1 Robusta, and 1 Blended) were consumed at 50°C, 60°C and 70°C. Results showed significant interactions of temperature and coffee samples for coffee like attributes such as coffee identity, fidelity, and blended. The consumption temperature played a major impact on perceived flavor attributes of coffee and influenced Arabica, Blended and Robusta coffee differently and we have to consider that when blending coffees. Coffee identity and fidelity significantly increased with an increase in all temperatures, but most attributes showed significantly higher intensity only for samples served at 70°C regardless of insignificant differences at 60°C and 50°C. Three coffee samples (light, medium, and dark roasted) were tasted with and without milk or sugar. The data were submitted to principal component analysis and cluster analysis. The first 2 PC's allowed to separate coffee into three categories and CA revealed similar distribution of coffee into three clusters. Coffee like attributes were seemed to play a more important role in the determination of clusters as the addition of milk and sugar decreased the intensity of key flavor attributes such as coffee identity, bitterness, fidelity, roasted, blended, and longevity. The flavor attributes of dark roasted coffee was more impacted by the addition of milk and sugar. Results suggested that the effect of addition (milk and/or sugar) is correlated to the degree of roasting and we have to consider the milk and sugar additions according to degree of roasting.

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Chapter 1 - Literature Review

COFFEE

Coffea whose seeds called coffee seeds belong to the family *Rubiaceae* and is a genus of flowering plant *Coffea* and are used to make coffee beverage after processing. There are several types of coffee species. The two main species, *Coffea arabica* and *Coffea canephora* (Robusta), account for 70-75% and about 25% of the world production respectively (Pohlan & Janssens, 2015). The variations in soil, sun, moisture, slope, illness and pest conditions direct which coffee is most effectively cultivated in each region of the world (Luttinger & Dicum, 2011).

C. arabica is a bush originally from Ethiopia and develops well in high altitudes (600–2,000 m), while *C. canephora* plantations adapt well in altitudes below 600 m (Café, 1997). Arabica and Robusta coffee are different in various ways such as chemical composition, sensory properties and caffeine content (Casal, Alves, Mendes, Oliveira, & Ferreira, 2003).

They differ in taste, lipid and sugar content, shape, chromogenic acid content. Robusta taste is described as burnt and rubbery and it has more caffeine content than Arabica coffee. Likewise, Arabica contains almost 60% more lipids and almost twice the concentration of sugar than Robusta. These factors have impacted on why we prefer the taste of Arabica and it produces good quality of coffee (Belitz, Grosch, & Schieberle, 2009; Pack, 2014). Table 1-1 shows the chemical composition of Arabica and Robusta coffee.

Table 1-1 Chemical constituents of green Arabica and Robusta coffee

Component	Arabica^a	Robusta^a	Constituents
Soluble carbohydrates	9–12.5	6–11.5	
Monosaccharides	0.2–0.5		Fructose, glucose, galactose, arabinose (traces)
Oligosaccharides	6–9	3–7	Sucrose (>90%), raffinose (0–0.9%), stachyose (0–0.13%)
Polysaccharides	3–4		Polymers of galactose (55–65%), mannose (10–20%), arabinose (20–35%), glucose (0–2%)
Insoluble polysaccharides	46–53	34–44	
Hemicelluloses	5–10	3–4	Polymers of galactose (65–75%), arabinose (25–30%), mannose (0–10%)
Cellulose, β (1–4)mannan	41–43	32–40	
Acids and phenols			
Volatile acids	0.1		
Nonvolatile aliphatic acids	2–2.9	1.3–2.2	Citric acid, malic acid, quinic acid
Chlorogenic acid	6.7–9.2	7.1–12.1	Mono-, dicaffeoyl-, and feruloylquinic acid
Lignin	1–3		
Lipids	15–18	8–12	
Wax	0.2–0.3		
Oil	7.7–17.7		Main fatty acids: 16:0 and 18:2 (9,12)
N compounds	11–15		
Free amino acids	0.2–0.8		Main amino acids: Glu, Asp, Asp-NH ₂
Proteins	8.5–12		
Caffeine	0.8–1.4	1.7–4.0	Traces of theobromine and theophylline
Minerals	3–5.4		

Source: (Belitz et al., 2009)

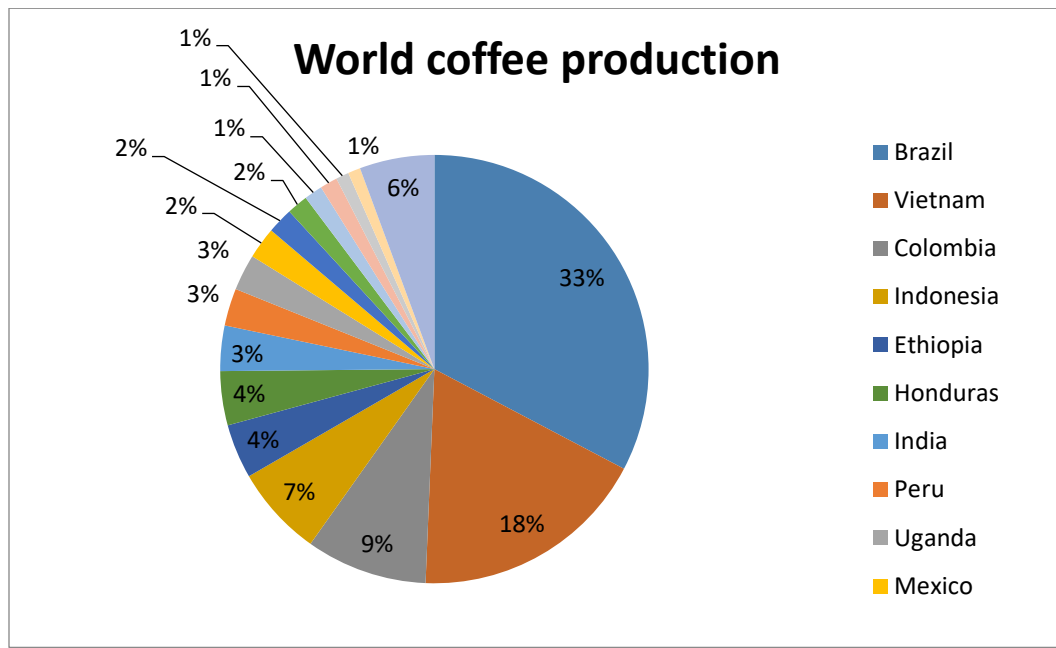
^aValues in percent dry-weight basis

^bMain components: 5-caffeoylquinic acid (chlorogenic acid: Arabica 3.0–5.6%; Robusta 4.4–6.6%)

World Production and Consumption

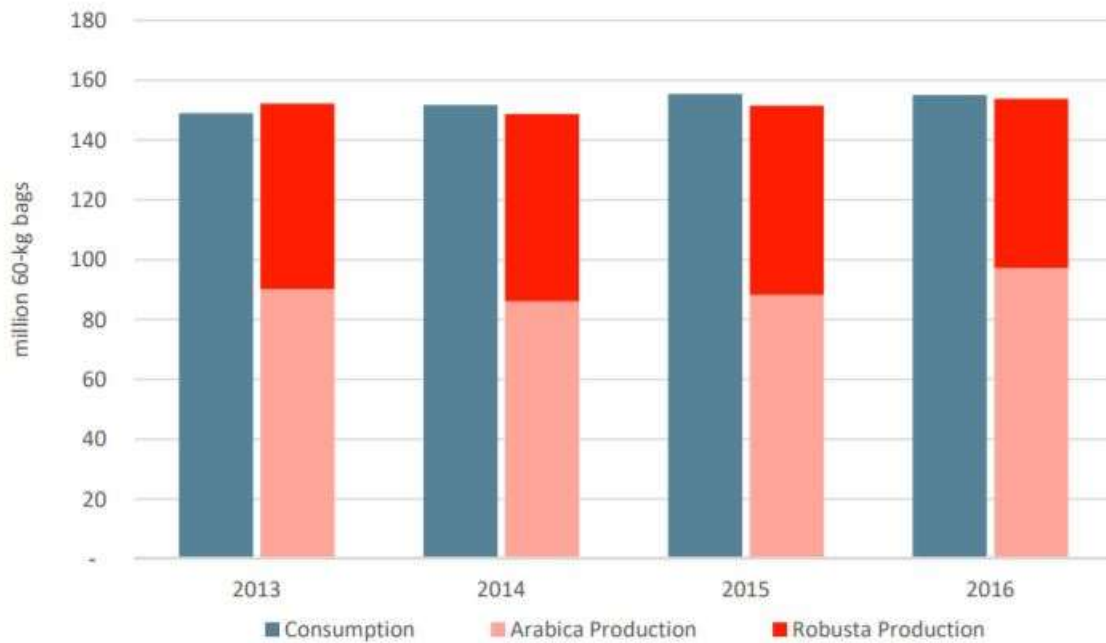
Coffee has been consumed for over 1,000 years and it is the most consumed drink in the world (more than 400 billion cups yearly) (Sobésa Café, 2008). World coffee production for 2017/18 is forecast at 159 million bags (60 kilograms). Similarly, world exports of green coffee are 111 million bags. Figure 1-1 shows coffee production in 2016/2017 and total production is 159,312 (United State Department of Agriculture, 2017)

Brazil produces one-third of the world production followed by Vietnam which produces 18% of the world production in 2016/2017. Arabica production is 97.3 million bags and is increased by 10.2% from 2015 to 2016 whereas Robusta are estimate 56.6 million bags and is decreased by 10% from 2015 to 2016 as shown in figure 1-2 (International Coffee Organization, 2017)



Source: (United State Department of Agriculture, 2017)

Figure 1-1 World Coffee Processing in 2016/2017



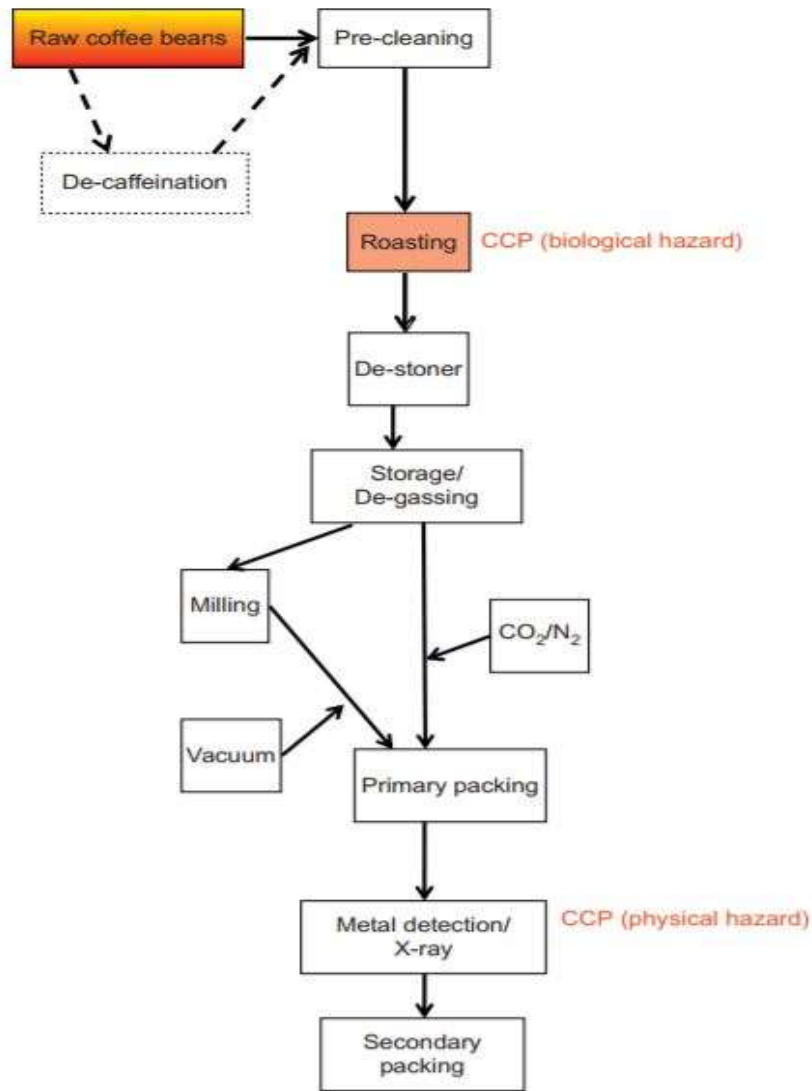
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Source: (International Coffee Organization, 2017)

Figure 1-2 Consumption by types and production of coffee from 2013/14- 2016/17
Coffee Processing

Coffee processing is one of the six reasons that affect the sensory properties of coffee beside plant varieties, growing region/conditions, roasting levels, grinding size, and brewing methods (Illy & Viani, 2005). The processing of coffee starts with the conversion of coffee cherries into green coffee beans, and starts with the removal of both the pulp and hull using either a wet or dry method. Depending on the method of coffee cherries processing, i.e., wet or dry process, the solid residues obtained have different terminologies: pulp or husk, respectively (Pandey, 2000). Coffee has a lot of chemical constituents and processing method impact coffee taste and composition such as the antioxidant activity, polyphenols, caffeine and melanoidins. To illustrate, the harvesting ways, the degree of roasting or even the method to dry the coffee seeds could make difference in the quality of coffee (Aeschbacher,

Wolleb, Löliger, Spadone, & Liardon, 1989; Vignoli, Bassoli, & Benassi, 2011). Figure 1-3 shows the general flow diagram of coffee processing.



Source: (WINKLER, 2004)

Figure 1-3 Flow Diagram of the general coffee processing

After coffee beans are ready for harvesting, manual and mechanical methods are used for picking, sorting and grading the coffee beans. During this period, different factors will impact the quality of the coffee beans. For example, the maturation of coffee beans, methods of picking, fungus contamination and the storage of seeds before processing (Farah, 2009).

After harvesting process, coffee seeds are extracted by the processing of cherries. Two different main methods of processing are used to obtain intermediate products that will subsequently be treated in exactly the same way to provide the coffee beans ready to brew. These methods are dry processing and wet processing. Coffee beans can be dried immediately after harvesting in dry processing (Vincent, 1987). The wet (washing) process is more sophisticated as fermentation occurs, and by general consent leads to better quality coffee. The method is usually done for Arabica coffee. The freshly harvested berries are brought to a pulper in which the coffee cherries are squeezed between a rotating cylinder and a slotted plate, the gap of which is adjustable for rubbing action to detach pulps from coffee seeds without damaging the seeds (Belitz et al., 2009; Farah, 2009).

