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Coffee is more than flavor, the creation of a coffee character wheel

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Abstract

Coffee is more than flavor. Though many articles focus on assessing coffee's flavor, the coffee characteristics for the acidity, mouthfeel, and aftertaste form part of the industry-standard assessment. The existing coffee flavor wheels provide commonly used terms for the assessment. However, there is limited discussion about the coffee acidity, mouthfeel, and aftertaste character. In this study, the terms used for describing coffee acidity, mouthfeel, and aftertaste were collated from published literature, coffee sensory panels, and internet material. A total of 679 unique sensory terms were identified for acidity, mouthfeel, and aftertaste and correlated into word maps. Based on word relationships and usage, the number of terms was reduced to a total of 95 for acidity, mouthfeel, aftertaste, and an overall grouping for shared terms. The reduced terms were arranged onto a coffee character wheel organized from broad to specific. The created character wheel provides a concise list of terms for coffee cuppers to assess acidity, mouthfeel, and aftertaste.

Practical Applications: The coffee character wheel compliments the currently published coffee flavor wheels to provide explicit descriptors commonly used in the coffee industry. In addition to flavor, acidity, mouthfeel, and aftertaste are also used to assess coffee quality. Many sensory terms have been used to describe these attributes, but these used terms have not been summarized or discussed. Analysis of the used terms can assist in creating a common language surrounding the coffee character. The broad to specific terms on this coffee character wheel can help coffee cuppers to describe coffee acidity, mouthfeel, and aftertaste.

1 | INTRODUCTION

Coffee is assessed and marketed on its fragrance/aroma, flavor, aftertaste, acidity, and body/mouthfeel (Fernández-Alduenda & Giuliano, 2021). Yet, only the fragrance/aroma and flavor have standardized sensory descriptors and lexicons (Chambers et al., 2016; SCENTONE, 2016; Sensory Lexicon Advisory Group, 2017; Steen, 2018). The World Coffee Research (WCR) Sensory Lexicon has standardized aroma and flavor sensory terms to create a common sensory vocabulary for research and industry (Seninde & Chambers, 2020; Sensory Lexicon Advisory Group, 2017). The sensory descriptors for coffee acidity, mouthfeel, and aftertaste have not been widely discussed, though a coffee emotion wheel has been developed (de Souza et al., 2022). Currently, coffee professionals and researchers use a range of descriptors, with some terms used interchangeably and others overlapping with flavor terms (Conley & Wilson, 2018; Hayakawa et al., 2010; Lingle, 2011; Navarini et al., 2004).

Coffee gains its acidity from the combination and intensity of chlorogenic acids, carboxylic acids, and phosphoric acid contained in the beverage (Fernández-Alduenda & Giuliano, 2021). Coffee acidity can be described in three ways: the pH of the coffee describing the dissociation of [H^+] ions into the coffee from acids contained in the coffee, the sour taste imparted to the coffee from said acids, and the character provided to the coffee from the acids (Fernández-Alduenda & Giuliano, 2021; Sensory Lexicon Advisory Group, 2017). The coffee pH can be measured via instrumentation, and the sour taste can be described using the WCR sensory lexicon (Sensory Lexicon Advisory Group, 2017; Yeager et al., 2021). Many sensory terms such as bright, sharp, mellow, low, and flat describe the character of the acidity when the coffee is assessed (Conley & Wilson, 2018; Fernández-Alduenda & Giuliano, 2021; Hayakawa et al., 2010). However, little research has been carried out to summarize the sensory terms for describing the character of coffee acidity.

The tactile experience of drinking coffee is often described by the coffee's body or mouthfeel, with the two terms used interchangeably (Agorastos et al., 2020; Fernández-Alduenda & Giuliano, 2021). Body is favored when reporting on the quality of the coffee as it forms one of the assessed categories in the standard industry method (Fernández-Alduenda & Giuliano, 2021; International Trade Centre, 2011). However, the term mouthfeel is used more broadly within coffee literature (Table 1) and other industries when a more detailed description of the tactile response is required (Agorastos et al., 2020; Fernández-Alduenda & Giuliano, 2021). In general, mouthfeel covers the texture and body of the coffee, where the body combines the weight and viscosity of the coffee (Fernández-Alduenda & Giuliano, 2021; Technical Committee ISO/TC 34, 2018). Though there is agreement in using mouthfeel as a broad primary term, a range of related but different secondary terms provide more specific descriptions (Table 1).

Aftertaste or finish is the residual sensory experience that remains in the mouth after the coffee is removed (swallowed or expelled; Fernández-Alduenda & Giuliano, 2021; Technical Committee ISO/TC 34, 2018). The residue coats the oral cavity and releases volatile compounds that are detected as the aftertaste (Fernández-Alduenda & Giuliano, 2021). The released chemicals in the residue correlate with the least soluble compounds that generally belong to the nutty/cocoa, roasted, or chemical flavor groups found in the WCR lexicon (Fernández-Alduenda & Giuliano, 2021; Sensory Lexicon Advisory Group, 2017). The amount of compounds with low solubility in the residue affects the length of time that the aftertaste is experienced (Fernández-Alduenda & Giuliano, 2021). Aftertaste is often expressed as its flavor components in combination with its length when reported (Hayakawa et al., 2010; Narain et al., 2004).

