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Development of a "living" lexicon for descriptive sensory analysis of brewed coffee

Edgar Chambers IV[1] | Karolina Sanchez[1] | Uyen X. T. Phan[1] | Rhonda Miller[2] | Gail V. Civille[3] | Brizio Di Donfrancesco[1]

[1]Center for Sensory Analysis and Consumer Behavior, Kansas State University, Manhattan, Kansas

[2]Department of Animal Science, Meat Science Section, Texas A&M University, College Station, Texas

[3]Sensory Spectrum, Inc., New Providence, New Jersey

Correspondence
E. Chambers IV, Center for Sensory Analysis and Consumer Behavior, Kansas State University, 1310 Research Park Drive, Manhattan, KS 66502.
Email: eciv@ksu.edu

Abstract

Coffee is one of the most common beverages in the world. However, a sensory lexicon for determining descriptive differences resulting from breeding, agronomic, processing, storage, and brewing modifications is needed. This study developed a sensory lexicon for brewed coffee. More than 100 different coffee samples from 14 countries around the world were used to create this lexicon in four Phases. A highly trained panel assessed all coffee samples using descriptive analysis. The sensory panel identified 110 attributes (many used both for aroma and flavor) and references. Principal component analysis was used to map the scores obtained during the validation phase. For this phase the coffee lexicon allowed the panelists to describe specific characteristics that were present in the coffee samples such as sweet, nutty and fruity notes, as well as the differentiation of notes such as burnt, smoky, astringent, acrid and bitter. The developed attributes and references were successfully used by the trained panel to describe a wide range of coffee samples. The lexicon is considered "living" because additional terms should be added as needed to expand the lexicon to include attributes that are not included here.

Practical applications

The terminology developed during this study is clear, easy to reproduce in future research, and accompanied by reference standards that provide a guide for future studies. This lexicon will provide an important tool for the coffee industry to conduct sensory evaluation to improve the understanding of coffee quality. It is a "living" lexicon that can be added to when samples exhibit notes that were not present in the samples used for this lexicon development.

1 | INTRODUCTION

Coffee is one of the most popular beverages in the world. Its production is an important factor for the world's economy according to the International Trade Centre (2011). In 2010 around 97 million 60 kg bags of coffee were shipped to different parts of the world. This popular beverage has a high demand worldwide; gross imports quadrupled from 33 million bags in 1949 to 132 million bags in 2010. Coffee is mainly grown in tropical countries because the plant can only survive in a narrow temperature range that is neither too hot nor too cold. However, it can grow on a broad range of soil types with varying water requirments (Carr, 2001).

The coffee plant originated in Africa and Madagascar with cultivation first being reported in Ethiopia and Yemen (Oestreich-Janzen, 2010; Thurston, Morris, & Steiman, 2013). Coffee includes numerous species but only two of them are of real economic importance: Arabica and Robusta (genus *canephora*). Arabica represents the 60–70% of world's production while Robusta represents the 30–40% of world's production (International Trade Centre, 2011). Arabicas tend to be considered higher in quality than Robustas because of their flavor differences. Those differences are in constituents, the amount of sugars and acids present in each variety, the lipid concentration and the fact that Arabica varieties tend to contain about twice as much sucrose as Robustas (Clarke & Vitzthum, 2001). It is because of those differences

TABLE 1 Coffee samples used in the development of the lexicon

Coffee samples	Country	Number of samples
Set 1: (single varietal, various growing conditions)	Colombia	13
Set 2: purchased commercial samples (multi varietal)	Indonesia, USA, Ethiopia, Guatemala, Kenya, Papua New Guinea, Colombia, India, Thailand, Vietnam, includes coffees from unknown origins	45
Set 3: donated commercial samples (single varietals and micro-lot coffees)	Brazil, Guatemala, Mexico, Ethiopia, Kenya, Costa Rica, Indonesia	27
Set 4: (multi varietal, various growing conditions)	Colombia	20

in varieties, growing conditions (altitude, rainfall, sunlight, etc.), processing variables (such as ferementation, drying, and roasting), packaging, storage, and brewing conditions that make it important to have a lexicon to help identify the variations in sensory profiles in coffees around the world. This vocabulary must be able to offer a wide range of terms for a beverage that has a wide range of variable components.

The industry has accepted some common criteria used to define coffee characteristics. This criteria has been used to discuss coffee properties and is mainly divided into two groups: overall characteristics and attributes. The overall characteristics include terms such as fragrance and aroma, acidity, body, flavor, aftertaste and balance, while the attributes are descriptors that may not occur in every cup of coffee but when they are present can add complexity and uniqueness to the coffee (Thurston et al., 2013). The Specialty Coffee Association of America (SCAA) has cupping procedures that focus on scoring coffee primarly based on overall characteristics, but also identifies specific attributes (Specialty Coffee Association of America, 2015). However, trained descriptive panelists appear to use specific attribute terminlogy more consistently than do cuppers (Di Donfrancesco, Gutierrez Guzman, & Chambers, 2014).

A few studies have been conducted on the sensory properties of coffee in its various stages, from the green bean to the brewed coffee. For example, studies in Italy (Masi, Dinnella, Barnabà, Navarini, & Monteleone, 2013) and Japan (Hayakawa et al., 2010) used descriptive analysis with consumers and untrained coffee professionals to define the sensory properties of brewed coffee and found 16 and 31–60 terms repectively that they suggested could be used for coffee. Other studies have used highly-trained sensory panels and focused on certain sensory attributes. For example, Bhumiratana, Adhikari, and Chambers (2011) studied 15 aroma sensory attributes in green and roasted beans (light, medium, and dark), ground coffee, and brewed coffee. They found aroma profiles were more influenced by preparation and degree of roasting than variety. Sanchez and Chambers (2015) used a small set of 13 descriptive attributes to measure the primary differences among a set of three coffees prepared using four different brewing methods.

Through a four step process of collection, description, defining and referencing, and verification Seo, Lee, and Hwang (2009) developed a sensory attribute pool of brewed coffee that consisted of 74 terms, and indicated that 16 of the terms were unique sensory attributes influenced by the Korean culture.

Although these studies describe different methods for creating a group of sensory attributes to conduct sensory studies, in some cases they did not use trained panels, had limited sets of samples or attributes, or were focused on cultural issues in addition to sensory description. Thus, the purpose of the this study was to develop a lexicon using trained sensory panels containing clear terminology and references that can be used for future research of varietals, processing, brewing, and other studies of coffee.

2 | MATERIALS AND METHODS

2.1 | Coffee samples

For the process of the coffee lexicon development a total of 105 coffee samples from 14 different countries were used. The coffees include a range of commercial blends and single origin coffees, some "broad-stroke" or general samples obtained from suppliers that attempt to represent coffees grown in different countries, and sets of coffee that represent a microcosm of coffee grown in specific growing area of a country. This range of coffees was chosen to have samples representing both the wide range of coffee available as well as the more narrow differences that might be noted in samples grown and processed close to each other. These coffees were placed in sets depending on the phase of the coffee lexicon development in which they were used (Table 1). The first set included 13 arabica samples from the region of Pitalito, Colombia. Set 2 included 45 commercial coffees (Arabica, robusta, and blends), set 3 included 27 speciality coffees samples (arabica) from different parts of the world, and set 4 included 20 arabica coffee samples from the San Adolfo, Colombia region.

Set 1 was a narrow range of samples to begin the lexicon process with a limited number of samples. Set 2 broadened the samples to include an array of commercial samples that might be encountered in coffee tasting. Set 3 included a number of samples that procurers believed may contain unique notes typical of certain countries, varieties or processes, and set 4 again was a more narrow range of samples included to address the use of the lexicon for examining small differences among samples and to help guide additional reference development.

2.1.1 | Sample preparation and serving

For coffee that was obtained in bean form (most single origin coffee), grinding was done using a burr grinder. Samples were ground to a grind

size appropriate for the brewing conditions no more than 30 min before infusion. Different brewing methods were used to prepare the coffee samples depending on the coffee sets:

2.1.1.1 | Sets 1 and 4

Filtered infusion method. Ground coffee (7 g per 100 ml of water) was placed in a beaker and 98°C purified water was poured over the coffee. After brewing for 3 min the infusion was strained through a stainless steel tea strainer into an insulated pump container. This ratio is in accordance with the International Standard for the preparation of coffee samples for use in sensory analysis that suggests a ratio in a 5–9 g range per 100 ml of water (International Organization for Standardization, 2008).