The green beans after wet or dry methods will be graded and sorted to eliminate the defective seeds that could deteriorate the final quality, and seeds are ready for further process i.e. roasting (International Trade Center, 2012). Green coffee beans are roasted by numerous processes. In the conventional roasting, hot roasting gas comes in contact with the coffee beans that transfer heat and increase the temperature of coffee beans. This heat roasts the coffee beans to the desired color. As conventional method takes a long time, modification of conventional roasting process have been done which improves the quality of coffee as it increases the amount of water soluble solid from the roasted coffee. Green coffee beans are heated to between 180°C and 240°C for 1.5 to 20 minutes. Stronger roasting will generate darker color and more intense aroma and flavor. During roasting, the characteristic coffee taste aroma components are formed, along with the typical brown color of the beans. More than 1000 different aroma components of coffee are known. By variation of the roasting conditions it is possible to achieve the specific flavor profile of the final coffee according to the preferences of the consumer (Wasserman, Rerngsamai, Hayes, Mofford, & Dabdoub, 2001).

The roasting process can be controlled by the roasting temperature and time. The Specialty Coffee Association of America (SCAA) has created a standard for colorimetric measurements. Developed in the early 1990s, this system is called the Agtron/SCAA 9 Roast Classification Color Disk System. This system has eight reference points that are matched to eight available color discs with descriptors that go from “Very light brown” to “Very dark brown”. Figure 1-6 shows the different discs that are described in this system, from right to left, the first disc corresponds “Very light brown” and the last disc corresponds to “Very dark (nearly black) brown” (Davids, 2010). Table 1-5 shows the compounds developed in coffee during roasting. The compounds are responsible for coffee-like attributes. To illustrate, the degree of roasting increases the bitterness (Buffo & Cardelli-Freire, 2004)



Figure 1-3 Specialty Coffee Association of America (SCAA), Roast Classification Color Disc System.

Table 1-2 Classes of volatile compounds identified in roasted coffee

Sulphur compounds	Thiols, Thiophenes (esters, aldehydes, ketones), Hydrogen sulphide, Thiazoles (alkyl, alcoxy and acetal derivatives)
Pyrazines	Pyrazine itself, Thiol and furfuryl derivatives, Alkyl derivatives (primarily methyl and dimethyl)
Pyridines	Methyl, ethyl, acetyl, and vinyl derivates
Pyrroles	Alkyl, acyl and furfuryl derivatives
Oxazoles Furans	Aldehydes, ketones, esters, alcohols, acids, thiols, sulfides and in combination with pyrazines and pyrroles
Aldehydes and ketones	Aliphatic and aromatic species
Phenols	

Source: (Buffo & Cardelli-Freire, 2004)

Sensory Analysis of Coffee

The balanced combination of flavor, body and aroma without faults gives a pleasant sensation, which has been described as good sensory quality of coffee. Flavor profile of coffee is important consumer parameters and warrants through analysis by sensory and compositional perspective (Mori et al., 2003). Coffee beverage contains several components and the investigation of sensory and chemical properties of coffee has been continuous research for over a century.

Descriptive sensory analyses are distinguished from other sensory testing methods in that they seek to profile a product on all of its perceived sensory characteristics. Descriptive analysis can be done in various ways such as Flavor Profile Method, Texture Profile Method, Quantitative Descriptive Analysis, Quantitative Flavor Profiling, Spectrum method and Free-Choice Profiling. The use of various descriptive analysis method depends on the research and its objectives (Murray, Delahunty, & Baxter, 2001).

The sensory attributes of coffee is described by the language. Descriptive analysis techniques will be applied to describe the flavor of a product or commodity that is a set of words known as flavor lexicon. Lexicon is the set of attributes, their definition and references that simplify the use of this vocabulary and its replicability (L. J. Lawless & Civille, 2013). The study by SCAA has developed the grading system of coffee that includes a list of standard attributes, such as Body and Acidity, to be scored in order to describe the product. Vocabularies (International Coffee Organization, 2010) and handbooks (Castle, 1986; Lingle, 2001) have been developed to list terms that can describe sensory properties of coffee. Often these vocabularies focus on trying to develop terms influenced by specific cultural and linguistic aspects in order to be also recognized by local consumers of a given country (Hayakawa et al., 2010; Seo

et al., 2009). A recent study has found a total of 110 coffee attributes and their references are identified (Sanchez Alan, 2015). Within the research and development function, lexicons allow product developers and researchers to recognize and study the attributes of products, which have applications in product development, product maintenance, quality control and shelf-life studies (Koppel & Chambers IV, 2010)

Product control is the crucial things to maintain the quality of final beverage. While coffee beverage making process, procedure such as roasting, brewing and sample presentation such as consumption temperature, addition of flavor, cream or sweeteners plays a great role in the final sensory quality of coffee beverage. For sensory analysis, the various things had to consider that impact the sensory testing of coffee.

Sample Preparation

There are several factors to consider while preparing samples for sensory testing. From literature, roasting, grinding, brewing and presentation are the key factors that are directly correlated to the sensory quality of coffee. For the sensory testing, the sample presentation impacts the testing. According to literature, for the beverage like coffee, the amount served must be at least two sips to the participants in sensory testing session. The consistency in the protocol for testing plays a great role. For instance, amount of sample for testing must be equal each time as well as holding time between samples should be the same throughout the testing. The holding time is defined as the minimum and maximum time after preparation that a product can be used for a sensory test (Choi, 2014)

First, green coffees are roasted to desired degree of roasting which is determined by the color of the roasted coffee sample (SCAA, 2015). This process is followed by grinding which is also one of the most important steps that impact the final quality of coffee. The brew time is dependent on the grind size. Usually, coffee beans are grinded just before brewing to keep the freshness and prevent the aroma loss of

the coffee. The brew time is dependent on the grind size. It takes more time to brew for the coarse grinded than fine grinded coffee as shown in figure 1-4.



Source: SCAA, 2015

Figure 1-4 Particle size and its relationship with the brewing time

During brewing, time of brewing, ratio of coffee and water play a great role as water-soluble compounds are extracted, whereas most of the lipophilic fraction is left with the solid material (Farah, 2009). The flavors and aromas of the coffee bean are extracted on water and the ratio of coffee/water for brewing as well as time of brewing affect the final quality of hot brewed coffee. SCAA has recommended 55 gram of grounded coffee for one liter of water and the proportion could be adjusted depending on the grind size and contact time. The recommended standard time of brewing for grounded coffee is to be more than four minutes but less than eight minutes (SCAA, 2015)as according to another study, the attributes rancid and smoke were found in brewed coffee during the over extraction that is considered not desirable attribute of coffee (Modern Process Equipment, 2015).

Coffee sample temperature

Each person likes to drink his coffee at a different temperature. In coffee restaurant and cafes, the temperature of the coffee is usually served at about 87° C, which is too hot to drink as for most people as drinkable coffee temperature is between 55° to 65° C. So each person has to wait for 10-20 minute until the temperature cool down (Gallo, 2002). Since there is high chance of flavor loss during the cooling

time, the optimum serving temperature is necessary. This literature supports the fact that during sensory analysis, the serving and consumption temperature must be same each time as specified in the test protocol by the study done by Eun Choi (Choi, 2014). The National Coffee Association of U.S.A., Inc., recommends that the temperature of a coffee must be maintained between 180 °F and 185 °F (82.2 °C and 85 °C) for optimal flavor notes (Lingle, 1996; National Coffee Association of America).

It is important to maintain consistency in the serving temperature as the sensory properties and perceived intensity of coffee beverage are temperature dependent. Even a few degrees lower can result in different intensities for certain attributes, in both aroma and flavor as shown by the previous study in green tea (Lee, 2008). In their study, they have developed a three-step protocol to secure consistency in the temperature of green tea during sensory evaluation. The first step involved on preheating the infusion flask prior the green tea infusion. Next they used a water bath and finally the samples were poured into an individual thermos to minimize the heat loss during the testing session (Lee, 2008). The temperature of coffee sample can be maintained by the use of equipment such as thermos, water bath, double layered glass and other equipment that ensure to maintain the serving temperature that provide desired sensory characteristics.

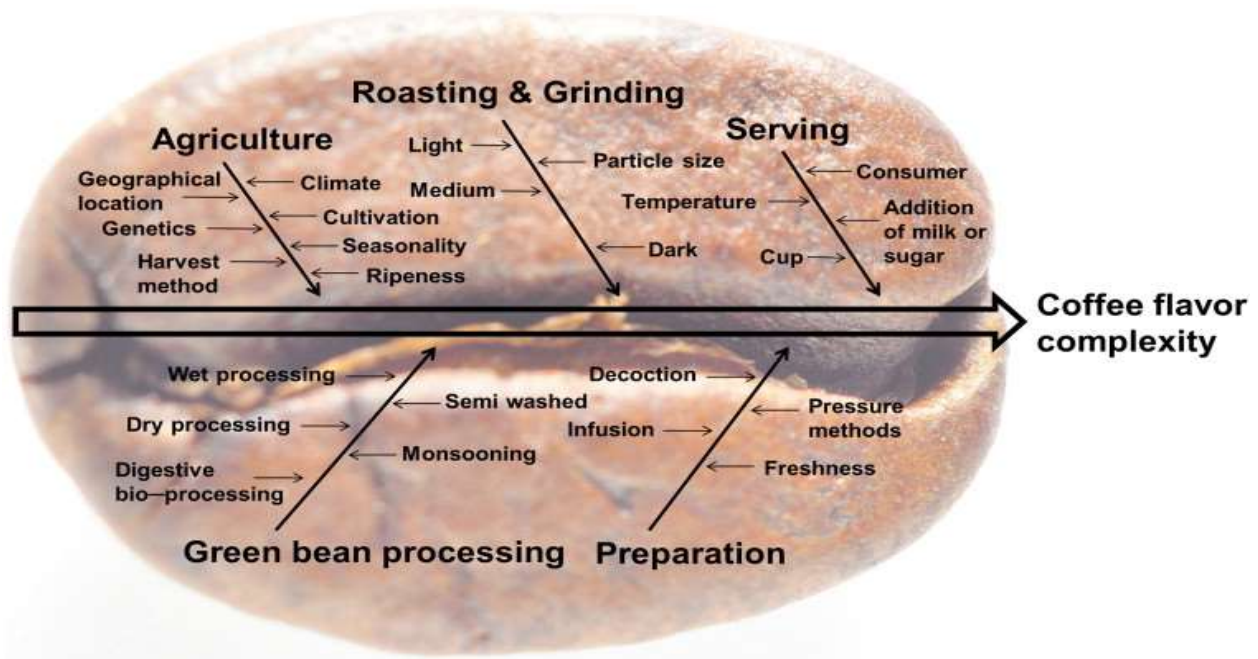
Additions on Coffee

Consumers like to drink coffee with or without addition of flavors, milk and sweeteners. The amount of milk and the protocol of adding impact the sensory properties of coffee. The creamers, flavors and sweeteners are added to brewed coffee to enhance the physical and sensory quality of coffee. There is no standard amount. People in the USA generally add whatever tastes best to them, which can range from none to very creamy and sweet. However, that being said, we can probably work with some averages if we like. In fast-food restaurants, coffee creamer comes in containers of 0.5 ounces (15 mL), and most people use just one or two. Similarly, sugar comes in packets of 1 teaspoon (4 grams), and

people typically use one or two. So the amount usually used is either 15 or 30 mL of cream/milk and 4g or 8g of sugar in an 8 ounce (approx. 250 mL) cup of coffee. According to a study, milk or milk derivate is mixed with a coffee extract by wet method in order to prepare a beverage composition of the instant white coffee type. This helps to control the flocculation of the protein and is applied before the mixture is dried by spray drying (Chaveron, 1997). The level of sugar mainly increased the sweetness, caramel and vanillin notes (Koeferli, Piccinali, & Sigrist, 1996). (Dupas, Marsset-Baglieri, Ordonaud, Ducept, & Maillard, 2006) showed that compounds of coffee and milk bound usually in a more reproducible way when the solution is heated up. Likewise, another research showed milk and vegetable products as additives affected the release of aroma substances in the brew via lipid, protein and carbohydrate components. The beverages with an additive have shown reduced odor profile for each additive (Bücking, 2002)

Research Objectives

Coffee is consumed for its sensory characteristics and the sensory properties of coffee are impacted by various factors as shown in figure 1-5.



Source: Sunarharum et al., 2014

Figure 1-5 Factors effecting coffee flavor complexity

This study was done to find out 1) the impact of consumption temperature on different coffee samples For this study, impact of three different consumption temperature on four different types of coffee (Arabica, Robusta and Blended) was analyzed Another aim was to find out 2) the impact of milk and sugar as additives on sensory properties of hot brewed coffee, samples different by degree of roasting. For this study, impact of milk and sugar as additives on dark, medium and light roasted coffee was evaluated. In both studies, descriptive analysis of 38 flavor attributes of coffee was done.

Chapter 2 - Impact of Consumption temperature on sensory properties of hot brewed coffee

ABSTRACT

Different type of coffee samples (2 Arabica, 1 Robusta, and 1 Blended) were consumed at 50°C, 60°C and 70°C. Results showed significant interactions of temperature and coffee samples for coffee like attributes such as coffee identity, fidelity, and blended. The consumption temperature played a major impact on perceived flavor attributes of coffee and influenced Arabica, Blended and Robusta coffee differently and we have to consider that when blending coffees. Coffee identity and fidelity significantly increased with an increase in all temperatures, but most attributes showed significantly higher intensity only for samples served at 70°C regardless of insignificant differences at 60°C and 50°C.

Practical Application

The impact of consumption temperature is varied according to coffee samples and these results can be used for further research in sensory properties of coffee. Likewise, the recommended consumption temperature can be used by different coffee shops and coffee beverage manufacturing companies to increase the consumer acceptance with sensory quality.

Introduction

The recommended serving temperature for hot beverages is typically at 85°C (185°F) which scalds consumers (Roberts, Whitaker, & Drew, 2007) and this is happening (Eadie, Williams, & Dickson, 1995; Hankins, Tang, & Phipps, 2006). A deduction in the burn injury and its severity by the hot beverage has been foremost objective of coffee shops. The further investigation is to find the right serving temperature of hot beverages without diminishing its quality. It is not good to serve consumers at low temperature

either as they will complain hot beverage is not warm enough. Instead, we can find a threshold serving temperature that can meet the consumers' satisfaction and have good quality.

Brewed coffee is one of the most popular aromatic beverages around the world. It has desirable flavor characteristics such as bitter, nutty, spicy, fidelity, blended and so on, that are appreciated by consumers everywhere (SCAA, 1995). Brewed coffee is usually consumed as a hot beverage although cold variations are becoming more popular. The brewed coffee is evaluated and consumed at different temperatures, with the ideal serving temperature 68 to 79 °C (154 to 174 °F) (Borchgrevink, Susskind, & Tarras, 1999). Other researches have contrasted the recommended serving temperature as it identifies consumer's preference to drink coffee to be around 60°C (Brown & Diller, 2008; Lee & O'Mahony, 2002). Often, the temperature of coffee cools down during consumption. Such differences in temperature are almost never considered when evaluating the sensory quality of coffee. The sensory properties of coffee are impacted by the consumption temperature. The National Coffee Association of U.S.A., Inc., recommends that the temperature of a coffee must be maintained between 180 °F and 185 °F (82.2 °C and 85 °C) for optimal flavor notes (Lingle, 1996; National Coffee Association of America). The consumption temperature range that would give the best optimal flavor notes of hot brewed coffee is required to increase the consumer preference.