Sensory lexicons provide a standardized vocabulary to communicate the sensory attributes of food and beverages. The previously developed coffee lexicon primarily focuses on the flavor or taste of brewed coffee (Chambers et al., 2016; Sensory Lexicon Advisory Group, 2017). Acidity is presented under the sour flavor category as some of the acids found in coffee (acetic acid, butyric acid, isovaleric acid, citric acid, and malic acid; Sensory Lexicon Advisory Group, 2017). In contrast, mouthfeel is presented with terms that do not correspond with those used by the industry; mouth drying, thickness, metallic, and oily (Fernández-Alduenda & Giuliano, 2021). Aftertaste is effectively split with the flavor component covered by the flavor section of the lexicon and the length falling under the longevity attribute (Sensory Lexicon Advisory Group, 2017). The coffee sensory vocabulary presented in ISO 18794 again focuses on the flavor and taste with minimal focus on mouthfeel, acidity, and aftertaste (Technical Committee ISO/TC 34, 2018). As acidity, mouthfeel, and aftertaste are three categories often used in the assessment of brewed coffee (Fernández-Alduenda & Giuliano, 2021; International

TABLE 1 Examples of the use of mouthfeel and body reported in coffee literature since the year 2000.

Reference	Primary term	Secondary terms

Fernández-Alduenda and Giuliano (2021)	Mouthfeel	• Temperature
		• Astringency
		• Body
		  ○ Thickness (viscosity)
		  ○ Texture (rough to smooth)

Cordoba et al. (2021)	Mouthfeel	• Body • Astringency

Technical Committee ISO/TC 34 (2018)	Mouthfeel	• Physical Sensations (Texture)
		  ○ Density
		  ○ Viscosity
		  ○ Particulate
		• Chemical Sensations (Flavor)
		  ○ Astringency
		  ○ Cooling

Sensory Lexicon Advisory Group (2017)	Mouthfeel	• Mouth drying • Thickness • Metallic • Oily
Hayakawa et al. (2010)	Mouthfeel	• Body • Astringent • Rounded Mouthfeel • Smooth Mouthfeel • Thick • Coarse • Grainy • Sticky
Navarini et al. (2004)	Mouthfeel	• Viscosity related • Substance • Resistance to tongue movement • Feel on soft tissue • Coating of oral cavity
Alliance for Coffee Excellence (2002)	Mouthfeel	• Texture • Viscosity • Sediment • Weight • Astringency

Trade Centre, 2011), there should be a refined list of terms available to communicate these sensory attributes.

The development of a traditional lexicon uses a trained sensory panel exposed to various products and a range of targeted products that might include different processing methods, geographical locations, and varieties (Lawless & Civille, 2013). Through hours of testing, a list of terms is generated in relation to the targeted product before the terms are critically assayed, classified, and validated into the final lexicon format (Lawless & Civille, 2013). The WCR sensory lexicon was developed using the trained sensory panel format (Chambers et al., 2016) and then into a sensory wheel for ease of use (Spencer et al., 2016). The traditional sensory panel format is expensive and time-consuming to run and is limited to the samples sourced for the panel. Ickes et al. (2017) and Hamilton and Lahne (2020) utilized internet-based reviews of rum and whiskey to create sensory lexicons for these products. Using internet-based reviews has the additional benefit of using terms already commonly used by the industry, allowing coffee experts and cuppers to adapt their sensory vocabulary more easily (Ickes et al., 2017).

It is difficult to characterize the coffee on acidity, mouthfeel, and aftertaste by score-based tests alone (e.g., SCAA cupping protocols; Spencer et al., 2016) although those tests were the most used methods. Previous coffee studies have mentioned many sensory terms for acidity, mouthfeel, and aftertaste (Hayakawa et al., 2010; Navarini et al., 2004; Seo et al., 2009; Technical Committee ISO/TC 34, 2018). However, the relationship between these terms has not been discussed. Further, confusion can arise when food terms are used to describe the acidity or mouthfeel of a coffee, as this can suggest the flavor of the food rather than the acidity or mouthfeel trait being alluded to (Fernández-Alduenda & Giuliano, 2021). Using distinct non-food descriptors for acidity and mouthfeel improves communication and reduces confusion when comparing samples (Fernández-Alduenda & Giuliano, 2021). This study seeks to utilize a combination of literature review, descriptive coffee panels, and internet-based material to refine the terms used for acidity, mouthfeel, and aftertaste to fill the current gap in the coffee lexicon (Sensory Lexicon Advisory Group, 2017).