2.1.1.2 | Sets 2 and 3

Consumer drip coffee maker. A General Electric Coffee Maker Machine (Model 169058, capacity 12 cups, GE Appliances, Louisville, KY) was used to brew the coffee at 3.9 g (set 2) and 5.5 g (set 3) per 100 ml of water. For this method Melitta Cone Coffee Filters (No. 4, Melitta USA, In. Clearwater, Fl) were used for the preparation of the samples. Sets 2 and 3 used different amounts during brewing because the commercial lexicon (used during training and lexicon development with set 2 samples) was developed using a lower concentration of coffee and set 3 used an amount recommended by many commercial drip coffee makers. These variations in brew strength are an advantage during lexicon development because they can highlight different attributes that may occur at different strengths of coffee.

Automated espresso machine. Some samples from sets 3 and 4 also were prepared in an automated espresso machine (La Marzocco, model GS-3, Florence, Italy). Each sample was prepared individually, and the machine took around 10–15 s to prepare each sample.

Serving. For all samples, coffee was served at approximately 60°C from insulated "hot pots" (Zojirushi AASB-22SB Air Pot, Zojirushi Corp, Osaka, Japan). For sets 1–3, approximately 60 ml of brewed coffee was pumped into 120 ml Styrofoam cups (Dart, Mason, MI) and was immediately covered with a watchglass to maintain aroma. The headspace in the cup filled with this amount was perceived by panelists as optimal for the aroma evaluation. Sample aroma was evaluated using this first cup of coffee. A second cup of coffee was served (90 ml) in a new cup of the same type for flavor evaluation. This second cup allowed the temperature to be maintained. Evaluation of the coffee in set 4 was changed to 250 ml double-walled borosilicate glass flared top glasses (Assam style, Bodum Design Group, Luzern, Switzerland) to ensure no extraneous odors or flavors were present.

2.2 | Panel

The sensory panel consisted of five highly trained panelists from the Sensory Analysis Center (SAC) at Kansas State University (Manhattan, KS) (one male and four females). The panelists' experience included 120 hr of general descriptive analysis training and a minimum of 2,000 hr of general sensory testing of beverages and food products. All had previously tested coffee. For this project, the panelists received further orientation to coffee using samples that may or may not be included in the study. In addition, a coffee training was held by a coffee training consultant from Sensory Spectrum™ with the purpose of increasing panelists' experience in coffee tasting. In total, more than 50 hr of training was conducted.

2.3 | Development and testing

2.3.1 | Lexicon development

The panel was informed about the objective of the orientation and lexicon sessions. It was decided that a 0–15 scale, with 0.5 increments would be used, and that the panelists would give intensities on that scale to the various reference material used for describing the attributes.

Throughout the process of the lexicon development, the panelists used a consensus process to determine the attributes, the definitions, references, and scores for those references. That technique has been used commonly in lexicon development (Cherdchu & Chambers, 2014; Heymann, Hopfer, & Bershaw, 2014; Pereira, Dionisio, Matos, & Patarata, 2015; Ting et al., 2015). According to the literature, to generate a lexicon it is necessary to collect a product frame of reference, generate the terms, review references and examples and finally develop a final descriptor list. Based on these steps the process to develop the coffee lexicon began with daily 1.5 hr sessions over the course of 1 month. Each of these sessions was designed with various activities to establish, discuss and refine the lexicon attributes, definitions, and references to avoid redundant information and overlapping descriptive terms (Drake & Civille, 2003; Lawless & Civille, 2013).

Phase 1 of any lexicon development is a combination of tasting samples to determine testing procedures and reviewing terms and references, if any, that have been provided by the sensory analyst. In this project that was done with Set 1 samples. Researchers proposed terms based on previous work (Di Donfrancesco et al., 2014; Sanchez & Chambers, 2015) and literature was consulted to include more terms that had been used in previous sensory research (Bhumiratana et al., 2011; Hayakawa et al., 2010; Narain, Paterson, & Reid, 2003). At this point, additional, terms, definitions, and references were proposed by the panel.

Panelists were asked to develop terms not exclusively belonging to the samples that were shown, but potentially to the wider coffee category based on their previous experiences with coffee.

The evaluation of the coffee samples begun with aroma, then flavor, and finally aftertaste. For aroma evaluation each panelist lifted the watch glass of a snifter and took 3–4 short sniffs to detect the smells that were present on the coffee samples. They could re-sniff as needed to evaluate the samples. Next, panelists took a sip of the sample to evaluate flavor. Again, they could re-taste as needed (with appropriate rinsing as necessary and obtaining new hot sample as needed). At least one sip had to be swallowed to allow for appropriate retronasal evaluation, but other sips were expectorated. Finally, they waited 15 s after expectorating to determine aftertaste. For each group of attributes that was proposed, references were introduced and then modified until each of the participants agreed with the references.

The panelists rinsed their mouths with water between samples and also had crackers, bagels and apples to clean their palate, if needed. For some of the sessions they breathed through a warm, clean, cotton terry cloth filter to clean their nasal passages.

Phase 2 of most lexicon development projects broadens understanding and evaluation to a larger range of samples to help expand the lexicon and incorporate additional attributes. It also allows panels to more easily examine overlapping attributes across a broader range of samples. In this research, Sets 2 and 3 served this purpose.

The coffee samples from set 2 (phase 2) were used for a coffee training that was held by a consultant from Sensory Spectrum™. The training consisted of five sessions of 2.5 hr over 5 days. In those sessions the panelists were able to practice with references from the existing commercial lexicon from Sensory Spectrum, Inc. After the five sessions new attributes and references were added to the original lexicon.

Further practice sessions were held with the coffee samples from set 3 (phase 2). For these training sessions a group of acids were added to the coffee lexicon after recommendations from coffee experts gathered by World Coffee Research (WCR) as advisors for this project and panelist' discussions. This group of acids were isovaleric, butyric, acetic, and malic. Further discussion from the panelists and researchers also lead to the addition of extra attributes that were found in the group of coffee samples present in this set, for example, coconut and the addition of "boozy" to whiskey. Also based on discussion from the panelists and researchers, a few attributes' names were changed to make them easier to interpret across the sensory panelists and coffee experts from WCR.

2.3.2 | Descriptive analysis of coffee samples to validate the lexicon

In Phase 3, six highly trained panelists from the SAC participated in the tasting sessions of 20 coffee samples (set 4 coffee samples). These samples were scored by the trained panel using the coffee lexicon to validate the attributes and references. From the complete list of attributes of the lexicon, the panel ultimately scored 50 terms that were present in those coffee samples (see "selecting the list of terms for specific tests" below). A statistical analysis was conducted using SAS (Version 9.2, SAS Institute, Inc., Cary, NC) to calculate the analysis of variance with the panel measures in three replications. Fisher's least significant difference test was used with a confidence level of 95%. The scores of the statistically significant attributes were mapped using principal components analysis (PCA) to determine how useful the developed terms were in explaining the diverse characteristics present in each of the samples.

2.4 | Selecting the list of terms for use in specific tests

Any lexicon of this length must be adapted to the particular use. To suggest that each study would need to use all 110 terms would be absurd. Not only would it be unwieldy and expensive, it would be unnecessary. A better use of the lexicon is as a base from which to determine the terms necessary for any particular use (phase 4). Potential ways to use the lexicon are multiple, but we provide two ways the lexicon are being used.

1 One way to use the lexicon is to establish a list of terms that are always scored (e.g., 20–40 terms chosen for that project or ongoing objective) and then provide a check all that apply list of the additional terms such that panelists can check and score those additional terms only if they apply to a particular sample. For example, in this case, for the validation test above, a list of 35 commonly used terms was established and other terms were put into a check all that apply list from which the panelists could check and score additional attributes that might appear in the samples. In a corporate environment, a company may want to establish a list of 30 terms (example only, the number of terms will vary) that it typically wants to score for each of its and its competitors coffee sample. However, it also wants to know if any unusual or special terms appear in any coffee blends. Thus, the sensory panel scores the 30 terms on a regular basis to track typical attributes, but the panel is allowed to check additional terms if they appear. If, for example, in one sample the panel notes a "blueberry" note that it normally does not track, it would check "blueberry" and then score that sample for blueberry. That information is conveyed back to the sensory analyst and developer who notes that the sample contains an Ethiopian Yirgacheffe, which occasionally does have a noticeable blueberry note.