The study was conducted with multiple hypotheses that how the consumption temperatures impact sensory properties of hot brewed coffee. Similarly, another hypothesis of the study was that the consumption temperatures impact the flavor profile of coffee differently by its type (Arabica, Robusta, and Blended).

Materials and Methods

Coffee Samples

For this study, coffee samples were selected according to its origin, rich flavor notes and degree of roasting as these variations have an effect on coffee flavor and body (Bhumiratana, Adhikari, & Chambers, 2011; Sunarharum, Williams, & Smyth, 2014). Three high quality coffees of different origins were chosen to evaluate the flavor attributes of coffee. Some of the different in characteristics of coffee samples are summarized in Table 2-1. Blended coffee was made by mixing 90% of Arabica 1 and 10% of Robusta coffee. Both Arabica coffee were roasted and packaged by PT's Coffee Roasting Co., Topeka, Kansas 66619 while Robusta coffee was roasted and packaged by Coffee Co-Packing in New Jersey, USA. Arabica 1 was blend of variety *Geisha* and *Typica* while Arabica 2 was mixed variety. Roasted whole coffee beans were shipped to the Center for Sensory Science and Consumer Behavior, Kansas State University immediately after roasting to preserve the flavor profile of coffee.

Table 2-1 Description of the three coffee samples used for the present study as shown in packaging

Coffee Sample	Degree of Roasting	Rich Flavor Notes	Place of harvesting	Altitude (feet)
Arabica 1	Light	Mango, Honey, Lemonade	Panama	5000
Arabica 2	Light-Medium	Salted caramel, Black currant, Baker's Chocolate	Helena	5575
Robusta	Medium			

Sample Preparation

Samples were stored in their own package and were ground no more than 30 minutes before the evaluation to preserve the volatile compounds and freshness of the coffee samples. Coffee samples were

grounded by Baratza Forte BG (Brew Grinder) - Flat Steel Burr Commercial Grade Coffee Grinder (Designed and Engineered in Seattle, WA, USA) at G5 grind scale.

For this study, deionized and carbon-filtered water was used with the aim of keeping the water neutral in pH and odor-free, with the purpose of minimizing the component for unwanted flavors from the brewing water that might impact the flavor profile of coffee (Hoehl, Schoenberger, & Busch-Stockfisch, 2010; H. T. Lawless, Stevens, Chapman, & Kurtz, 2005). The International Standard ISO 3972 recommends that water should be neutral, tasteless, still and odorless, and preferably of known hardness (International Standard ISO 3972:2011)

The weight of coffee sample per liter of water for brewing was determined according to the ISO 6668:2008 reference that recommends a ratio of 7.0 g of coffee per 100 ml of water, with an individual notified coffee range of 5-9 g (International Standard ISO 6668. 2008). For this project, 77 gm of coffee sample was used and brewed in 1400 ml of water. Evaluation was carried out in a controlled room with no interfering external factors like sunlight, aroma and sound.

Twelve samples were made; four types of coffee samples consumed in three different consumption temperature. Consumption temperature was adjusted by immersing the brewed coffee container in a cold water bath to reach 52°C, 62 °C, or 72 °C, then transferred to a controlled temperature insulated container, and served in a double-layered glass. However, the research was focused on the consumption temperature of 50°C, 60°C and 70°C, 2°C more temperature was maintained to overcome the temperature loss until the panelist consumed the coffee. The temperature of coffee was measured by thermometer (Digi-Sense Traceable Water-Resistant Pocket Thermometer with Calibration). Panelist served themselves the required amount for evaluation whenever needed. Panelists were allowed to serve no more than 50 ml of coffee at one time to maintain the temperature of coffee. The coffee samples used in this study were labeled with four-digit codes.

Panelists and Descriptive Sensory Analysis

For this study, seven highly trained panelists (two males and five females; ranging in age from 50–70 years old) from the Center for Sensory Analysis and Consumer Behavior at Kansas State University, evaluated the coffee samples. The panelists' experience included 120 h of general training and a minimum of 1,200 h of general sensory testing of beverages and food products including coffee. All had previously tested coffee. For this study, panelists received a further two days of orientation (1.5-h sessions each day), with the primary objective of familiarizing the panelists with the references, the coffee samples, and the evaluation process. After these orientation sessions, 12 sessions of 1.5 h were held for the sample evaluations. A total of three samples were evaluated per session.

The panelists evaluated 38 different flavor attributes for each sample. The list of references used in this study is shown in Appendix 2. These flavor attributes were selected from previous study (World Coffee Research coffee lexicon, Chambers et al, 2016). The attributes of each sample were identified and the intensity was quantified utilizing a 0–15 point scale with 0.5 increments (0.0 = none; 0.5–5.0 = slight; 5.5–10.0 = moderate; 10.5–15.0 = extreme). To cleanse their palate between each sample, the panelists used bagels and apples, they also breathed through a warm, clean, cotton terry cloth filter to clear their nasal passages.

Data Analysis

The statistical program SAS v.9.4 developed by SAS Institute was used to conduct this analysis of variance, for the source of variation “sample” with three degrees of freedom and another analysis of variance for the source of variation of consumption temperature with two degrees of freedom. Significant differences between samples with respect to consumption temperature 50°C, 60°C, and 70°C and their interaction were assessed using two-way ANOVA, mixed effect model with LS means and significance of $p < 0.05$

RESULTS AND DISCUSSION

Effect of Coffee Samples' and Consumption temperatures' interaction

The effect of interaction was shown by plotting radar plot. The radar plot was drawn for each coffee sample as it was able to distinguish each samples consumed at different temperature by the perceived flavor attributes. Figure 2-1 showed that for Robusta coffee, major attributes like coffee identity, overall impact, blended, longevity, fidelity, roasted attributes had higher intensity served at 70°C than 50°C. Figure 2-2 showed Arabica1 coffee sample had higher intensity for attributes like Coffee Identity, overall impact, blended, longevity and fidelity at consumption temperature 70°C than 50°C. The score for most of the key attributes increased with increase in consumption temperature for Robusta and Arabica1. Figure 2-3 presented Arabica2 coffee samples consumed at 60°C had higher intensity for major flavor attributes like coffee identity, overall impact, longevity and fidelity. However, for blended coffee, intensity for major attributes like coffee identity, overall impact, blended, longevity, fidelity, bitterness and roasted were lower for samples consumed at 60°C than samples consumed at 50°C and 70°C as revealed by Figure 2-4. Also, blended coffee consumed at 70°C had higher intensity than consumed at 50°C for those major attributes. The variability for Blended and Arabica 2 showed that the impact of consumption temperatures was not static across coffee, nor across sensory attributes as the score for key attributes like overall impact, longevity, fidelity was higher for Arabica 2 coffee when consumed at 60°C, while they had low intensity for Blended coffee when consumed at 60°C.

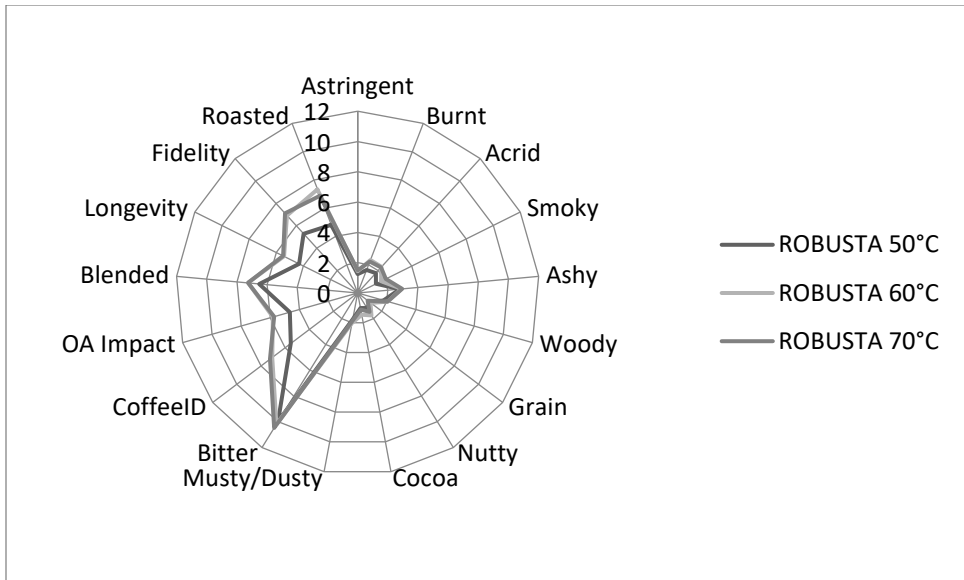


Figure 2-1 Radar plot for Flavor attributes of Robusta coffee at different consumption temperature

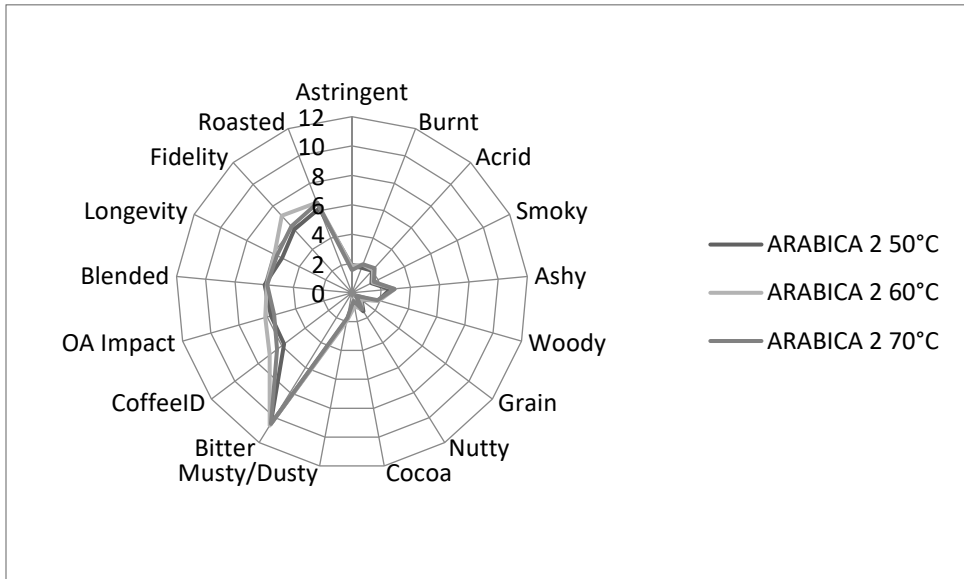


Figure 2-2 Radar plot for Flavor attributes of Arabica1coffee at different consumption temperature

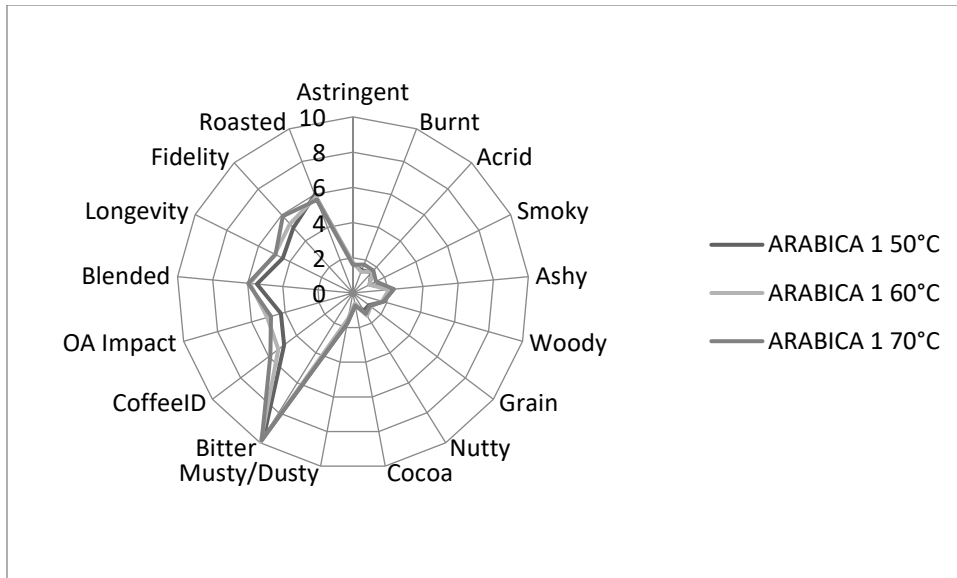


Figure 2-3 Radar plot for Flavor attributes of Arabica2 coffee at different consumption temperature

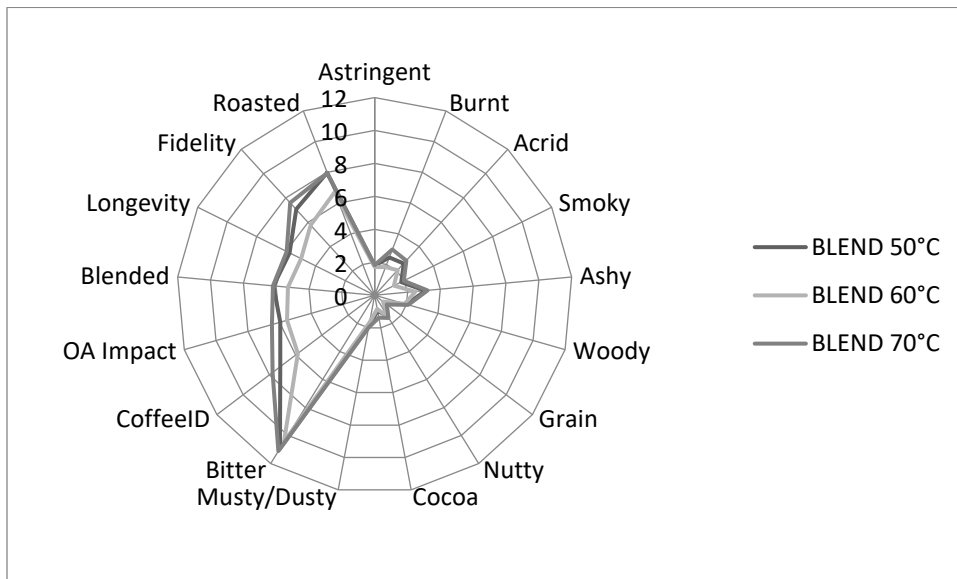


Figure 2-4 Radar plot for Flavor attributes of Blended coffee at different consumption temperature
Effect of coffee samples

Different coffee samples combining the intensity at different consumption temperature showed different scores for attributes among coffee sample at significance level, $\alpha=0.05$. Figure 2-5 showed blended coffee had significantly higher intensity than other coffee samples for roasted, burnt, acrid, bitter, coffee identity and fidelity. Bitterness was significantly different to each sample. Arabica 1 coffee had significantly low

intensity than other coffee samples for coffee identity, bitter, overall impact, blended, longevity, fidelity, cardboards, musty/dusty, burnt, and acrid and roasted. This was because Arabica 1 had low degree of roasting i.e. light roasted, as difference in origin and degree of roasting had impacted the perceived flavor attributes of coffee (Bhumiratana et al., 2011) This result was supported by another research which showed Arabica and Robusta coffee had chemical composition like Sulphur compounds, benzoic compounds, aldehydes, ketones, alcohols, pyrroles in different amount and these chemical compounds were responsible for most of the flavor notes like burnt, caramel, nutty, earthy and roasted (Sunarharum et al., 2014).

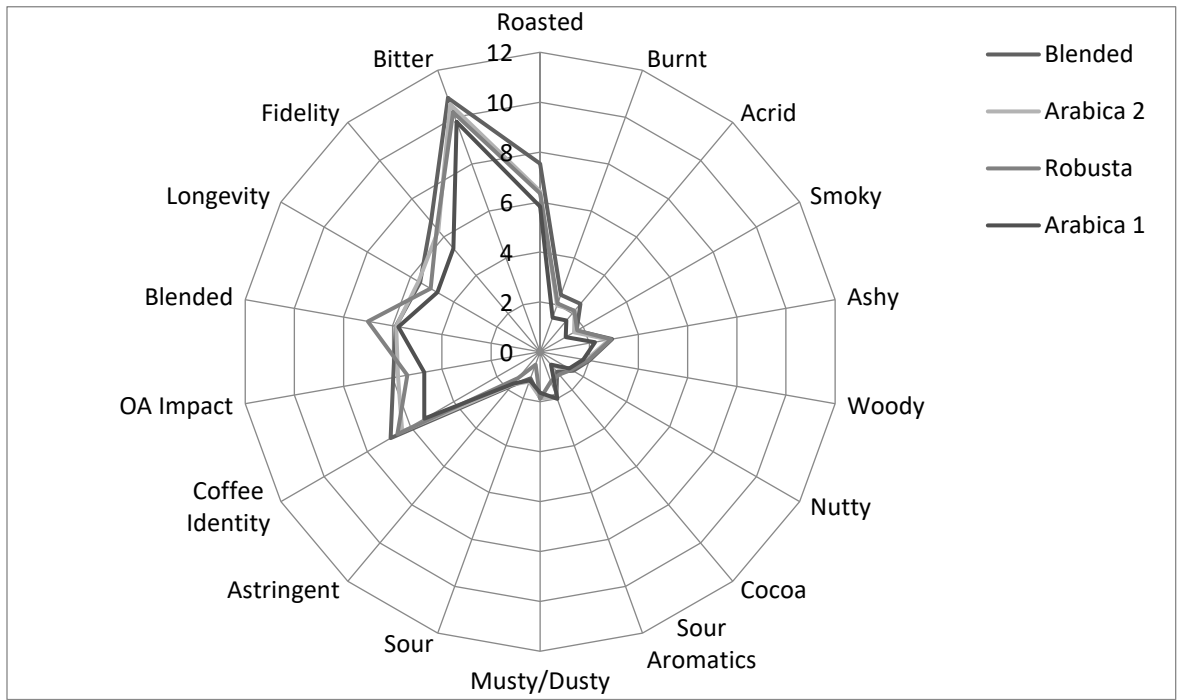


Figure 2-5 Radar-plot for effect of coffee samples on flavor attributes of hot brewed coffee

Effect of consumption temperature

As expected, coffee samples consumed at 70°C had significantly higher intensity for key attributes like burnt, acrid, smoky, ashy, fidelity, blended, and coffee identity while score for raw attribute was

significantly low than samples consumed at 50°C and 60°C for significance level, $\alpha= 0.05$. The optimal flavor notes is achieved if coffee temperature is maintained between 180 °F and 185 °F (82.2 °C and 85 °C) (Lingle, 1996; National Coffee Association of America). This finding supported that higher the consumption temperature, higher the intensity of perceived flavor note. However, some of the key attributes such as blended, fidelity and blended were not significantly higher for sample tasted at 60°C to sample tasted at 50°C. The burnt, raw and marginally blended attributes were not significantly different for samples tasted at 50°C and 60°C. Coffee samples tasted at 50°C had significantly lower intensity for fidelity, coffee identity, beany, overall impact, roasted than samples tasted at 60°C and 70°C. The perceived intensity for roasted, overall impact, and longevity was not significantly different for samples consumed at 60°C and 70°C. Overall, consumption temperature impact significantly the flavor attributes' score for samples served at lower and higher temperature. This showed consumption temperature impact the sensory properties of hot brewed coffee and this result suggested that it is always better to drink coffee hot rather than cold to have higher coffee like flavor attributes such as coffee identity, fidelity, blended and roasted.

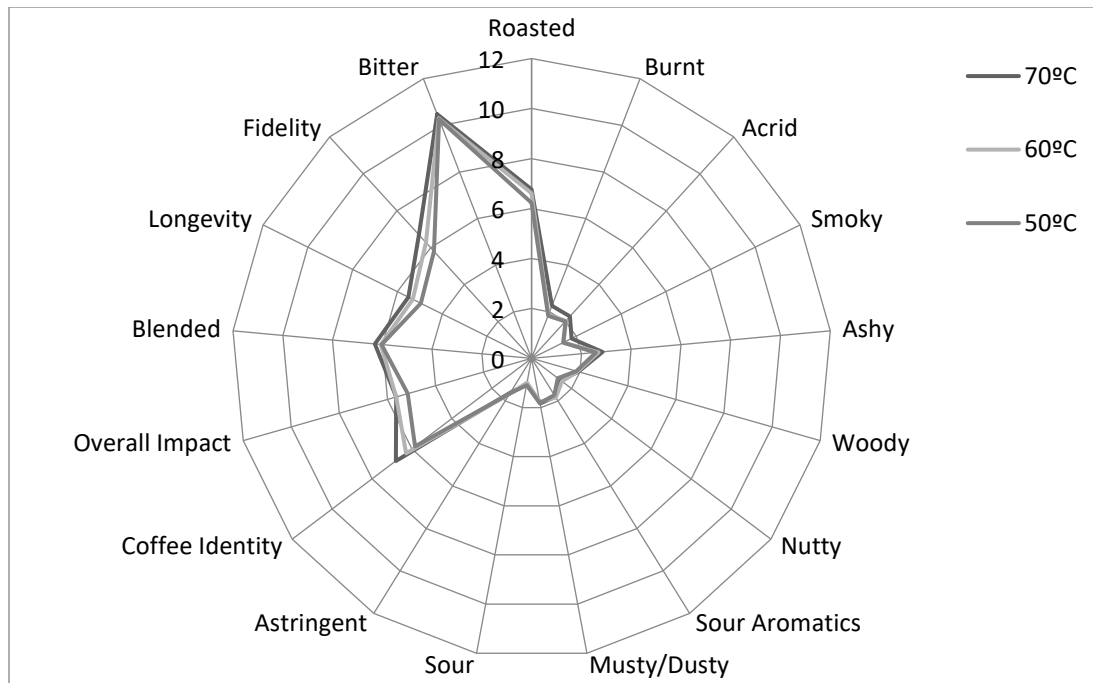


Figure 2-6 Radar-plot for effect consumption temperature on flavor attributes of hot brewed coffee

CONCLUSION

The impact of consumption temperature depends on the type of coffee. The results showed inconsistent score for Arabica 2 and Blended coffee i.e. consumption temperature influenced different types of coffee differently. There needs to be consideration of consumption temperature especially during the blending process. This is because chemical composition is responsible for the sensory properties of coffee (Sunarharum et al., 2014), therefore, blending impacts the chemical composition and sensory attributes of coffee.

The score for key attributes such as coffee identity, fidelity, blended, overall impact was directly proportional to consumption temperature when consumed at 60 and 70°C. Another research has suggested that the ideal serving temperature is 68 to 79 °C (154 to 174 °F) (Borchgrevink et al., 1999) to have optimal flavor notes. We must consider that the consumption temperature is often lower than the serving temperature as the difference can depend on factors such as time delay between serving and

consuming coffee which can impact the sensory properties of coffee. For further analysis, it is suggested to consume coffee at 70°C as most of the key attributes has higher score. Consumption beyond optimal temperature of 70°C is not recommended as there is high chance of scald burn injuries (Roberts, Whitaker, & Drew, 2007). While serving temperature must be higher than consumption temperature, it is recommended to inform the consumer beforehand regarding the serving temperature of coffee to lessen the burn injury and to increase the consumer acceptance.

Chapter 3 - Impact of Additions(Milk and/or Sugar) on Sensory Properties of Hot Brewed Coffee

ABSTRACT

The objective of the research was to determine the effect of additions (milk and/or sugar) on sensory properties of coffee. 3 coffee samples (light, medium, and dark roasted) were consumed with variation in addition (milk and sugar, only milk, only sugar, and no addition). Cluster analysis classified samples into 3 clusters (1st - light coffee, 2nd -coffee with sugar, and sugar plus milk, 3rd - dark and medium coffee with or without milk). The addition of milk and sugar decreased the intensity of main flavor attributes (coffee identity, bitterness, fidelity, roasted, blended, and longevity) except with overall dairy and milky. Result suggested that the effect of addition (milk and/or sugar) is affected by the degree of roasting and we have to consider the adding amount of milk and sugar according to the degree of roasting.

PRACTICAL APPLICATIONS

This finding demonstrated how each of the flavor attributes of coffee is affected by the addition of milk and sugar in coffee and to classify coffee according to their flavor profile properties. This can be applied in the restaurant and coffee business sectors to meet the consumer acceptability.

INTRODUCTION

Coffee can be prepared in many different ways by consumers and also after brewing; it can be consumed in a variety of ways. Some consumers prefer with a dairy product such as milk or cream, while some consumers prefer black coffee with no such addition. Similarly, some consumers prefer coffee with extra flavoring and sweeteners (Petracco, 2001).

The sensory properties of hot brewed coffee is influenced by various factors like the degree of roasting (De Rovira Sr, 2017), brewing methods, additions of dairy products, sweeteners and extra flavorings (Bhumiratana et al., 2011). There are number of research on the effect of sensory properties of coffee due to these different factors but not much of them have focused on the correlation between these properties. In this research, we aim to find the effect of addition of milk and sugar and degree of roasting on sensory properties of coffee, emphasizing on their correlation

The sensory properties of hot brewed coffee were analyzed by descriptive analysis (DA). DA studies are conducted in order to describe the specific sensory characteristics (e.g., flavor, texture, appearance) of coffee, often using trained panelists for evaluation. DA provides a method to obtain an objective description of the evaluated product in terms of the perceived sensory attributes (Stone, Sidel, Oliver, Woolsey, & Singleton, 2008). Since DA produces a large amount of data, there is an need of using multivariate correlation analysis that deals with technique of multidimensional sensory evaluation to extract pertinent information i.e. to describe a set of food products through several attributes (Borgognone, Bussi, & Hough, 2001).

Principal component analysis (PCA) is one of the frequently applied methods for multivariate overview analysis of sensory data (Helgesen, Solheim, & Næs, 1997). PCA reduces an original set of correlated observed variables into a smaller set of artificial uncorrelated called principal components (PCs). Each PC is a particular linear combination of the original variables (Jolliffe, 2002). Thus, the purpose of PCA

is to achieve parsimony and reduce dimensionality by finding the smallest number of components that explain most of the variation in the original data and to summarize the data with little loss of information. If the first few PCs explain a large proportion of the variability (usually more than 80%–84% for sensory data), our purpose of dimension reduction has been achieved (Cadima & Jolliffe, 1995). Cluster analysis (CA) is a multivariate statistical analysis, useful for studying the correlation in a set of measurements of a given number of variables for a determined number of assessors (Resurreccion, 1988). Cluster analysis or clustering is the task of grouping a set of objects in the same cluster which are more similar according to perceived intensity of flavor attributes to each other than to those in other clusters (Rousseeuw, 1987). The major objective of this study was to determine the impact of addition (Milk and/or Sugar) on sensory properties of hot brewed coffee and also correlating the impact of degree of roasting (Light, Medium, Dark) and additions on sensory properties of hot brewed coffee.

MATERIALS AND METHODS

Coffee Samples

The study was conducted in the Center for Sensory Science and Consumer Behavior at Kansas State University. For this study, the coffee samples were bought from the Dillons, Manhattan, Kansas, USA just before the day of evaluation. Coffee samples were of same brand and were selected according to degree of roasting as degree of roasting have an effect upon coffee flavor and body (De Rovira Sr, 2017). Samples selected were dark roasted, medium roasted and light roasted coffee.

Sample Preparation

For this study, deionized and carbon-filtered water was used with the aim of keeping the water neutral in pH and odor-free, with the purpose of minimizing the component for unwanted flavors from the brewing water that might impact the flavor profile of coffee (Lawless & Heymann, 2010). The International

Standard ISO 3972 recommends that water should be neutral, tasteless, still and odorless, and preferably of known hardness (International Organization and for Standardization, 1991).

The weight of coffee sample per liter of water for brewing was determined according to the ISO 6668:2008 reference that recommended a ratio of 7.0 g of coffee per 100 ml of water, with an individual notified coffee range of 5-9 g (International Standard ISO 6668, 2008). However, for this project, 77 gm of coffee sample was used and brewed in 1400 ml water i.e. 5.5g for 100 ml water. Evaluation was carried out in a control room with no interfering external factors like light, aroma and sound.

Completely randomized block design was used for sample preparation. Three coffee samples was a block as they were different by degree of roasting and origin, were randomly assigned four treatments- addition of milk and/or sugar, with three replications. Four treatments were no addition of milk and sugar (C), addition of only milk (CM), addition of only sugar (CS), and addition of both milk and sugar (CMS). Each treatment (C, CM, CS and CMS) assigned to each samples (Light, Medium and Dark roasted) and with three replications, 36 samples were made ready for evaluation.

120 ml of (2% fat) milk and 60 gm of sugar was poured into the coffee sample after brewing. The serving temperature for this study was adjusted to 70C as consuming at this temperature was shown to produce the most flavor attributes from the previous study (see chapter 2). The temperature was maintained by pouring brewed coffee into a thermos and served in 6 oz. double wall glasses (Double Wall Thermo Insulated Coffee Cups). Panelists served themselves the required amount for evaluation as needed. The coffee samples used in this study were labeled with four-digit codes. The RedJade software was used to design the experiment and for the collection of data.

Panel and Quantitative Descriptive Analysis

For this study, six highly trained panelists (two males and four females; ranging in age from 50–70 years old) from the Center for Sensory Analysis and Consumer Behavior at Kansas State University, evaluated

the coffee samples. The panelists' experience included 120 h of general training and a minimum of cumulative 1,200 h of general sensory testing of beverages and food products including coffee. All had previously tested coffee. For this study, panelists received a further two days of orientation (1.5-h sessions each day), with the primary objective of familiarizing the panelists with the references, the coffee samples, and the evaluation process. After these orientation sessions, six sessions of 1.5 h were held for the sample evaluations. A total of six samples were evaluated per session.