2 A second way of using the lexicon is to shorten the lexicon to a screening set of attributes that may be critical for a certain application. In this case, for example, WCR will use the lexicon to screen more than 800 coffee varietals from around the world to select particular varietals that have positive environmental characteristics (e.g., coffee rust resistance, temperature tolerance) and meet sensory quality guidelines based on a limited number of particular sensory attributes. Because of the large number of varietals and the potential that at some point each varietal or cross-breeds of those varietals may be grown in up to 5 or 6 test plots around the world, a short list of terms is essential to conduct sensory testing on all the samples. A group of more than 15 coffee experts met in Manhattan, KS to review the lexicon and to determine what attributes were key to the coffee industry for screening cultivars. The experts were clear that the key attributes were not necessarily those that would be appropriate for other types of screening or testing, but were those most appropriate for WCRs cultivar screening.

3 | RESULTS AND DISCUSSION

3.1 | Lexicon

More than 100 coffee samples were tasted to develop a coffee lexicon, this document went through several reviews before concluding with a total of 110 attributes and references. A first phase of attribute development with the coffee samples from set 1 was conducted by the

TABLE 2 Initial list of lexicon terms generated by the descriptive panel from coffee set 1

Attributes	
Individual attributes	**Layered attributes**
Roasted	Spice Brown:
Malt	Nutmeg
Vanilla	Clove
Chocolate	Cinnamon
Overripe/near fermented	Green:
Burnt	Peapod
Brown	Herb-like
Vanillin	Hay-like
Floral	Fruity-Dark:
Sour aromatics	Prune
Acrid	Raisins
Honey	Fruity, Citrus:
Fruity	Lemon
Smoky	Lime
Pepper	Grapefruit
Syrup (maple)	Orange
Raw	Fruity, berry:
Ashy	Blackberry
Pungent	Raspberry
Molasses	Blueberry
Beany	Strawberry
Woody sweet aromatics	Brown Sweet:
Nutty	Caramelized
Tobacco	Fruity, non citrus:
Grain	Grape
Cocoa	Cherry
Fermented	Peach
Phenolic	Pear
Stale	Apple
Cardboard	Alcohol:
Rubber-like	Whiskey
Petroleum-like	Cordial
Medicinal	Musty:
Astringent	Dusty
Metallic	Earthy
Bitter	Damp
Sour	
Sweet	

trained panel. An initial set of individual attributes and "layered" attributes (those attributes that are part of a larger category of attriubutes) totalling 74 attributes including many of of the commonly found characteristics in coffee and some unique notes only found in one or a few coffee samples were determined based on this set (Table 2).

The initial list of terms were defined by the consensus technique, each of the attributes had a group of references that represent the high, medium, and/or low intensity in the 15-point scale used to evaluate the coffee samples in set 1. These terms are similar to those reported being used by trained panelists by Di Donfrancesco et al. (2014). There are some similarities among these attributes an those of Hayakawa et al. (2010), but there are a number of attributes

used by those authors that are not found in this lexicon primarily because they overlap with other attributes, are vague or general in nature, or have connotations associated with pleasantness, which are not descriptive in nature. Similarly, some terms are similar to those of Seo et al. (2009), but the present lexicon contains more specific flavor terms perhaps because the previous authors used mass-media terms and consumers as well as trained panelists to develop the lexicon they proposed.

A second phase consisted of examining 45 coffee samples from set 2 (Table 1). This phase was part of a training held by a consultant from Sensory Spectrum™. For this training the panel reviewed a commercial lexicon to explore additional attributes that could be included in the lexicon. They also received training sessions related to basic tastes and coffee roasting. At the end of this training several terms were revised including terms related to roast notes, a number of alternative references were included for terms already in the lexicon from phase 1, and seven additional attributes and appropriate references were added: green vegetative, green fresh, cigar tobacco, meaty-brothy, fermented-winey, papery and skunky.

Additional sessions were held to further evaluate and add references from 27 additional arabica and robusta samples from various parts of the world (set 3 from Table 1). During those lexicon development sessions, panelists were asked not to focus on existing attributes in the lexicon, but to taste the coffee samples and write down new attributes for aroma, flavor and aftertaste, and also were asked to explore attributes for texture and amplitude.

Once a consensus was reached that a new attribute needed to be included in the lexicon, references were suggested and intensities were given. For aroma, 19 attributes were added: hazelnut, almond, peanuts, dark chocolate, rose, jasmine, chamomile, pomegranate, pineapple, coconut, olive oil, green under-ripe, dark green, pipe tobacco, black tea, animalic, butyric acid, isovaleric acid, and malic acid. For flavor, 12 attributes were added: overall sweet, hazelnut, almond, peanuts, dark chocolate, chamomile, pomegranate, pineapple, green vegetative, dark green, black tea, and salty. In addition, five attributes were added for amplitude (coffee impact/fullness, overall impact, balance-blended, longevity, and fidelity) and three for texture (mouth drying, viscosity, and oily).

During this third phase, a few terms were added, and also some references were changed or modified to better describe each of the attributes. For example, for the term "nutty," a combination of almonds and hazelnuts were initially used as a reference. However, the panelists often found a slight rancid note in the hazelnuts and the reference was changed to a blend of almonds and walnuts, which gave a closer match to the overall "nutty" character.

Another example occurred with the attributes "roasted" and "bitter"; these two attributes had additional references added to enhance understanding of the scale and to provide more specific determination of the intensities. Whenever references were changed or added, the trained panel reviewed the intensity of the new reference to readjust the intensities of all references for that attribute.

Attributres such as "roasted" were modified to ensure that they were focused more on the intensity of roast character rather than the

degree of roast. This is important because dark roast is not a high level of roast, but a separate characteristic. It is common for panelists to some flavor attributes that seem to relate to color, with a direct measure of intensity as they would with color, but this may not be correct. For example, in this project, panelists initially scored degree of roasted character—from a light roast to a dark roast—a measure based on a color-like characteristic. However, "roastedness" does not simply change intensity from light to dark, it changes character. A dark roast contains some caramelized, burnt notes that are not present in a light roast. Thus, simply equating the degree of roast to degree of color (i.e., the more brown it is the darker the color) is not correct. There is not a linear relationship of light to dark roast. One can not simply add more brown notes and get a darker roast flavor because the flavor actually changes to different types of notes.

After the three phases of the coffee lexicon development a total of 110 attributes with their respective definitions and references was developed. This final list is shown in Table 3.

3.2 | Descriptive analysis to validate the coffee lexicon

Figure 1 shows the results of the validation with key terminology found in most coffee samples. Based on this test, the trained panel found differences among the coffee samples; these differences were visualized using PCA. Although the map shows that the attributes tend to group together in this case, it clearly shows that the attributes can effectively separate coffees, even those single varietal coffees grown in a similar location (San Adolfo, Colombia) in slightly different microclimates with some processing variation.

As seen on the map, samples A, C, and D were stretched in the area of the flavor attributes sweet and dried fruit. Sample E was characterized by having higher grain and sweet aromatics notes. The samples B, G, and F were close to the flavor attributes grain and nutty, and still on the side of the map with sweetness. Nebesny and Budryn (2006), stated that sweetness has a beneficial impact on the overall harmony of the taste of coffee which means that sweeter coffees will probably be better balanced than less sweet ones. These researchers also suggested that nutty notes are as important as the sweetness of the coffee. They explained that substances conferring nutty notes (mainly pyrazines) are mostly produced during the initial stage of roasting. However, a continuation of roasting contributes to the degradation and generation of other compounds that will lower the intensity perception of the nutty flavor (Nebesny & Budryn, 2006).