The panelists evaluated 38 different flavor attributes for each sample (Chambers, 2016). The attributes of each sample were identified and the intensity was quantified utilizing a 0–15 point scale with 0.5 increments. To cleanse their palate between each sample, the panelists used bagels and apples, they also breathed through a warm, clean, moist cotton terry cloth filter to clear their nasal passages.

Data Analysis

Significant differences among samples (light, medium and dark roasted) with respect to additions- Milk (CM), Sugar (CS) and Milk+ Sugar (CMS) and their interaction was assessed using two-way ANOVA, mixed effect model with LS means and significance level of $\alpha=0.05$ by the statistical program SAS v.9.4. Principal component analysis was applied first to the descriptive data based on the correlation matrix to determine relationships among attributes and differences among samples in the design. The sensory data averaged over the assessors for each of the 38 attributes and 12 coffee samples were analyzed by Agglomerative Hierarchical Clustering (AHC). AHC was performed using Ward's method as the aggregation criterion (XLStat 2015 Agglomerative hierarchical clustering). A dissimilarity plot was utilized to determine how many clusters were appropriate for each analysis. After that, a dendrogram was employed to determine the cluster structure of the data and backing the conclusion that was made by means of the dissimilarity plot.

RESULT AND DISCUSSION

Impact of addition on coffee samples

Figure 3-1 and Figure 3-2 display the radar plot for perceived flavor attributes of dark roasted coffee by descriptive sensory analysis. Similarly Figure 3-3 and Figure 3-4 show of medium roasted whereas Figure 3-5 and Figure 3-6 show of dark roasted coffee. For each sample (differ in degree of roasting), two radar plots were plotted according to perceived flavor intensity. The interaction of samples and addition was analyzed by 2-way ANOVA for significance level, $\alpha=0.05$.

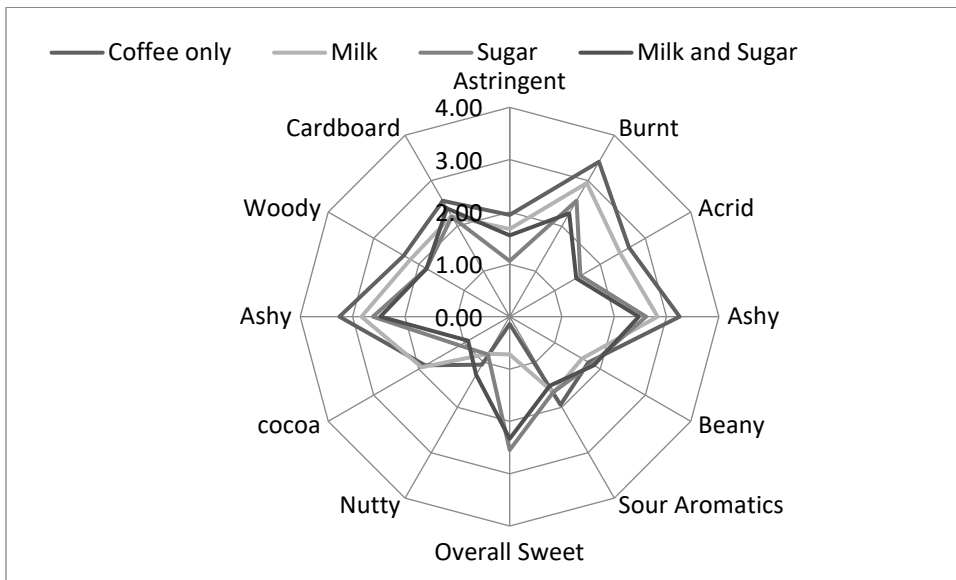


Figure 3-1 Radar plot for flavor attributes for dark coffee with low intensity

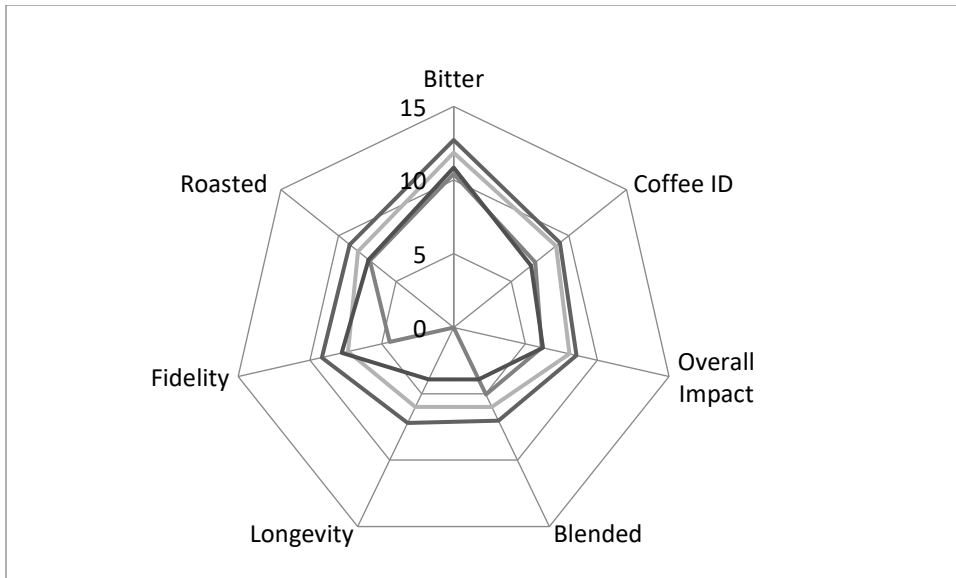


Figure 3-2 Radar plot for flavor attributes for dark coffee with high intensity

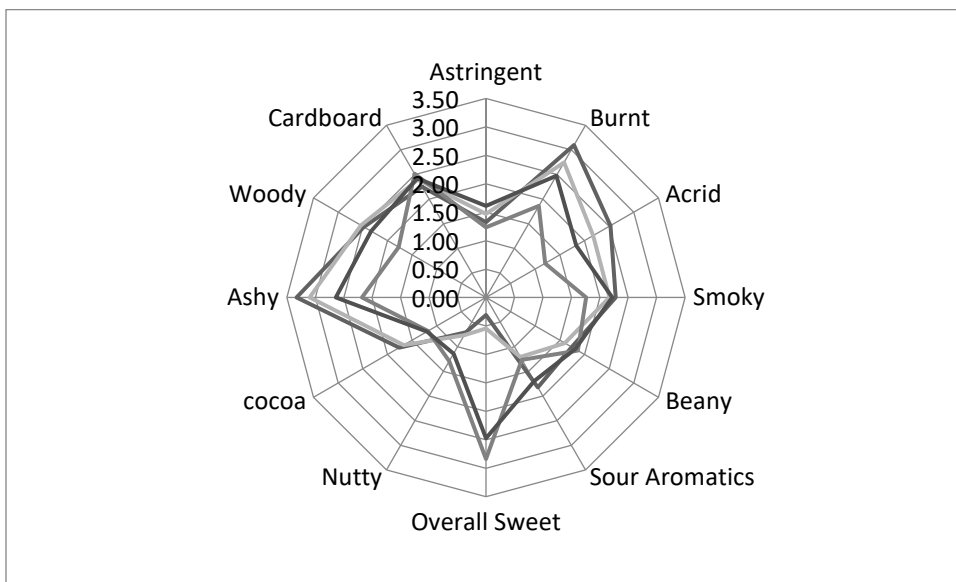


Figure 3-3 Radar plot for flavor attributes for medium coffee with low intensity

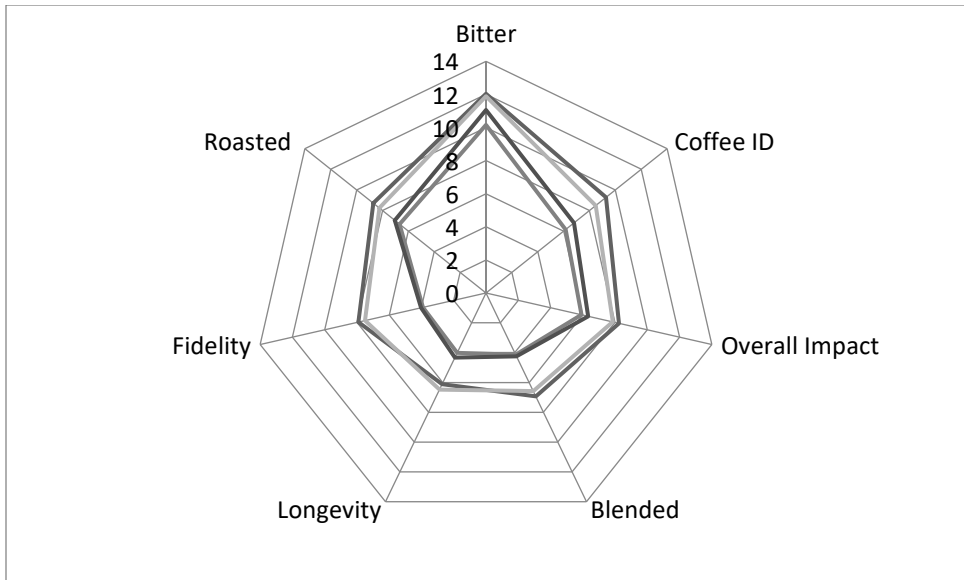


Figure 3-4 Radar plot for flavor attributes for medium roasted coffee with high intensity.

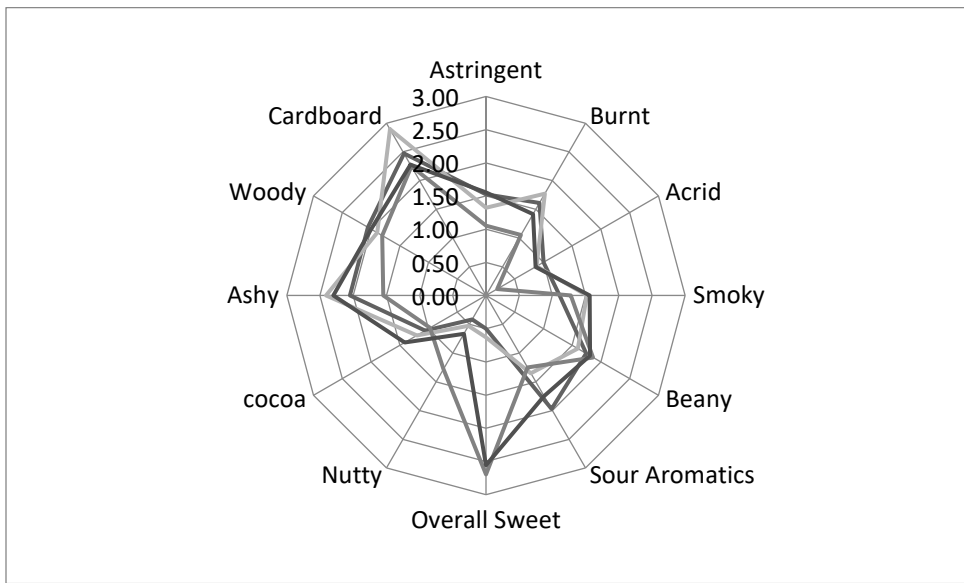


Figure 3-5 Radar plot for flavor attributes for low roasted coffee with low intensity

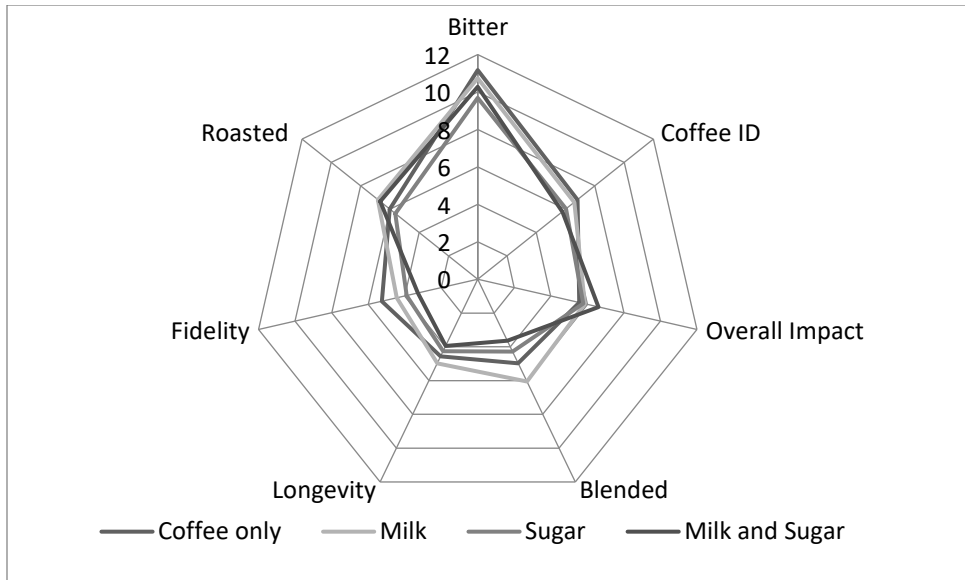


Figure 3-6 Radar plot for flavor attributes of low roasted coffee with high intensity

These radar plots show many of the attributes' intensity decreased by the addition of milk and sugar but some of the key attributes such as coffee identity, blended, fidelity, overall impact were impacted differently by the additions to the samples according to degree of roasting. The increase in intensity of flavor attributes is inversely proportional to the degree of roasting for most of the attributes. The flavor attributes in dark roasted coffee was impacted more than in dark roasted coffee. In light roasted coffee, sugar had increased overall impact, cocoa while milk had increased blended, and longevity. For dark and medium roasted coffee, the flavor attributes were not impacted similarly to light roasted coffee. In dark roasted coffee as well as in medium roasted coffee, the key attributes such as coffee identity, blended, overall impact, fidelity, bitterness, and roasted were impacted by the addition of sugar and milk. This could be because the roasting increased the coffee related flavor attributes such as coffee identity, bitterness (Bhumiratana et al., 2011) and the impact of milk and sugar might depend on the flavor development during roasting.

Impact of Coffee Samples on sensory properties of coffee

The flavor attributes with perceived intensity less than 1 in 0-15 line scale and not significant for 0.05 are not included in Table 3-1 and Table 3-2. Table 3-1 showed dark roasted coffee had significantly higher intensity for coffee identity, roasted, bitter, overall impact, blended, longevity and fidelity than light roasted coffee but not significant to medium roasted coffee. Light roasted coffee had significantly lower intensity for burnt, acrid, ashy and significantly higher intensity for raw, overall dairy than medium and dark roasted coffee. This was because degree of roasting impacted the sensory properties of coffee (Bhumiratana et al., 2011; De Rovira Sr, 2017).