This situation could explain the other side of the PCA map where samples T and S were stretched together in the area of sour, metallic, petroleum, bitter, astringent, burnt, acrid, ashy, smoky, and pungent notes that could be characteristic of coffee that are more roasted coffees. Burnt aroma and bitter flavor attributes are characteristic of dark roasted coffees. Astringency and bitterness are generated by the thermal degradation of chlorogenic acids during the roasting process (Kreuml, Majchrzak, Ploederl & Koenig, 2013; Nebesny & Budryn, 2006). According to some authors, attributes such as burnt, smoky, astringent, and bitter are negative aroma and flavor attributes of cof-

fee, whereas, sweet, nutty, and fruity are positive attributes (Kreuml, et al., 2013; Nebesny & Budryn, 2006). As shown on Figure 1, the coffee lexicon allowed panelists to described specific characteristics that were present in the coffee samples; the developed attributes and references were successfully used to describe coffee sample diversity, even within one region of Colombia.

3.3 | Organization of the lexicon

Based on further discussion from the trained panel and researchers some of the attributes were organized depending on their complexity level in different categories. Table 4 shows those categories that were put together depending on the attribute characteristics and complexity.

The attributes that are classified in the first level are shown in Table 3 without any letter or italic font, examples of those are acrid, smoky or olive oil. Conversely, there are some attributes that are components of the first level attributes, those attributes represent a second level of complexity, for example, the attribute nutty is located on the first level of complexity, and it is later divided into three more specific attributes: hazelnuts, almonds, and peanuts. The second level is represented in Table 3 with a letter "a" as a superscript.

There is also a third level of complexity for some attributes, for example, fruity is part of the first level. Then fruity is divided into (for example), citrus fruit (second level), and citrus fruit at the same time is divided in lime, lemon, grapefruit, and orange (third level of complexity). This third level is represented in Table 3 with a letter "b" as a superscript and italic font.

The categories in the coffee lexicon help represent different characteristics that can be present in coffee samples from different varieties. These categories are hard to describe in charts, for this reason a "coffee tree" was created with the purpose of visually show the multiple levels of representation of the lexicon. This tree is shown in Figure 2. This was the first approach to understand the relationships between attributes, and also the complexity of the categories that help describe the aromas and flavors present in coffee. There are other ways to organize the attributes, such as wheels, but some complexity in the dynamics of the attributes is lost in any two-dimensional way of organizing the attributes.

3.4 | Use of the lexicon

This research highlighted two ways to use the lexicon. In the first case, the validation study, all 110 terms were used, with 35 terms being selected by the panel before the validation started and scored for every sample. The other terms were included in a check all that apply (CATA) format and only those terms that were checked were then scored by the panel. Because the ballot was computerized, using the CATA checklist automatically added any attributes that were checked to the list of terms to score for that product to all panelists' scorecards. However, this also has been handled on paper ballots simply by having the panel leader ask for additional terms to score at the end of the usual scoring for the product (see for example, Appendix 1). The use of a shortened ballot (fewer terms scored for every product and a CATA format) allows all terms to be included for every product, but does not

TABLE 3 Attributes and references for the coffee lexicon

Sensory attribute	Definition	References and intensities*
Raw	Aromatics associated with uncooked products	Flavor Fisher Whole Natural Almonds = 3.0
Roasted	Brown impression characteristic of products cooked to a high temperature by dry heat. Does not include bitter or burnt notes	Aroma/Flavor Le Nez du café n. 34 "roasted coffee": 7.5(a) Medium roasted peanuts = 6.5 (f)
Dark Roast	Dark brown impression characteristic of products cooked to a high temperature by dry heat Includes some bitter and burnt notes that are integral to the product	Aroma/flavor Dark roasted peanuts = 9.5 (f)
Burnt	The dark brown carbon impression of an over-cooked or over-roasted product that can be sharp, bitter, and sour	Aroma/Flavor Benzyl disulfide = 4.5 (a) Alf's Red Wheat Puffs (2 pieces in the mouth) = 8.0 (a), 3.0 (f) Over Roasted Peanuts/Burnt = 7.5 (f)
Acrid	The sharp, pungent, bitter, acidic aromatics associated with products that are excessively roasted or browned	Aroma/Flavor Alf's Red Wheat Puffs = 3.0 (a), 3.0 (f) Wright's Liquid Smoke = 9.5 (a)
Smoky	An acute pungent aromatic that is a product of combustion of wood, leaves or non-natural product	Aroma/Flavor Benzyl disulfide = 3.5 (a) Wood Ashes = 5.0 (a) Diamond Smoked Almonds = 6.0 (a), 5.0 (f)
Ashy	Dry, dusty, dirty smoky aromatics associated with the residual of burnt products	Aroma/Flavor Benzyl disulfide = 4.0 (a) Paper ashes = 4.0 (a) Gerkens Midnight Black (BL80) cocoa Powder = 2.5 (a), 3.5(f)
Woody	The sweet, brown, musty, dark aromatics associated with a bark of a tree	Aroma/Flavor Diamond Shelled Walnuts = 4.0 (a), 4.0(f) Popsicle sticks = 7.5 (a)
Grain	Light brown, dusty, musty, sweet aromatics associated with grains	Aroma/Flavor Cereal Mix (dry) = 5.0 (a), 8.0 (f)
Malt	Light brown, dusty, musty, sweet, sour and or slightly fermented aromatics associated with grains	Aroma/Flavor Post Grape Nuts Cereal = 3.5(a), 8.0(f)
Spices/Pungent[a]	The sharp physically penetrating sensation in the nasal cavity	Aroma Majestic Mountain Sage Orange, Brazil Essential Oil = 5.0
Spices/Spice Brown[a]	Sweet, brown aromatics associated with spices such as cinnamon, clove, nutmeg, allspice	Aroma/Flavor Private Selection cinnamon sticks = 3.0 Private Selection Nutmeg/Clove = 7.0 Spice brown complex = 10.5 (a), 10.5 (f)
Spice Brown/Nutmeg[b]	Sweet, brown, woody, pungent, petroleum like heavy aromatic with a slightly lemony impression	Aroma McCormick ground nutmeg = 9.0
Spice Brown/Clove[b]	A sweet, brown spicy, pungent, floral, citrus, medicinal, and slightly minty aromatic	Aroma Le Nez du café "clove" n.7 = 6.5
Spice Brown/Cinnamon[b]	A sweet, brown, slightly woody, slightly pungent, spicy aromatic	Aroma McCormick cinnamon = 13.0
Spices/Pepper[a]	Spicy, pungent, musty, and woody aromatics characteristic of ground black pepper	Aroma McCormick Ground Black Pepper = 13.0
Spices/Anise[a]	A pungent, sweet, brown, caramelized aromatic that may contain petroleum, medicinal, and floral notes	Aroma Tone's Pure Anise extract: 7.5
Sweet	A fundamental taste factor of which sucrose is typical	Flavor 1% Sucrose Solution = 1.0
Honey	Sweet, light brown, slightly spicy aromatics associated with honey	Aroma/Flavor Busy Bee Honey in water = 6.0 (a), 6.5 (f)
Maple Syrup	A woody, sweet, caramelized, brown, slightly green	Aroma/Flavor

TABLE 3 (continued)