Table 3-1 Effect of degree of roasting on sensory properties of hot brewed coffee

Flavor Attributes	Coffee Sample			Pr>F
	Light Coffee	Medium Coffee	Dark Coffee	
Roasted	6.28 ^b	7.67 ^a	7.99 ^a	<0.0001
Burnt	1.46 ^b	2.54 ^a	2.8 ^a	<0.0001
Acrid	0.73 ^b	1.93 ^a	2.03 ^a	<.0001
Ashy	2.08 ^b	2.81 ^a	2.80 ^a	<.0001
Woody	1.93 ^b	2.28 ^a	2.04 ^{ab}	0.0255
Overall Sweet	1.6	1.54	1.43	0.2906
Cocoa	1.16	1.45	1.45	0.2059
Sour Aromatics	1.58	1.49	1.7	0.3435
Beany	1.65	1.77	1.83	0.4408
Cardboard	2.47	2.39	2.34	0.4712
Sweet	1.18	1.15	1.07	0.1339
Astringent	1.37	1.40	1.56	0.2681
Smoky	1.366 ^b	2.107 ^a	2.312 ^a	<0.0001
Bitter	10.470 ^b	11.285 ^a	11.463 ^a	<0.0001
Coffee ID	6.301 ^b	7.674 ^a	7.98 ^a	<0.0001
Overall Impact	5.951 ^b	7.089 ^a	7.246 ^a	<0.0001
Blended	4.734 ^b	5.475 ^a	5.497 ^a	<0.0001
Longevity	4.431 ^b	5.235 ^a	5.331 ^a	<0.0001
Fidelity	4.214 ^b	5.838 ^a	7.189 ^a	0.0001

*Numbers with different alphabets are significantly different to each other for significance level, $\alpha=0.05$

Impact of Additions on sensory properties of coffee

The impact of adding 60 ml of (2% fat) milk and 30 g of sugar on sensory properties of hot brewed coffee after brewing is shown in Table 3-2. It showed that coffee with milk and sugar had significantly higher intensity for overall sweet and significantly lower intensity for roasted and ashy than other samples, with a significance level $\alpha=0.05$. Coffee without milk and sugar had significantly higher intensity for bitter, coffee identity and fidelity than other samples and significantly lower intensity for overall sweet. The samples with addition of milk were not significant to samples without addition for key attributes such as overall impact, blended, longevity, fidelity, and roasted. On the other hand, coffee with sugar was significantly different as compared to coffee without addition for key attributes such as roasted, coffee identity, fidelity, bitterness, and burnt. This could explain that the addition of sugar had higher impact than addition of milk on sensory properties of hot brewed coffee for that amount of addition. The level of sugar mainly increased the sweetness, caramel and vanillin notes (Koeferli et al., 1996) and this could be the reason that the coffee with sugar had high impact as the flavor notes increased by sugar obstructed the perception of coffee flavor notes. However, the addition of both milk and sugar impacted the sensory properties more than the addition of sugar alone. Another work (Dupas et al., 2006) showed that compounds of coffee and milk bound usually in a more reproducible way when the solution is heated up. For the present work, milk was added just after brewing at temperature 92-95°C. This could explain that the addition of milk had bounded chemical compounds of coffee that impacted the sensory properties of coffee (Sunarharum et al., 2014).

Table 3-2 Effect of additions on sensory properties of hot brewed coffee

Flavor Attributes	Additions				Pr>F
	No Additions	Milk	Milk and Sugar	Sugar	
Roasted	7.91 ^a	7.79 ^a	6.53 ^c	7.03 ^b	<0.0001
Burnt	2.70 ^a	2.48 ^{ab}	2.15 ^b	1.73 ^c	<0.0001
Acrid	2.05 ^a	1.83 ^a	1.42 ^b	0.95 ^c	<.0001
Ashy	2.88 ^a	2.78 ^{ab}	2.07 ^c	2.52 ^b	<.0001
Woody	2.29 ^a	2.2 ^a	1.8 ^b	2.05 ^{ab}	0.007
Overall Sweet	0.31 ^c	0.63 ^b	2.62 ^a	2.52 ^a	<.0001
Cocoa	1.56 ^a	1.60 ^a	1.02 ^b	1.23 ^{ab}	0.0237
Dark/Dried Fruit	0.04 ^c	0.02 ^c	0.34 ^b	0.84 ^a	<.0001
Sour Aromatics	1.91 ^a	1.41 ^{bc}	1.34 ^c	1.7 ^{ab}	0.0016
Beany	1.74	1.60	1.86	1.81	0.3906
Cardboard	2.43	2.50	2.38	2.30	0.4452
Sweet	0.06 ^c	0.04 ^c	2.15 ^b	2.3 ^a	<.0001
Astringent	1.60	1.49	1.28	1.41	0.1636
Smoky	2.02	2.01	1.67	2.0	0.0964
Bitter	11.97 ^a	11.49 ^b	10.09 ^c	10.72 ^d	<.0001
Coffee ID	8.43 ^a	7.98 ^b	6.42 ^c	6.43 ^c	<0.0001
Overall Impact	7.45 ^a	7.26 ^a	5.94 ^c	6.39 ^b	<0.0001
Blended	6.31 ^a	6.21 ^a	4.49 ^b	3.93 ^c	<0.0001
Longevity	5.96 ^a	5.81 ^a	4.17 ^b	4.06 ^b	<0.0001
Fidelity	7.44 ^a	6.43 ^{ab}	4.08 ^c	5.03 ^{bc}	0.0002

*Numbers with different alphabets are significantly different to each other for significance level, $\alpha=0.05$.

Principal Component Analysis

Eigenvalues and Variability

PCA examined correlations between variables to reduce the number of dimensions in the dataset. We can see that PC1 equaled 13.47 and represented 58.57% of variability. Likewise, PC2 equaled 3.66 and represented 15.92% of variability. The first three PCs were able to explained 83.47 % of the total variability of the data. In this work, the first two PCs which explained 74.49% of the total variability of the initial data were used for the biplot as the samples distribution by first 2 PCs was supported by Cluster analysis.

Table 3-3 Cumulative eigenvalue from each principal component of coffee evaluation

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Eigenvalue	13.47	3.66	2.06	1.18	0.94	0.53	0.39	0.35	0.26	0.10	0.04
Variability (%)	58.57	15.92	8.98	5.13	4.09	2.32	1.70	1.53	1.12	0.46	0.18
Cumulative %	58.57	74.49	83.47	88.60	92.7	95.02	96.71	98.24	99.36	99.82	100.00

Figure 3-8 showed light roasted coffees and coffees with sugar had low PC₁ values and were thus concentrated on the left of the plot, on the opposite side from dark and medium roasted coffee without sugar. Light roasted and coffee with sugar had lower coffee related attributes such as bitter, overall impact, fidelity, longevity and blended and high intensity for attributes such as sour and cardboard. Dark and medium coffee had higher value for PC₁ as they had higher attributes for coffee related attributes such as woody, bitter, cocoa, coffee identity and sour aromatics. Light roasted coffees had higher PC₂ values and were at the top of the plot while coffee with sugar had lower value for PC₂ and are at the bottom of the plot.

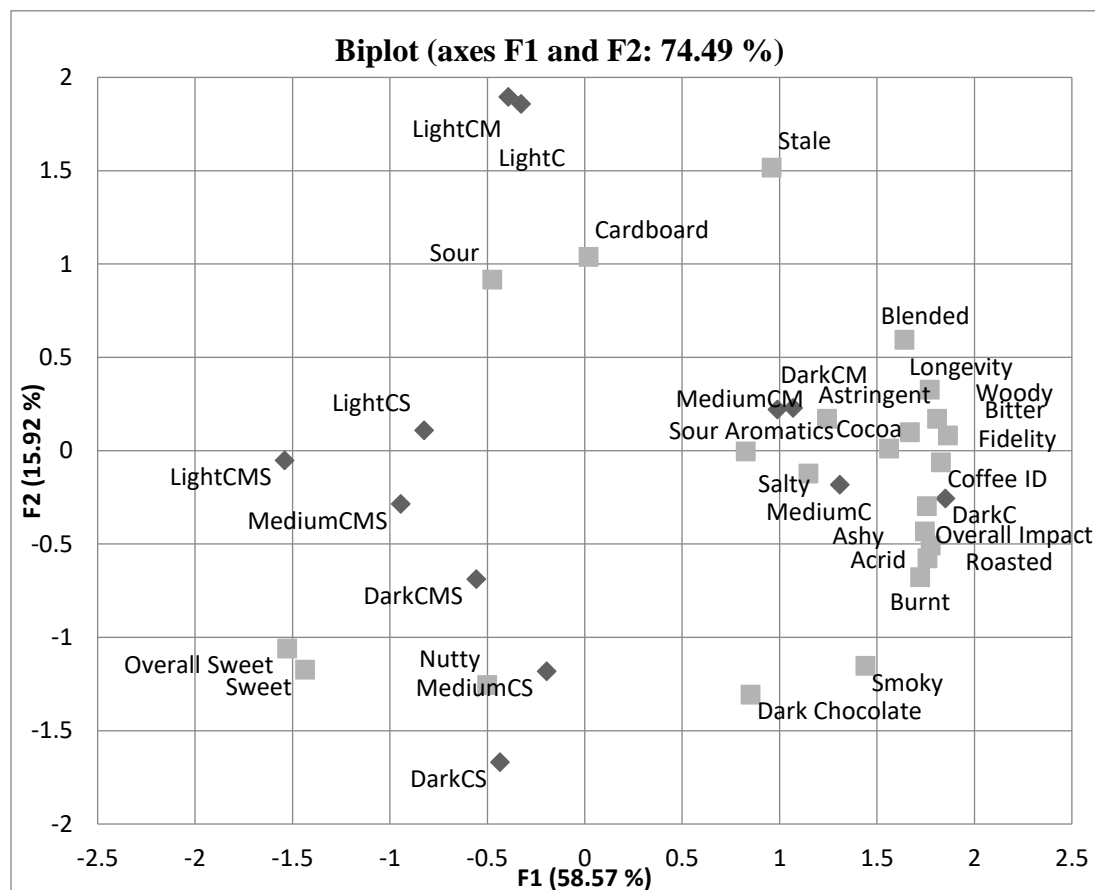


Figure 3-7 Biplot of trained panel evaluation for flavor attributes of various coffee samples

The PC₁ abridged our findings so far - it had paired coffee with perceived intensity for coffee related attributes. It also took into account the inverse relationship between the pairs. Hence, PC₁ likely served to differentiate coffee according to perceived intensity for coffee related flavor attributes and also differentiate coffee according to sweetness as flavor enhanced by the addition of milk and sugar. The second principal component (PC₂) was able to differentiate coffee sample by attributes with low intensity such as stale, cardboard, and sour. PC₂ showed that addition of sugar and milk lower the coffee and degree of roasting impact the main attributes such as blended, coffee identity, fidelity and roasted.

Cluster Analysis

Cluster analysis was done to support the PCA. Both correlation-PCA and Agglomerative Hierarchical Clustering(AHC) Table 3-4 demonstrated the class centroids of each attribute in each of the clusters. Dissimilarity plot (Fig 3-10) determined how many clusters were appropriate for each analysis. Dendrogram (Fig 3-11) did the arrangement of clusters according to dissimilarity. Table 3-5 showed class centroids of each attributes for the clusters. Higher value of centroid for particular attribute defined more to the samples in that cluster than sample in other cluster. Samples with less intensity of roasting and only with milk were grouped into cluster 1. Class 1 had higher centroids for raw, stale, cardboard and stale. Cluster 2 had samples with the addition of sugar. Class 2 had higher centroids for attributes with low intensity overall such as milky, sweet, beany, cocoa and woody. Cluster 3 had samples with dark and medium roasted coffee with and without milk. Class 3 had higher centroids for coffee related attributes such as coffee identity, blended, longevity and fidelity. We could say the distribution of cluster depended on degree of roasting and the impact of sugar and milk on perceived flavor intensity of coffee.

Fig 3-10

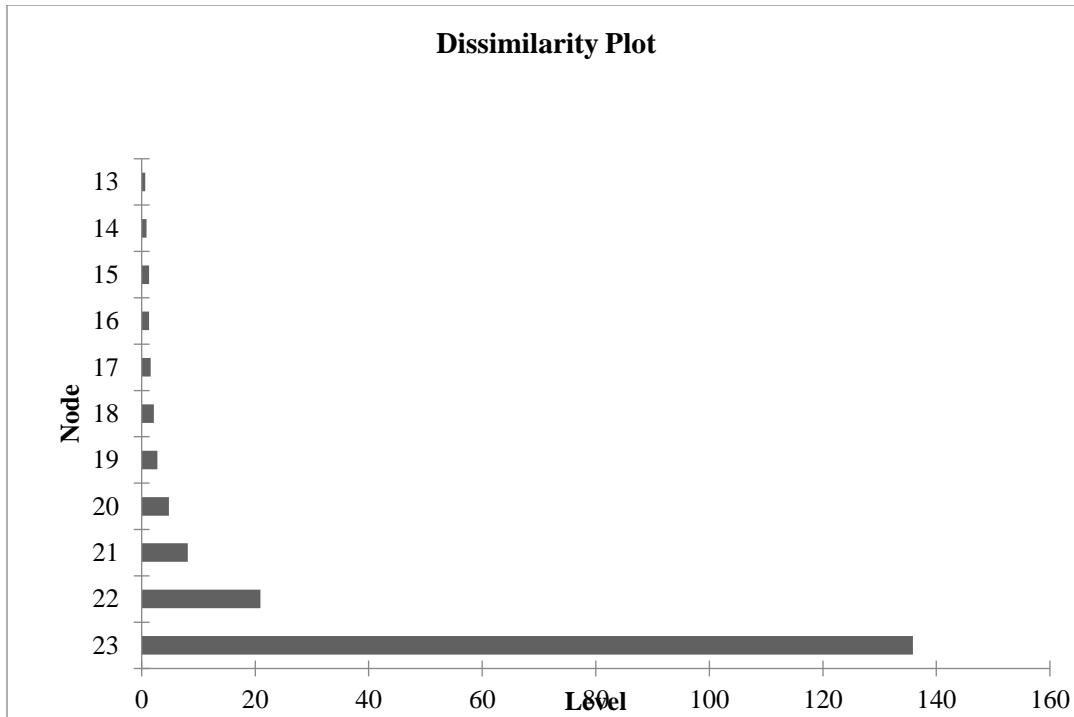


Figure 3-8 Dissimilarity plot that subjectively indicate the number of clusters that coffee samples should be grouped into

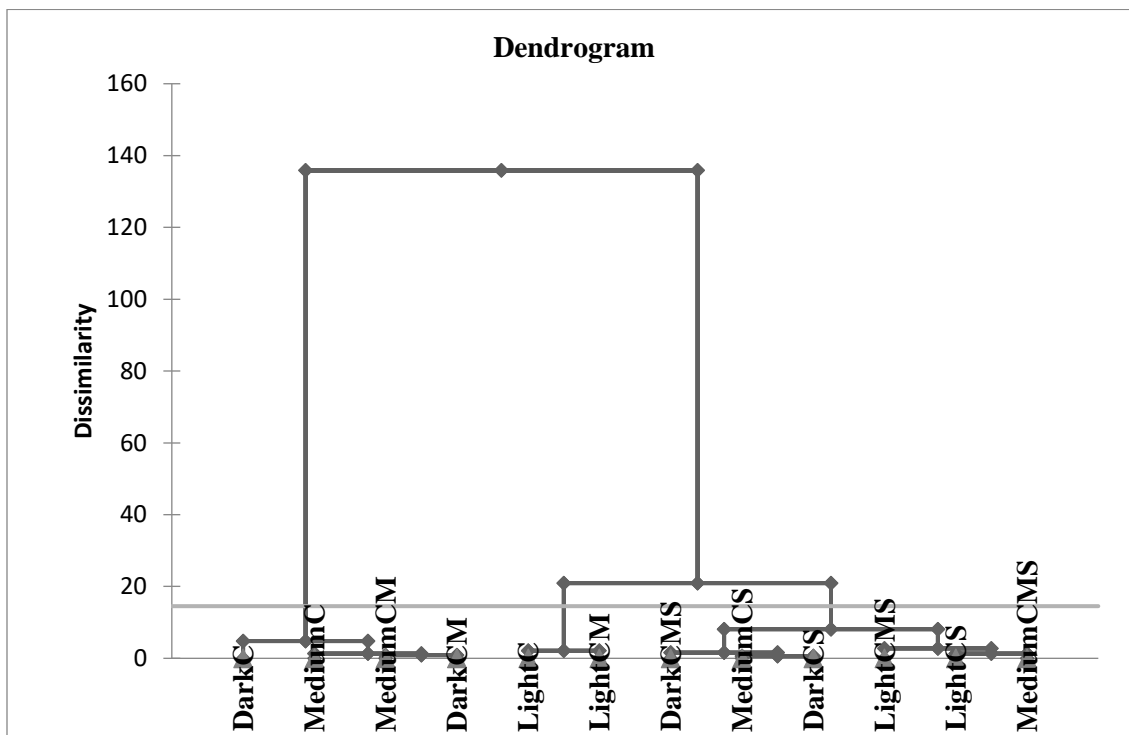


Figure 3-9 Dendrogram showing how coffee samples were grouped together into clusters

Table 3-4 Class centroids of each attributes for the clusters.

Class	1	2	3
Roasted	6.412	6.783	8.566
Burnt	1.703	1.949	3.067
Acrid	0.941	1.197	2.446
Smoky	1.320	1.852	2.373
Ashy	2.248	2.304	3.143
Woody	1.984	1.932	2.400
Overall Sweet	0.544	2.563	0.395
Nutty	0.458	1.080	0.815
Cocoa	1.145	1.132	1.833
Dark Chocolate	0.000	0.149	0.209
Sour Aromatics	1.677	1.537	1.685
Stale	1.217	0.481	0.970
Cardboard	2.692	2.355	2.367
Sweet	0.056	2.231	0.037
Bitter	10.951	10.403	12.122
Sour	0.836	0.697	0.669
Salty	0.139	0.128	0.279
Astringent	1.440	1.365	1.626
Coffee ID	6.697	6.420	8.960
Overall Impact	5.719	6.168	8.198
Blended	5.501	4.204	6.617
Longevity	4.763	4.110	6.438
Fidelity	4.846	3.951	7.983

CONCLUSION

Differences were observed for coffee-related attributes on coffee samples according to the degree of roasting. The addition of milk and sugar impacted the intensity of coffee flavor attributes and the impacts were not similar for all attributes across samples. The application of multivariate analysis were able to classify samples according to the degree of roasting and the addition of milk and sugar. Samples were grouped according to the degree of roasting and the additions –milk and/or sugar. Dark roasted coffee was more impacted by the addition of sugar and milk as compared to light roasted coffee. The addition of milk did not significantly increase the milky and overall milky attributes but had impacted other coffee related attributes.

Results suggest that the degree of roasting and the impact of milk and sugar are interrelated to each other specially for attributes that has low perception as it could be impacted by the flavor notes developed by milk and sugar.

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Appendix A - Reference sheet for both study

FLAVOR

Roasted: Dark brown impression characteristic of products cooked to a high temperature by dry heat. Does not include bitter or burnt notes.

Reference: *Lightly roasted peanuts* = 2.5 (f)
Medium roasted peanuts = 6.5 (f)
Dark roasted peanuts = 9.5 (f)
Over roasted peanuts = 15.0 (f)

Preparation: Lightly Roasted Peanuts

Preheat oven to 425°F Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 7 minutes – peanuts will not show any color.

Medium Roasted Peanuts

Preheat oven to 425°F Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 10 minutes or until peanuts are medium brown in color

Dark Roasted Peanuts

Preheat oven to 425°F Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 15 minutes or until peanuts are dark brown in color.

Over Roasted Peanuts/Burnt

Preheat oven to 425°F Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 20 minutes – peanuts will be burnt.

Raw: Aromatics associated with uncooked products.

Reference: Kroger Whole Natural Almonds = 3.0 (f)

Preparation: Serve the almonds in 1 oz. cups.

Burnt: The dark brown impression of an over-cooked or over-roasted product that can be sharp, bitter and sour.

References: *9.5 Over Roasted Peanuts/Burnt* = 3.0 (f)

15.0 Oven Roasted Peanuts/Burnt = 6.5 (f)

Preparation: Dark Roasted Peanuts

Preheat oven to 425°F Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 15 minutes or until peanuts are dark brown in

Over Roasted Peanuts/Burnt

Preheat oven to 425°F Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 20 minutes – peanuts will be burnt.

Acrid: The sharp pungent bitter acidic aromatics associated with products that are excessively roasted or browned.

References: 9.5 *Over Roasted Peanuts/Burnt* = 3.0 (f)
15.0 *Oven Roasted Peanuts/Burnt* = 8.5 (f)

Preparation: *Dark Roasted Peanuts*
Preheat oven to 425°F Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 15 minutes or until peanuts are dark brown
Over Roasted Peanuts/Burnt
Preheat oven to 425°F Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 20 minutes – peanuts will be burnt.

Smoky: An acute pungent aromatic that is a product of combustion of wood, leaves or non-natural product.

References: Diamond Smoked Almonds = 5.0 (f)

Preparation: Diamond Smoke Almonds: Place 1 TBSP in 3.25 oz. cup

Ashy: Dry, dusty, dirty smoky aromatics associated with the residual of burnt products.

Reference: Gerkens Midnight Black (BL80) cocoa Powder = 3.5(f)

Preparation: Gerkens Midnight Black: Mix ¼ teaspoon of cocoa powder with 100 of water. Serve in 1 oz. cup

Milky: Aromatic reminiscent of powdered milk and reconstituted powdered milk

Reference: Carnation natural nonfat dry milk = 5.0 (f)

Preparation: As instructed in the package
Serve in 1oz cup

Overall Dairy A general term for the aromatics associated with products made from cows milk

Reference: Great Value Non Fat Dry Milk= 4.5(f)
2% Dillon's Milk = 8.0(f)

Preparation: As instructed in the package
Serve in 1oz cup

Woody: The sweet, brown, musty, dark aromatics associated with a bark of a tree.

Reference: Diamond Shelled Walnuts = 4.0 (f)

Preparation: Diamond Shelled Walnuts: Serve walnuts in a 1 oz. cup.

Grain: Light brown, dusty, musty, sweet aromatics associated with grains.

Reference: Cereal Mix (dry) = 8.0 (f)

Preparation: Mix ½ cup of each General Mills Rice Chex, General Mills Wheaties and Quaker Quick Oats. Put in a blender and “pulse” blend into small particles. Serve 1 tsp in a 1 oz. cup (f)

- Molasses:** Dark caramelized top notes which may include slightly sharp, acrid and sulfur notes characteristic of molasses.
 Reference: Grandma's molasses = 6.5 (f)
 Preparation: Mix 2 tsp molasses with 250 ml of water. Stir and Place in 1 oz. cups.
- Overall Sweet:** The perception of a combination of sweet taste and aromatics.
 References: Post Shredded Wheat 1.5 (f)
 General Mills Wheaties = 3.0 (f)
 Nabisco Lorna Doone Cookies 5.0 (f)
 Preparation: Post Shredded Wheat: Serve 2 TBSP in 3.25 oz cups.
General Mills Wheaties: Serve 2 TBSP in 3.25 oz cups.
Nabisco Lorna Doone Cookies: Place 2 cookies in 3.25 oz. cup.
- Nutty:** A combination of slightly sweet, brown, woody, oily, musty, astringent, and bitter aromatics commonly associated with nuts, seeds, beans, and grains.
 Reference: Kretschmer Wheat germ=7.5 (f)
 Preparation: Serve Wheat germ in 1oz cup
- Cocoa:** A brown, sweet, dusty, musty, often bitter aromatic associated with cocoa bean, powdered cocoa and chocolate bars.
 Reference: Hershey's Cocoa Powder in water = 5.0 (f)
 Preparation: Mix 1/4 teaspoon of cocoa powder with 100 ml of water. Serve in 1 oz. cups.
- Dark Chocolate:** A high intensity blend of cocoa and cocoa butter that may include dark roast, spicy, burnt, must notes which includes increased astringency and bitterness.
 Reference: Lindt Excellence Dark Chocolate bar 90% cocoa: 11.0 (f)
 Preparation: Lindt Excellence Dark Chocolate: Serve 3 ½ inch squares of chocolate in 1 oz. cups.
- Floral:** Sweet, light, slightly fragrant aromatic associated with (*fresh*) flowers.
 References: Diluted Welch's White Grape juice, diluted 1:1 = 5.0 (f)
 Preparation: White Grape juice: Mix 1 part of water and one part of juice. Serve in 1oz cup.
- Fruity:** A sweet, floral aromatic blend of a variety of ripe fruits.
 Reference: Welch's white grape juice diluted (1:1) = 5.0 (f)
 Preparation: Welch's white grape juice: Mix 1 part of water and one part of juice. Serve in 1oz cup.

- Citrus Fruit:** The citric, sour, astringent, slightly sweet, peely, and somewhat floral aromatics which may include lemons, limes, grapefruits, and oranges.
Reference: Five Alive Frozen Concentrate = 6.5 (f)
Preparation: Five Alive Frozen Concentrate: Prepare the concentrate according to the package (can) direction. Fill in a 1 oz. cup.
- Dried Fruit/Dark Fruit:** An aromatic impression of dried fruit that is sweet and slightly brown associated with dried plums and raisins.
References: 1/4 cup Sun Maid raisins and 1/4 cup of Sun Maid prunes (chopped), 3/4 cup of water = 6.0 (f)
Preparation: Sun Maid raisins and prunes: Mix raisins (whole) and prunes (chopped). Add 3/4 cup of water and cook in microwave on high for 2 minutes. Filter with a sieve. Grind. Serve the paste into 1 oz cups.
- Sour Aromatics:** An aromatic associated with the impression of a sour product.
References: Bush Pinto Beans (canned) = 2.0 (f)
Preparation: Drain Pinto beans and rinse with de-ionized water. Serve in 3.25oz cup
- Green:** Aromatic characteristic of fresh plant-based material. Attributes may include leafy, viney, unripe, grassy, peapod.
Reference: Parsley water= 9.0 (a), 6.0 (f)
Preparation: Rinse and chop 25 g of fresh parsley. Add 300 ml of water. Let sit for 15 min. Filter. Serve 2 tsp in a 1 oz. cup (f).
- Dark Green:** The aromatics commonly associated with cooked green vegetables such as spinach, kale, green beans that may include bitter, sweet, dusty, musty, earthy, and may have a dark heavy impression.
Reference: Del Monte Leaf Spinach water: 7.0 (a), 6.0 (f)
Preparation: Serve in 1 oz. cup
- Beany:** Aromatic characteristic of beans and bean products includes musty/earthy, musty/dusty, sour aromatics, bitter aromatics, starchy and green/pea pod, nutty or brown.
References: Bush Pinto Beans (canned) = 7.5 (f)
Preparation: Drain beans and rinse with de-ionized water. Serve in 3.25 oz cups.
- Tobacco:** The brown, sweet, slightly pungent, fruity, floral, spicy aromatic associated with cured tobacco.
Reference: Carter Hall Pipe Tobacco= 6.5 (a)
Preparation: Put 1 teaspoon of tobacco in a medium snifter. Cover.

- Musty/Dusty:** The aromatics associated with dry closed air spaces such as attics and closets. May be dry, musty, papery, dry soil or grain.
Reference: Kretschner Wheat Germ = 5.0 (f)
Preparation: Serve 1 tablespoon wheat germ in 1 oz. container, cover.
- Earthy:** Aromatics associated with damp, wet soil.
Reference: Fresh chopped mushrooms = 10.5 (f)
Preparation: Slice mushrooms into thin slices not including stem and serve in 3.25 oz. cups
- Stale:** The aromatics characterized by lack of freshness.
Reference: Mission Wheat Tortillas = 4.0 (f)
Preparation: Serve 1 piece of 2" crust square in 3.25 oz. cup (f)
- Cardboard:** The aromatic associated with cardboard or paper packaging.
Reference: Mission Wheat Tortillas = 4.0 (f)
Preparation: Serve 1 piece of 2" crust square in 3.25 oz. cup (f)
- Sweet:** A fundamental taste factor of which sucrose is typical.
Reference: 1% Sucrose Solution = 1.0
2% Sucrose Solution = 2.0
3% Sucrose Solution = 3.0
- Bitter:** The fundamental taste factor associated with a caffeine solution.
Reference: 0.035% Caffeine Solution = 5.0
0.06% Caffeine solution = 8.5
0.07% Caffeine solution = 10.0
0.1% Caffeine solution = 12.0
- Sour:** The fundamental taste factor associated with a citric acid solution.
Reference: 0.015% Citric Acid Solution = 1.5
- Salty:** A fundamental taste factor of which sodium chloride is typical.
Reference: 0.15% Sodium Chloride Solution = 1.5
- Astringent:** A drying puckering or tingling sensation on the surface and/or edge of the tongue and mouth.
Reference: 0.05% Alum Solution = 2.5

AMPLITUDE

- Coffee ID:** The foundation of flavors notes that gives substance to the product. The perception of robust flavor that is rounded with body; in this case a full, rounded coffee identity..

Reference: Dark French Roast(Starbucks) = 11.0(f)
Flogers Classic Roast Ground Coffee = 8.0(f)
Illy Whole Bean Coffee (Dark Roast) = 7.0(f)

Preparation:

Start brewing one hour before test.
Brew 77 g of each coffee in 1400ml. deionized water using coffee maker.
Serve coffee in coffee air pot (140F) in the panel room. Put empty 4 oz.
Styrofoam cups (with lids) on tray. *Panelists fill cup 2/3 full during testing.*

Overall impact: The maximum overall sensory impression during the whole tasting time.

Reference: Dark French Roast(Starbucks) = 12.0 (f)
Flogers Classic Roast Ground Coffee = 6.0 (f)
Illy Whole Bean Coffee (Dark Roast) = 5.0(f)

Preparation:

Start brewing one hour before test.
Brew 77 g of each coffee in 1400ml. deionized water using coffee maker.
Serve coffee in coffee air pot (140F) in the panel room. Put empty 4 oz.
Styrofoam cups (with lids) on tray. *Panelists fill cup 2/3 full during testing.*

Blended: The melding of individual sensory notes such that the products present a unified overall Sensory experience as opposed to spikes or individual notes.