Sensory attribute	Definition	References and intensities*
	aromatic associated with maple syrup	Le nez du café Maple Syrup essence (n.24) = 7.0 (a) Maple Grove Farms Pure Maple Syrup = 5.0 (f)
Molasses	Dark caramelized top notes which may include slightly sharp, acrid and sulfur notes characteristic of molasses	Aroma/Flavor Grandma's molasses = 6.5 (a), 6.5 (f)
Sweet Aromatics	An aromatic associated with the impression of a sweet substance	Aroma/Flavor Fisher Scientific Vanillin in water (0.5 g/250 ml) = 5.0 (a) Fisher Scientific Vanillin in water (2 g/250 ml) = 7.0 (a) Nabisco Lorna Done Cookies = 5.0 (f)
Sweet Aromatics/Overall Sweet[a]	The perception of a combination of sweet taste and aromatics	Flavor Post Shredded Wheat 1.5 General Mills Wheaties = 3.0 Nabisco Lorna Doone Cookies 5.0
Sweet Aromatics/Brown Sugar[a]	A rich, full round sweet aromatic impression characterized by some degree of darkness	Aroma/Flavor C&H Golden brown sugar = 6.0 (a) C&H Golden brown sugar in water = 5.0 (f)
Brown Sugar/Caramelized[b]	A round full bodied medium brown sweet aromatic associated with cooked sugars and other carbohydrates. Does not include burnt or scorched notes	Aroma/Flavor Le Nez du café n. 25 "caramel" = 8.0 (a) 6% C&H Golden brown sugar solution in water = 4.5 (f) C&H Golden brown sugar in water = 2.5 (f) Caramelized sugar = 7.5 (f)
Sweet Aromatics/Vanilla[a]	A woody, slightly chemical aromatic associated with vanilla bean which may include brown, beany, floral, and spicy	Aroma/Flavor Le nez du café Vanilla (n.10) essence = 2.5 (a) Spice Island Bourbon Vanilla Bean = 5.5 (a) McCormick pure vanilla extract in Hiland whole milk = 3.0 (f)
Sweet Aromatics/Vanillin[a]	An extremely sweet non-natural aromatic often associated with vanilla, cotton candy, and marshmallows	Aroma Fisher Scientific Vanillin in water (2 g/250 ml)
Nutty	A combination of slightly sweet, brown, woody, oily, musty, astringent, and bitter aromatics commonly associated with nuts, seeds, beans, and grains	Aroma/Flavor Le Nez du café n. 29 "roasted hazelnuts" = 7.5(a) Mixture of Diamond Sliced Almonds and Diamond Shelled Walnuts = 7.5 (f)
Nutty/Hazelnut[a]	A woody, brown, sweet, musty/earthy, slightly cedar aromatic. May include floral, beany, oily, astringent, bitter flavor notes	Aroma/Flavor 1/8 tsp McCormick Imitation Hazelnut extract in 1 cup whole milk= 3.5 (f) 1/4 tsp McCormick Imitation Hazelnut extract in 1 cup whole milk = 6.0 (f) Le Nez du café n. 29 "roasted hazelnuts" = 5.5 (a)
Nutty/Almond[a]	A sweet light brown, woody, buttery, aromatic with floral/fruity notes which may include rose, cherry, and apricot. It is also astringent and may slightly smoky	Aroma Le Nez du Café n.27 "roasted almonds" = 7.0
Nutty/Peanuts[a]	A sweet, light brown, oily, somewhat musty/dusty, beany aromatic which may be slightly astringent	Aroma/Flavor Roasted peanuts (shelled blanched peanuts from bulk)
Cocoa	A brown, sweet, dusty, musty, often bitter aromatic associated with cocoa bean, powdered cocoa, and chocolate bars	Aroma/Flavor Hershey's Cocoa Powder in water = 7.5 (a), 5.0 (f)
Chocolate	A blend of cocoa including cocoa butter and dark roast aromatics at varying intensities	Aroma/Flavor Nestlè Semi-sweet chocolate chips (taste 1 chip) = 8.0 (a), 7.5 (f)
Chocolate/Dark Chocolate[a]	A high-intensity blend of cocoa and cocoa butter that may include dark roast, spicy, burnt, must notes which include increased astringency and bitterness	Aroma/Flavor Lindt Excellence Dark Chocolate bar 90% cocoa: 6.0 (a), 11.0 (f) Dove dark chocolate = 8.5 (f)

(continues)

TABLE 3 (continued)

Sensory attribute	Definition	References and intensities*
Floral	Sweet, light, slightly fragrant aromatic associated with (fresh) flowers	Aroma/Flavor Diluted Welch's White Grape juice, diluted 1:1 = 6.0 (f), 5.0 (a) Carnation essence oil: 7.5 (a) Le Nez du café n.12 "coffee blossom" = 8.0 (a)
Floral/Rose[a]	A sweet, soft, slightly musty/dusty floral fragrance associated with fresh or dried roses	Aroma Rose water = 5.0
Floral/Jasmine[a]	An intense, slightly pungent, sweet, floral aromatic with underlying green, musty/dusty notes	Aroma Jasmine extract = 8.5
Floral/Chamomile[a]	Sweet, slightly floral/fruity somewhat woody, green associated with chamomile	Aroma/Flavor Celestial Chamomile tea (brewed) = 5.0 (a) 5.0 (f)
Fruity	A sweet, floral aromatic blend of a variety of ripe fruits	Aroma/Flavor Juicy Juice Nestle All Natural 100% Kiwi Strawberry diluted (1:1) = 4.0 (f), 3.0 (a) Le Nez du café n.17 "Apple" = 7.0 (a)
Fruity/Dried Fruit[a]	An aromatic impression of dried fruit that is sweet and slightly brown associated with dried plums and raisins	Aroma/Flavor Diluted Sunsweet prune juice = 3(a), 4.5 (f) 1/4 cup Sun-Maid raisins and 1/4 cup of Sun Maid prunes (chopped), 3/4 cup of water = 5.0 (a), 6.0 (f)
Dried Fruit/Prune[b]	The aromatic impression of dark fruit associated with dried plums that are sweet, slightly brown, floral, musty, and overripe	Aroma/Flavor 1/2 cup of Sun Maid prunes (chopped), 3/4 cup of water = 4.5 (a), 5.0 (f)
Dried Fruit/Raisins[b]	The concentrated sweet, somewhat sour, brown, fruity, floral aromatic characteristic of dried grapes	Aroma/Flavor 1/2 cup Sun Maid raisins (chopped), 3/4 water = 6.0 (a), 5.5 (f)
Fruity/Citrus Fruit[a]	The citric, sour, astringent, slightly sweet, peely, and somewhat floral aromatics which may include lemons, limes, grapefruits, and oranges	Aroma/Flavor Peels of lemon and lime = 4.5 (a) Grapefruit peel = 7.5 (a) Five Alive Frozen Concentrate = 6.5 (f)
Citrus Fruit/Lemon[b]	The citric, sour, astringent, slightly sweet, peely, and somewhat floral aromatics associated with lemon	Aroma/Flavor Fresh lemon juice = 5.0 (a), Fresh lemon juice in water (1:4) = 7.0 (f) Le Nez du café n.15 "lemon" = 5.5 (a)
Citrus Fruit/Lime[b]	The citric, sour, astringent, bitter, green, peely, sharp, and somewhat floral aromatics associated with limes	Aroma/Flavor Lime peel: 6.5 (a) Rea Lime 100% Lime Juice = 7.0 (f)
Citrus Fruit/Grapefruit[b]	The citric sour, bitter, astringent, peely, sharp, slightly sweet aromatics associated with grapefruit	Flavor Kroger 100% White Grapefruit Juice= 13.5 (f)
Citrus Fruit/Orange[b]	The citric, sweet, floral, slightly sour aromatic associated with oranges, may include bitter, peely, and astringent notes	Flavor Orange juice Tropicana Pure premium, "Oxygen," no pulp = 10.0 (f)
Fruity/Berry[a]	The sweet, sour, floral, sometimes heavy aromatic associated with a variety of berries such as blackberries, raspberries, blueberries, strawberries	Aroma/Flavor Private Selection Triple Berry = 9.0 (f), 10.0 (a) Welch's Farmers Pick Blackberry juice = 7.5 (f)
Berry/Blackberry[b]	Sweet, dark, fruity, floral, slightly sour, somewhat woody aromatics associated with blackberry	Flavor Smuckers Blackberry Jam = 5.5
Berry/Raspberry[b]	Light sweet, fruity, floral, slightly sour, and musty aromatics associated with raspberries	Flavor Jell-O Raspberry Gelatin (dry) = 6.5
Berry/Blueberry[b]	Slightly dark, fruity, sweet, slightly sour, musty, dusty, floral aromatics associated with blueberry	Aroma/Flavor Oregon Blueberries in light syrup canned juice = 6.5 (a) Oregon Blueberries canned = 6.0 (f) Oregon Blueberries in light syrup canned = 6.0 (f)
Berry/Strawberry[b]	Somewhat sweet, slightly sour, floral, fruity, frequently viney aromatics associated with strawberry	Aroma/Flavor Chandler Frozen Strawberries = 13(a), 6 (f)

(continues)

TABLE 3 (continued)

Sensory attribute	Definition	References and intensities*
Berry/Pomegranate[b]	Sour, sweet fruity aromatics that may be somewhat dark, musty and earthy, reminiscent of dark fruits, and root vegetables such as beets and carrots; may also have an astringent mouthfeel	Aroma/Flavor KNUDSEN Organic Just Pomegranate Juice = 5.5 (a), 7.5 (f)
Berry/Grape[b]	The sweet fruity, floral, slightly sour, musty aromatics commonly associated with grapes	Flavor Welch's Concord Grape Juice diluted (1:1) = 5.0
Berry/Cherry[b]	The sour fruity, slightly bitter, floral aromatics associated with cherries	Flavor RW Knudsen Cherry Juice diluted = 4.0
Fruity/Stone Fruit[a]	A sweet, light fruity, somewhat floral, sour, or green aromatics which may include—apples, grapes, peaches, pears, cherry	Aroma Le Nez du café n.17 "Apple" = 7.0 (a)
Stone Fruit/Peach[b]	The floral perfuming, fruity, sweet, slightly sour aromatics associated with peaches	Aroma/Flavor Fresh Peach Pit = 8.0 (a) Jell-O Peach Gelatin (dry) = 7.0 (f)
Stone Fruit/Pear[b]	The sweet, slightly floral, musty, woody, fruity, aromatics associated with pears	Flavor Jumex Pear Nectar—can = 7.5
Stone Fruit/Apple[b]	A sweet, light, fruity, somewhat floral, aromatic commonly associated with fresh or processed apples	Aroma/Flavor Le Nez du café n.17 "Apple" = 5.0 (a) Gerber Apple sauce = 6.0(f)
Fruity, Tropical/Pineapple[b]	Sweet, slightly sharp fruit aromatic associated with pineapple	Aroma/Flavor Dole pineapple juice diluted (1:1) = 6.5 (a) 6.0 (f)
Fruity, Tropical/Coconut[b]	Slightly sweet, nutty, somewhat woody aromatic associated with coconut	Aroma Coconut imitation extract = 7.5
Over-ripe	An aromatic of fruit or vegetable past their optimum ripeness which may include sweet, slightly sour, damp, musty earthy characteristics	Aroma/Flavor Overripe banana (1 week not refrigerated): 6.5 (a), 6.5 (f)
Fermented	Pungent, sweet, slightly sour, sometimes yeasty, alcohol like aromatics characteristics of fermented fruits or sugar or over-proofed dough	Aroma Guinness Dark Stout beer = 5.0 Blackberry WONF 3RA654 (drop on cotton ball) = 7.0 Silage = 7.0
Sour Aromatics	An aromatic associated with the impression of a sour product	Aroma Bush Pinto Beans (canned) = 2.0
Olive Oil	A light oily aromatic which may have buttery, green, peppery, bitter, and sweet aromatics	Aroma Bertolli Extra Virgin Olive Oil: 8.5
Green	Aromatic characteristic of fresh plant-based material. Attributes may include leafy, viney, unripe, grassy, peapod	Aroma/Flavor Parsley water = 9.0 (a), 6.0 (f)
Green/Under-ripe[a]	An aromatic found in green/under-ripe fruit	Aroma Grapefruit peel: 7.5
Green/Peapod[a]	Green aromatics that include sweet, beany, fresh, raw, musty/earthy	Aroma Le nez du café n. 3 "Garden peas" = 7.0
Green/Herb-like[a]	The aromatic common associated with green herbs that may be characterized as sweet, slightly pungent, slightly bitter, and may or may not include green or brown notes	Aroma/Flavor Mixture of McCormick bay leaves, McCormick ground thyme, and McCormick basil = 6.0 (a), 5.0(f)
Green/Hay-like[a]	Slightly sweet dry dusty aromatic with a slight green character associated with dry grasses	Aroma/Flavor McCormick parsley Flakes = 7.5 (a), 7.5 (f)
Green/Vegetative[a]	Sharp slightly pungent aromatics associated with green/plant/vegetable matter such as parsley, spinach, pea pod, etc.	Flavor Green Giant Canned asparagus = 6.0
Green/Fresh[a]	A green aromatics associated with newly cut grass and leafy plants; characterized by sweet and pungent character	Aroma Fresh green grass = 7.0

TABLE 3 (continued)

Sensory attribute	Definition	References and intensities*
Green/Dark Green[a]	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	Aroma/Flavor Green giant Green beans water: 5.0 (a), 6.0 (f) Del Monte Leaf Spinach water: 7.0 (a), 6.0 (f)
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	Aroma/Flavor Bush Pinto Beans (canned) = 7.0 (a), 7.5 (f)
Tobacco	The brown, slightly sweet, slightly pungent aromatic associated with cured tobacco	Aroma Le Nez du café n. 33 "pipe tobacco" = 5.0 Camel cigarettes (Turkish and Domestic blend) = 7.0
Tobacco/Cigar[a]	The aromatics associated with cigar tobacco	Aroma Cigar tobacco = 10.5 Unscented pipe tobacco = 10.5
Tobacco/Pipe[a]	The brown, sweet, slightly pungent, fruity, floral, spicy aromatics associated with cured tobacco	Aroma Carter Hall Pipe Tobacco: 6.5
Tobacco/Black Tea[a]	Green tea leaves that have been oxidized, or fermented, imparting a characteristic reddish brew	Aroma/Flavor Lipton black tea leaves = 8.0 (a) Lipton Black tea (brewed) = 7.0 (f)
Animal/Animalic[a]	A combination of aromatics associated with farm animals and lives animal habitation	Aroma Unflavored gelatin = 3.0
Animal/Meaty-Brothy[a]	The aromatic associated with boiled meat, soup, or stock. Weak meaty notes	Flavor Campbell's beef broth = 9.5
Fermented-Winey	Sharp, pungent, somewhat fruity alcohol-like aromatic associated with red wine	Flavor Yellow Tail Cabernet Sauvignon = 10.0
Distilled-Alcohol	A colorless pungent chemical-like aromatics associated with distilled spirits or grain products	Aroma Absolute Vodka 80 Proof = 5.0
Distilled-Boozy/Whiskey[a]	Aromatics associated with distilled products from fermented grain mash	Aroma Jack Daniel's Whiskey Old No.7 = 5.5 (a)
Musty/Dusty[a]	The aromatics associated with dry closed air spaces such as attics and closets. May be dry, musty, papery, dry soil or grain	Aroma Kretschmer Wheat Germ = 5.0 2, 3, 4—Trimethoxybenzaldehyde = 10.0
Musty/Earthy[a]	Somewhat sweet, heavy aromatics associated with decaying vegetation and damp black soil	Aroma Miracle Soil Potting soil = 9.0 Le Nez du café n.1 "earthy" = 12.0
Musty/Moldy-Damp[a]	The aromatics associated with damp closed spaces or basements. May be musty, sharp, and slightly green	Aroma 2-Ethyl-1-Hexanol 10,000 ppm = 6.0 (a) 2,3,5,6—Tetrachloroanisole = 10.0 (a)
Musty/Phenolic[a]	The aromatic described as damp, musty, and like animal hide. Reminiscent of a tack room	Aroma Phenyl acetic acid = 6.0
Stale	The aromatics characterized by lack of freshness	Aroma/Flavor Mama Mary's Pizza Crust = 4.5 (a), 4.0 (f)
Papery	The aromatics associated with white paper cups	Flavor Pure Brew Coffee Filters = 2.5 (f)
Cardboard	The aromatic associated with cardboard or paper packaging	Aroma Cardboard = 7.5
Chemical/Rubber[a]	A dark heavy slightly sharp and pungent aromatic associated with rubber	Aroma A&W Rubber bands = 5.0
Chemical/Petroleum[a]	A specific chemical aromatic associated with crude oil and its refined products that have heavy oil characteristics	Aroma Vaseline Petroleum Jelly: 3.0
Chemical/Medicinal[a]	A clean, sterile aromatic characteristic of antiseptic-like products such as Band-Aids, alcohol, and iodine	Aroma Le Nez du café n. 35 "medicinal" = 6.0 Johnson & Johnson Band-Aid adhesive Bandage (2.5 × 7.6 cm size) = 6.0

TABLE 3 (continued)