Reference: Flogers Classic Roast Ground Coffee = 8.0(f)
Dark French Roast (Starbucks) = 6.0(f)
Illy Whole Bean Coffee (Dark Roast) = 5.0 (f)

Preparation:

Start brewing one hour before test.
Brew 77 g of each coffee in 1400ml. deionized water using coffee maker.
Serve coffee in coffee air pot (140F) in the panel room. Put empty 4 oz.
Styrofoam cups (with lids) on tray. *Panelists fill cup 2/3 full during testing.*

Longevity: The time that the full integrated sensory experience sustain itself in the month and after swallowing.

Reference: Dark French Roast(Starbucks) = 9.0(f)
Illy Whole Bean Coffee (Dark Roast) = 7.0 (f)
Flogers Classic Roast Ground Coffee = 4.0(f)

Preparation:

Start brewing one hour before test.
Brew 77 g of each coffee in 1400ml. deionized water using coffee maker.
Serve coffee in coffee air pot (140F) in the panel room. Put empty 4 oz.
Styrofoam cups (with lids) on tray. *Panelists fill cup 2/3 full during testing.*

Fidelity:

The total sensory experiences of the *trueness* of the product in the stated context; in this case its believability as coffee. Note: this does not imply any quality of the coffee.

Reference: Dark French Roast(Starbucks) = 11.0(f)

Flogers Classic Roast Ground Coffee = 8.0(f)

Illy Whole Bean Coffee (Dark Roast) = 7.0 (f)

Preparation:

Start brewing one hour before test.

Brew 77 g of each coffee in 1400ml. deionized water using coffee maker.

Serve coffee in coffee air pot (140F) in the panel room. Put empty 4 oz.

Styrofoam cups (with lids) on tray. *Panelists fill cup 2/3 full during testing*

Appendix B - SAS® codes for Descriptive Analysis of Coffee Samples

```
dm'log;clear;output;clear;';
Data (data name);
input Sample$ Rep$ Code$ Panelist$ attr1 attr2 attr3 attr4 attr5 attr6 attr7 attr8 attr9 attr10 attr11 attr12
attr13 attr14 attr15 attr16 attr17 attr18 attr19 attr20 attr21 attr22 attr23 attr24 attr25 attr26 attr27 attr28
attr29 attr30 attr31 attr32 attr33 attr34 attr35 attr36 attr37 attr38
; datalines; (input raw data here) ;
ods rtf;
Proc means; by sample; var attr1—attr38;
run;
Proc glimmix;
class Product Rep Panelist;
model attr# = Sample/ddfm=sat;
random rep panelist;
lsmeans Product/ pdiff lines;
title2 'Attribute Name';
run;
ods rtf close; quit;
```

Notes:

1. In the Proc Means statement, attr1 corresponds to the first attribute listed, and attr50 corresponds to the last attribute listed.
2. The Proc Glimmix procedure is repeated for all the attributes

Appendix C - ANOVA table score for the descriptive analysis

Table C-1 Effect of coffee samples on flavor attributes for chapter 2

Flavor Attributes	Coffee Samples				Pr>F
	Blended	Arabica 2	Robusta	Arabica 1	
Roasted	7.54 ^A	6.43 ^B	6.34 ^B	5.82 ^C	<0.0001
Burnt	2.43 ^A	1.98 ^B	2.05 ^B	1.46 ^C	<0.0001
Acrid	2.51 ^A	2.15 ^B	2.13 ^B	1.64 ^C	<0.0001
Smoky	1.69 ^A	1.57 ^A	1.72 ^A	1.18 ^B	<0.0001
Ashy	2.93 ^A	2.81 ^A	2.88 ^A	2.23 ^B	<0.0001
Woody	2.0 ^A	1.88 ^{AB}	1.96 ^A	1.76 ^B	0.002
Nutty	1.53	1.37	1.45	1.35	0.3337
Cocoa	1.05 ^A	0.74 ^B	1.2 ^A	0.68 ^B	<0.0001
Sour Aromatics	1.89 ^A	1.97 ^A	1.26 ^B	2.01 ^A	<0.0001
Musty/Dusty	1.85 ^A	1.84 ^A	1.89 ^A	1.65 ^B	0.0092
Bitter	10.82 ^A	10.55 ^B	10.21 ^C	9.8 ^D	<0.0001
Sour	1.13 ^A	1.27 ^A	0.55 ^B	1.22 ^A	<0.0001
Astringent	1.78 ^A	1.72 ^A	1.38 ^B	1.66 ^A	<0.0001
Coffee Identity	6.92 ^A	6.39 ^B	6.6 ^B	5.36 ^C	<0.0001
OA Impact	5.98 ^A	5.79 ^A	5.4 ^B	4.72 ^C	<0.0001
Blended	5.88 ^B	5.86 ^B	7.01 ^A	5.77 ^B	<0.0001
Longevity	5.56 ^A	5.63 ^A	5.07 ^B	4.76 ^C	<0.0001
Fidelity	6.81 ^A	6.35 ^B	6.44 ^B	5.41 ^C	<0.0001

Table C-2 Effect of consumption temperature on flavor attributes of coffee

Flavor Attributes	Consumption Temperature			Pr>F
	70°C	60°C	50°C	
Roasted	6.76 ^A	6.61 ^A	6.23 ^B	0.0002
Burnt	2.25 ^A	1.87 ^B	1.83 ^B	<0.0001
Acrid	2.28 ^A	2.04 ^B	2.0 ^B	0.0006
Smoky	1.79 ^A	1.42 ^B	1.41 ^B	<0.0001
Ashy	2.85 ^A	2.69 ^B	2.58 ^B	0.0014
Woody	1.94	1.91	1.86	0.4678
Nutty	1.44	1.52	1.31	0.0925
Sour Aromatics	1.8	1.83	1.72	0.3602
Musty/Dusty	1.83	1.77	1.82	0.7045
Bitter	10.48	10.3	10.26	0.1272
Sour	1.05	0.98	1.09	0.388
Astringent	1.61	1.67	1.63	0.7633
Coffee Identity	6.81 ^A	6.3 ^B	5.84 ^C	<0.0001
Overall Impact	5.63 ^A	5.63 ^A	5.15 ^B	<0.0001
Blended	6.30 ^A	6.06 ^B	6.03 ^B	0.051
Longevity	5.51 ^A	5.31 ^A	4.95 ^B	<0.0001
Fidelity	6.69 ^A	6.27 ^B	5.8 ^C	<0.0001

Table C-3 Impact of sample and consumption temperature interaction on flavor attributes of coffee in Chapter 2

	ROBUST A 50°C	ROBUST A 60°C	ROBUST A 70°C	BLEN D 50°C	BLEN D 60°C	BLEN D 70°C	ARABIC A 1 50°C	ARABIC A 1 60°C	ARABIC A 1 70°C	ARABIC A 2 50°C	ARABIC A 2 60°C	ARABIC A 2 70°C	Pr>F
Astringent	<u>1.24</u>	1.43	1.50	1.81	1.71	1.84	1.67	1.74	1.60	1.83	1.81	1.54	0.00
Burnt	1.63	2.33	2.21	2.48	1.83	2.98	<u>1.38</u>	1.29	1.74	1.83	2.05	2.08	<0.000 1
Acrid	1.79	2.33	2.29	2.62	2.07	2.86	<u>1.57</u>	1.64	1.71	2.05	2.12	2.29	<0.000 1
Smoky	1.35	1.74	2.07	1.81	1.31	1.98	<u>1.05</u>	<u>1.05</u>	1.45	1.48	1.57	1.68	<0.000 1
Ashy	2.80	2.90	2.95	3.10	2.48	3.22	<u>2.31</u>	2.05	2.33	2.60	2.93	2.92	<0.000 1
Woody	1.79	2.07	2.05	2.00	1.90	2.11	1.81	1.71	1.79	1.88	1.95	1.81	0.004
Grain	1.07	1.07	0.83	0.74	<u>0.64</u>	0.92	1.14	1.26	1.21	0.81	0.76	0.37	0.005
Nutty	1.16	1.74	1.48	1.45	1.55	1.61	1.17	1.52	1.38	1.50	1.29	1.33	0.22
Cocoa	1.01	1.47	1.12	0.95	0.83	1.36	0.71	0.62	0.71	0.71	0.95	<u>0.56</u>	0.0004
Musty/Dusty	1.78	2.02	1.88	1.90	1.67	1.98	1.74	<u>1.48</u>	1.74	1.86	1.95	1.73	0.0040
Bitter	<u>9.98</u>	10.19	10.48	10.93	10.45	11.11	9.64	9.95	9.83	10.52	10.64	10.51	<0.000 1
CoffeeID	<u>5.52</u>	7.07	7.24	7.17	5.83	7.77	4.90	5.31	5.88	5.79	7.02	6.39	<0.000 1
OA Impact	<u>4.65</u>	5.81	5.74	5.95	5.52	6.48	4.26	5.07	4.83	5.74	6.14	5.50	<0.000 1
Blended	6.52	7.26	7.26	6.17	5.29	6.20	<u>5.48</u>	5.88	5.98	5.98	5.83	5.80	<0.000 1
Longevity	<u>4.30</u>	5.43	5.50	5.76	4.98	5.95	4.45	4.95	4.90	5.31	5.90	5.70	<0.000 1
Fidelity	<u>5.28</u>	6.93	7.12	7.07	5.76	7.61	5.02	5.31	5.90	5.83	7.10	6.13	<0.000 1
Roasted	<u>4.82</u>	7.33	6.88	7.98	6.71	7.95	5.98	5.83	5.67	6.17	6.60	6.55	<0.000 1

Table C-4 Impact of sample and additions interaction on flavor attributes of coffee in Chapter 3

SAMPLE	Roasted	Burnt	Acrid	Smoky	Bitter	CoffeeID	OAImpact	Blended	Longevity	Fidelity
Dark Coffee	9.027a	3.42	2.64	2.67	12.72	9.22a	8.55a	7.03a	7.19a	9.17
Dark Milk Coffee	8.29b	2.95	2.44	2.34	11.86	8.88ab	8.07ab	5.99c	5.98b	7.35
Dark Milk & Sugar Coffee	7.27cd	2.28	1.47	2	10.42	7.08c	6.14cd	5.05d	4.25de	4.44
Dark Sugar Coffee	7.38c	2.56	1.56	2.24	10.85	6.72cd	6.22cd	3.92ef	3.90e	7.79
Light Coffee	6e	1.61	1	1.11	11.17	6.80c	5.55e	4.97d	4.55cd	5.25
Light Milk Coffee	6.82cd	1.77	0.88	1.52	10.74	6.59cde	5.86de	6.05c	4.97c	4.44
Light Milk and Sugar Coffee	5.64e	1.06	0.19	1.28	9.69	6.02ef	5.78de	4.28e	4.25de	3.89
Light Sugar Coffee	6.66d	1.42	0.86	1.56	10.28	5.77f	6.61c	3.64f	3.94e	3.28
Medium Coffee	8.71ab	3.1	2.53	2.28	12.04	9.26a	8.24ab	6.93ab	6.12b	7.91
Medium Milk Coffee	8.24b	2.74	2.17	2.17	11.89	8.47b	7.86b	6.58b	6.48b	7.5
Medium Milk and Sugar Coffee	6.68d	1.86	1.2	1.76	10.16	6.1def	5.91ed	4.14e	4.00de	3.91
Medium Sugar Coffee	7.05d	2.47	1.83	2.22	11.06	6.8c	6.33cd	4.25e	4.33de	4.03
Pr>F	<0.0001	0.6155	0.5474	0.303	0.36	<0.0001	<0.0001	<0.0001	<0.0001	0.2141

**Numbers with different alphabets are significantly different to each other at significance level, $\alpha = 0.05$.*

Appendix D - Eigenvalue of each attributes in each principal component

for impact of additions on sensory properties of coffee

Flavor	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Roasted	0.25	-0.14	-0.08	0.00	0.01	-0.04	-0.13	-0.27	-0.14	0.02	0.23
Burnt	0.25	-0.19	-0.06	0.11	-0.05	0.01	-0.04	-0.13	0.27	-0.11	0.10
Acrid	0.25	-0.16	0.01	0.02	-0.02	-0.07	-0.14	-0.09	0.35	-0.04	0.29
Smoky	0.21	-0.32	-0.07	0.10	0.05	-0.13	-0.03	-0.21	0.07	-0.11	-0.31
Ashy	0.25	-0.12	-0.07	0.07	-0.16	-0.18	-0.29	-0.09	-0.12	0.11	0.42
Woody	0.22	0.00	0.06	-0.21	-0.11	-0.27	-0.27	0.71	0.02	0.22	-0.04
Overall Sweet	-0.22	-0.29	0.04	-0.03	0.14	-0.17	-0.05	-0.09	-0.02	0.09	0.08
Nutty	-0.07	-0.35	-0.19	-0.06	0.59	0.17	0.21	0.17	0.30	0.33	0.09
Cocoa	0.24	0.03	0.09	-0.27	0.08	-0.32	0.12	-0.32	-0.19	0.29	-0.30
Dark Chocolate	0.12	-0.36	0.04	0.23	-0.37	-0.24	0.43	0.17	0.20	-0.02	-0.29
Sour Aromatics	0.12	0.00	0.49	0.33	-0.15	0.46	-0.16	-0.06	0.04	0.54	-0.14
Stale	0.14	0.42	-0.10	0.10	0.09	-0.09	0.14	-0.24	0.35	0.11	-0.14
Cardboard	0.00	0.29	-0.31	0.57	0.14	-0.38	0.07	0.07	-0.08	0.32	0.13
Sweet	-0.21	-0.32	0.09	0.01	0.12	-0.11	-0.08	0.02	-0.12	0.23	0.02
Bitter	0.27	0.02	0.07	0.08	-0.05	0.02	0.09	0.16	0.08	-0.14	0.04
Sour	-0.07	0.25	0.48	-0.32	0.09	-0.34	0.11	-0.07	0.39	0.09	0.20
Salty	0.16	-0.03	0.45	0.24	0.20	-0.02	0.43	0.07	-0.35	-0.16	0.28
Astringent	0.18	0.05	0.25	0.25	0.53	-0.09	-0.43	0.10	0.04	-0.36	-0.28
Coffee ID	0.26	-0.02	-0.06	-0.14	0.00	0.23	0.00	-0.02	0.20	0.01	-0.07
Overall Impact	0.25	-0.08	0.02	-0.25	0.10	-0.05	0.01	-0.14	-0.31	0.18	-0.10
Blended	0.24	0.16	-0.24	-0.05	0.03	0.21	-0.03	0.08	-0.07	0.17	-0.06
Longevity	0.25	0.09	-0.10	-0.12	0.15	0.05	0.21	0.18	-0.21	-0.06	-0.14
Fidelity	0.26	0.05	-0.04	-0.12	0.08	0.23	0.24	0.08	0.00	-0.05	0.31