Sensory attribute	Definition	References and intensities*
Chemical/Skunky[a]	A combination of aromatics associated with skunks. Somewhat like the aroma of urine	Aroma/Flavor Latex Balloon = 2.5 (a)
Metallic	An aromatic and mouthfeel associated with tin cans or aluminum foil	Flavor 0.10% Potassium Chloride Solution = 1.5
Bitter	The fundamental taste factor associated with a caffeine solution	Flavor 0.02% Caffeine Solution = 3.5 0.035% Caffeine Solution = 5.0 0.05% Caffeine solution = 6.5 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	Flavor 0.015% Citric Acid Solution = 1.5 0.05% Citric Acid Solution = 3.5
Salty	A fundamental taste factor of which sodium chloride is typical	Flavor 0.15% Sodium Chloride Solution = 1.5
Butyric Acid	A sour, fermented dairy aromatic associated with certain aged cheeses such as parmesan	Aroma/Flavor 0.4 μl/l Butyric acid solution = 2.5 (a) 3.0 (f)
Citric Acid	A mild, clean, sour aromatic with slight citrus notes accompanies by astringency	Aroma/Flavor 0.025% Citric Acid Solution = 0 (a), 2.5 (f) 0.05% Citric Acid Solution = 0 (a), 3.5 (f)
Isovaleric Acid	A pungent, sour aromatic associated with sweaty, perspiration generated foot odor and certain aged cheeses such as Romano	Aroma/Flavor 0.2 μl/l Isovaleric acid solution = 3.0 (a) 4.0 (f)
Malic Acid	A sour, sharp somewhat fruity aromatic accompanied by astringency	Flavor 0.5 g/l malic acid solution = 3.0 1 g/l malic acid solution = 5.0
Acetic Acid	A sour astringent, slightly pungent aromatic associated with vinegar	Aroma/Flavor 0.5% acetic acid solution = 2.0 (a), 2.0 (f) 1% acetic acid solution = 2.5 (a), 3.0 (f) 2% acetic acid solution = 3.0 (a) 4.5 (f)
Overall Impact	The maximum overall sensory impression during the whole tasting time	Starbucks Dark French Roast Coffee (brewed) = 12.0 (f) Folgers Classic Roast Ground Coffee (brewed) = 6.0 (f) Illy Whole Bean Dark Roast Coffee (brewed) = 5.0 (f)
Balance/Blended	The melding of individual sensory notes such that the products present a unified overall sensory experience as opposed to spikes or individual notes	Folgers Classic Roast Ground Coffee (brewed) = 8.0 (f) Starbucks Dark French Roast Coffee (brewed) = 6.0 (f) Illy Whole Bean Dark Roast Coffee (brewed) = 5.0 (f)
Longevity	The time that the full integrated sensory experience sustains itself in the mouth and after swallowing	Starbucks Dark French Roast Coffee (brewed) = 9.0 (f) Illy Whole Bean Dark Roast Coffee (brewed) = 7.0 (f) Folgers Classic Roast Ground Coffee (brewed) = 4.0 (f)
Coffee ID (Fullness)	The foundation of flavor notes that gives substance to the product. The perception of robust flavor that is rounded with body. A full-rounded coffee identity	Starbucks Dark French Roast Coffee (brewed) = 11.0 (f) Folgers Classic Roast Ground Coffee (brewed) = 8.0 (f) Illy Whole Bean Dark Roast Coffee (brewed) = 7.0 (f)
Fidelity	The total sensory experience of the trueness of the product in the stated context; its believability as coffee. Note: Does not imply any particular quality of coffee. Judged only when there is a stated context, e.g., fidelity of the sample in the context of "full-bodied coffee with peach, apricot, honey notes."	Starbucks Dark French Roast Coffee (brewed) = 11.0 (f) Folgers Classic Roast Ground Coffee (brewed) = 8.0 (f) Illy Whole Bean Dark Roast Coffee (brewed) = 7.0 (f)
Mouth Drying	A drying puckering or tingling sensation on the surface and/or edge of the tongue and mouth	Texture: 0.0 5% Alum Solution = 2.5 0.07% Alum Solution = 3.5
Viscosity	The thick feel of the beverage as you press your tongue through it	Texture: 5% sucrose solution = 2.0 Campbell's Tomato Juice = 4.0
Oily	The amount of fat/oily film left on surfaces of mouth after swallowing or expectorating	Texture: Horizon Organic low-fat UHT milk = 3.0 Kroger Half n' Half = 6.0

[ab]Attributes that do not have a superscript are first level attributes, those with a superscipt "a" are second level attributes underneath a first level (e.g., citrus underneath fruity), and those with a superscript "b" are third level attributes underneath a second level (e.g., orange undeath citrus).

*Intensities are based on a 0-15 numerical scale with 0.5 increments, where 0 means "none" and 15 means "extremely strong."

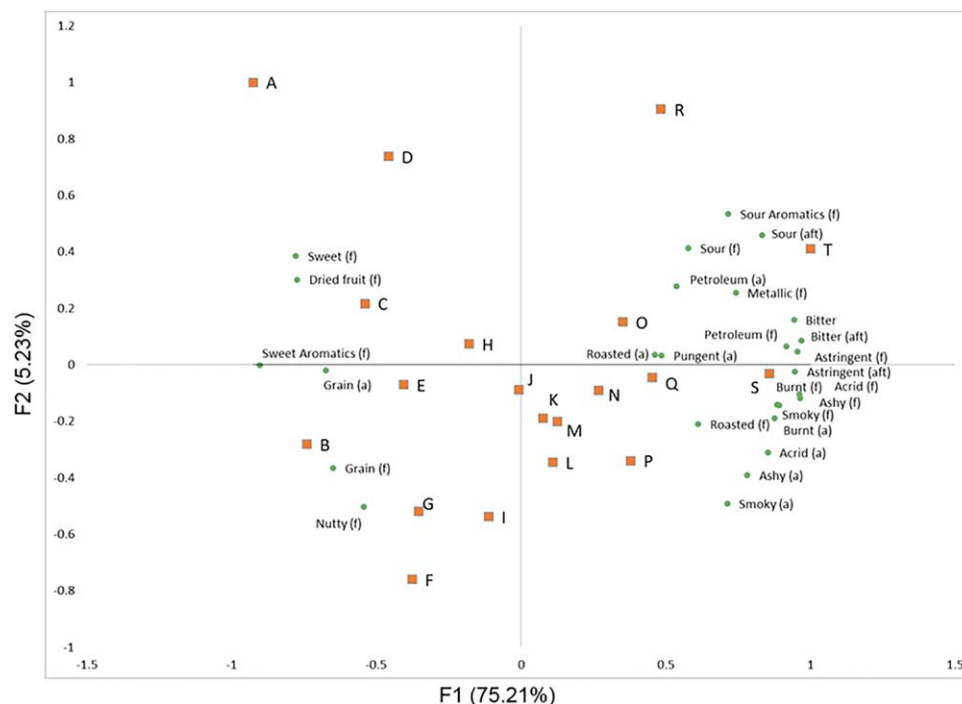Brewed coffee references are brewed at 5.5g ground coffee per 100ml water.

FIGURE 1 Principal Component Analysis (PCA) of the trained panel evaluations for aroma (a), flavor (f), and aftertaste (aft) attributes of various coffee samples

require that each one be scored every time, which reduces time spent in panel.

In the second format a shortened list of key attributes was selected by experts to focus only on a few attributes that were essential to the objective of the project and to allow for rapid assessment of samples. The 11 terms selected by the expert coffee group (Table 4) including the researchers and the experts selected by WCR and the Specialty Coffee Association of America were: Coffee Impact (Fullness), Woody, Roasted, Sour (taste), Sweet (taste), Sweet aromatics, Green, Bitter, Nutty, Fruity, and Floral. Ranges of appropriate levels of those attributes can be set using existing well established varietals and can be based on any number of criteria such as price, popularity with buyers and consumers, high cupping scores, etc. Those ranges can then be used to determine whether the existing cultivars or new varietals fall within the set standard ranges. Other objectives could use the same format, with the same or different key attributes and similar "standard ranges" to maintain quality. A similar system was employed by Vázquez-Araújo, Chambers, and Carbonell-Barrachina (2012) who developed a lexicon for industry professionals to use in evaluation of turron.

3.5 | The concept of a "living" lexicon

Lexicons are dependent on the samples used in the lexicon. An important concept introduced in this lexicon development project, and one that should be carried through even in the results, is that at each phase, new attributes were added and modified to produce an improved lexicon. The samples included in this study represent only a portion of the coffee samples available in the world. The samples were primarily

TABLE 4 TABLE 4 Different levels of complexity present in the coffee lexicon

Attributes		
Level 1	Level 2	Level 3
Spices	Pungent	
	Spice Brown:	Nutmeg
		Clove
		Cinnamon
	Black Pepper	
	Anise	
Sweet Aromatics	Overall Sweet	
	Brown sweet	Caramelized
	Vanilla	
	Vanillin	
Nutty	Hazelnut	
	Almond	
	Peanuts	
Chocolate	Dark Chocolate	
Floral	Rose	
	Jasmine	
	Chamomile	
Green	Under-ripe	

(continues)

TABLE 4 (continued)

Attributes		
Level 1	Level 2	Level 3
	Peapod	
	Herb-like	
	Hay-like	
	Vegetative	
	Fresh	
	Dark Green	
Fruity	Dried Fruit:	Prune
		Raisins
	Citrus Fruit:	Lemon
		Lime
		Grapefruit
		Orange
	Berry Fruit:	Blackberry
		Raspberry
		Blueberry
		Grape
		Cherry
	Stone Fruit:	Peach
		Pear
		Apple
	Other fruit:	Pineapple
		Coconut
Tobacco	Cigar	
	Pipe	
	Black tea	
Distilled/Boozy	Whiskey	
Musty	Dusty	
	Earthy	
	Moldy damp	
	Phenolic	
Animal	Animalic	
	Meaty/Brothy	
Chemical	Rubber	
	Petroleum	
	Medicinal	
	Skunky	

Arabica coffees with Robusta samples represented primarily by commercial blends that often contained Arabica beans. Similarly, there were few "distressed" samples used in the development of this lexicon.

TABLE 5 Example of a set of terms chosen for evaluation for a research project: the 11 attributes chosen by researchers and World Coffee Research experts for evaluation of coffee varietals

Attributes
Coffee Impact (Fullness)
Woody
Roasted
Sour (taste)
Sweet (taste)
Sweet aromatics
Green
Bitter
Nutty
Fruity
Floral
Figures

Thus, terms mostly associated with off-notes related to deterioration, abuse, or age may not be present in this lexicon. Those terms and others clearly will need to be added to future iterations of the lexicon if it is to be used with samples that exhibit problems not found in these samples. This leads to the concept that lexicons must be "living," that is, they must be allowed to grow, change, and adapt over time as new samples are tested, new references arise, or new understanding of the dimensions of attributes arise.

This does not change the importance or need for initial lexicons; in fact Di Donfrancesco, Koppel, and Chambers (2012) actually called their lexicon for dog food "An initial lexicon . . ." suggesting that lexicons are not static. Studies of additional logical arrays of samples that add key, important terms to expand, adapt, and nuance existing lexicons should be published when they are needed.

4 | CONCLUSIONS

An extensive lexicon including attributes, references, and intensities was developed for sensory evaluation of coffee. The lexicon was successfully used to evaluate coffee samples. Future studies should validate the use of this lexicon with different sensory panels, as well as samples from various parts of the world that contain unique features that use specific attributes such as blueberry or lime. This lexicon should be considered a living document that can be added to or modified over time when needed. The final version of the lexicon includes 110 individual attributes although some are useful for both aroma and flavor resulting in more than 110 possible evaluations per sample. In future research it will be necessary to narrow this list down to have appropriate sub lexicons for specific objectives such as evaluation of coffee varietals, processing evaluation, fermentation, degree of roasting, assessment of coffee defects, and even a coffee lexicon for specific kinds of coffee preparations; for example, a sub lexicon for espresso or
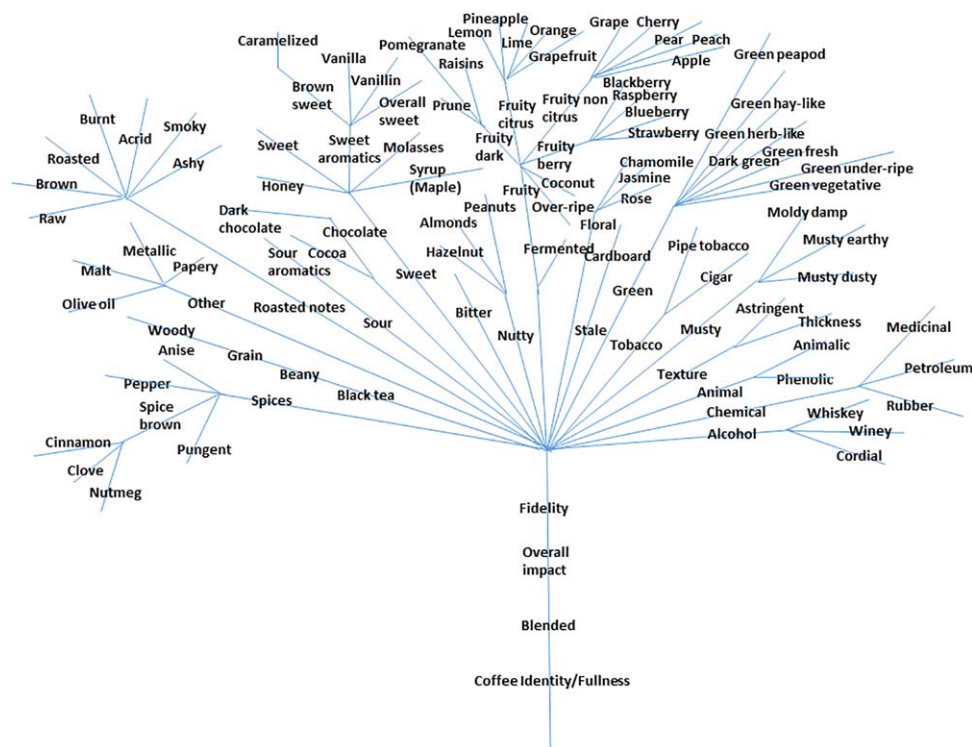
Pineapple Grape Cherry
Lemon Orange
Caramelized Pomegranate Lime Pear Peach
Vanilla Raisins Grapefruit Apple Green peapod
Brown Vanillin Blackberry
sweet Overall Prune Fruity Fruity non Raspberry Green hay-like
Burnt Smoky sweet citrus citrus Blueberry
Roasted Acrid Ashy Sweet Sweet Molasses Fruity Fruity Strawberry Green herb-like
Brown aromatics dark berry Green fresh
Honey Syrup Chamomile Dark green Green under-ripe
Raw (Maple) Coconut Jasmine Green vegetative
Dark Peanuts Fruity Rose Moldy damp
Metallic chocolate Chocolate Almonds Over-ripe Floral Pipe tobacco Musty earthy
Malt Papery Sour Cocoa Hazelnut Fermented Cardboard Cigar Musty dusty
Olive oil aromatics Sweet Green
Other Sour Bitter Astringent Thickness Medicinal
Woody Roasted notes Nutty Stale Musty Animalic
Anise Grain Tobacco Texture Phenolic Petroleum
Pepper Beany Black tea Animal Whiskey Rubber
Spice Spices Chemical Winey
brown Pungent Alcohol Cordial
Cinnamon
Clove
Nutmeg

Fidelity

Overall
impact

Blended

Coffee Identity/Fullness

FIGURE 2 Tree Diagram showing relationships among attributes in a base, branch, and stem arrangement. The base of the tree represents the fundamental attributes associated with all samples, the major branches represent major categories of attributes, and smaller branches and stems represent progressively smaller categories and sometimes, characteristics that are less often noted in coffee samples

cappuccino. Another purpose of future studies is to find a way to visually show the multiple levels of organization that are represented in the coffee lexicon. To accomplish this goal it is necessary to establish the relationships among attributes, this will help to understand the complexity of the coffee aroma and flavor from the sensory point of view.

The lexicon developed in this study is relevant for sensory scientists but also for industry and coffee producers. Coffee descriptions can be made based on this terminology and can be used for consumer education and also in product development of beverages related to coffee.

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