2 | MATERIALS AND METHODS

2.1 | Scoping survey

A small scoping survey was performed on Australian specialty coffee roasters to evaluate the occurrence of defined acidity, mouthfeel, and aftertaste descriptors in marketing material. Using Google™, the "Australian specialty coffee roasters" search phase was searched in "incognito" mode to reduce location impact on April 27, 2023. The first 100 search results were used for the scoping survey. The search results were filtered to include only websites that listed whole roasted coffee beans for sale and excluded roasted beans infused with additional flavors. Search results marked as paid advertisements were excluded. The marketing material for each whole roasted coffee bean type was assessed for each website identified in the search results. The sensory terms categorized as acidity, mouthfeel, or aftertaste were recorded, and the sensory terms specified as flavor were recorded as a control. To be included in the survey, the word "acidity," "mouthfeel," or mouthfeel related terms "texture" and "body," "aftertaste" or aftertaste related "finish" had to be provided within the marketing descriptor terms. The percentage occurrence of flavor, acidity, mouthfeel, and aftertaste terms was calculated over the coffees surveyed.

2.2 | Selection of academic and industry literature

Academic and industry publications were reviewed to identify those that clearly discussed and compared or measured acidity, mouthfeel, and aftertaste sensory descriptors. The Web of Science Database was searched on May 5, 2022 using the phase "coffee sensory," identifying 1395 articles. An abstract search identifying articles containing references to coffee sensory descriptors reduced identified articles to 250. A full article search identified 26 articles containing acidity, mouthfeel, or aftertaste sensory descriptors. Industry publications were identified as those used and promoted by coffee associations (e.g., SCA), traders (e.g., International trade center), and competitions (e.g., Cup of Excellence). Additionally, to provide a foundation to build upon, descriptive terms relating to acidity, mouthfeel and aftertaste were also drawn from red wine, white wine, beer, and water sensory wheels (Gawel et al., 2000; Langstaff et al., 1991; Pickering & Demiglio, 2008). In total 85 academic and industry references included in the Data S1 provided a foundation of coffee acidity, mouthfeel, and aftertaste sensory descriptor terms to start.

2.3 | Selection of internet material including international coffee

Search phases "coffee acidity," "coffee mouthfeel," "coffee body," "coffee aftertaste," and "specialty coffee roasters" were used in Google™ without limitation to "Australian Coffee" to identify internationally sourced internet material that contained references to acidity, mouthfeel, and aftertaste sensory terms in a broader context. Internet material was acquired between July 4, 2022 and October 26, 2022. The internet material identified was divided into two categories; coffee reviews and marketing, and coffee education material. The raw data acquired has been included in the Data S1.

The internet material had to contain a coffee review or marketing description related to a whole roasted coffee bean for inclusion in coffee reviews and marketing. The review or marketing descriptor was required to detail that a descriptor was related to acidity, mouthfeel, or aftertaste. As not all review and marketing material explicitly details terms of acidity, mouthfeel, or aftertaste, sources were manually checked for the targeted information.

Coffee educational material included blogs, glossaries, and vocabularies detailing acidity, mouthfeel, or aftertaste terms. The coffee

educational material was separated from the industry literature above as the source of information was not clearly referenced. Including online educational material describing acidity, mouthfeel, and aftertaste descriptors provided terms and their relationships as viewed by the industry.

For acidity 908 individual reviews and marketing descriptors were identified from internet material, while 1132 were identified incorporating mouthfeel and 660 were identified including aftertaste. Fifty-eight websites provided acidity-focused coffee education material, 60 websites provided mouthfeel-focused coffee education material, and 19 websites provided aftertaste-focused coffee education material.

2.4 | Coffee panel derived descriptors

Semi-trained coffee panels ($n = 38$, Aged 20–60, M = 26, F = 12) of consenting volunteer coffee professionals appraised the coffee. The coffee professionals consisted of coffee growers, importers, roasters, baristas, and Q graders who regularly drink, evaluate, and describe coffee. Cupping panels were conducted in Australia (Mareeba, Queensland; Brisbane, Queensland; Sydney, New South Wales) in rooms routinely used for coffee cupping and supplied by industry professionals. Multiple locations allowed a broader source of panelists. Panelists were briefed on how to use the sensory form, and two training coffees were prepared and presented to the panelists to familiarize them with the sample form.

Coffee was prepared for panelists using the SCA cupping procedure (Fernández-Alduenda & Giuliano, 2021; Technical Standards Committee, 2015). Briefly, 11.5 g of ground coffee was added to 210 mL ceramic cupping bowls, to which water 93°C was added to the bowl rim and allowed to stand for 4 min. Once the coffee was allowed to brew, the crust was broken and cleaned. The panelists began their assessment once the coffee reached a safe temperature ~70°C (Technical Standards Committee, 2015). The assessment consisted of panelists aspirating the coffee from a cupping spoon into their mouths. Panelists used a free-form sensory form to record the acidity, mouthfeel, and aftertaste terms they experienced from the samples.

A selection of acidity, mouthfeel, and aftertaste terms were provided to the panel based on published academic and industry literature to assist with starting vocabulary. Coffee was presented to the panelists in duplicate as batches of 10, with a break between batches. Coffee samples were deidentified and served with origins alternating. No more than 40 coffees (4 batches) were cupped during an individual panel. Green bean coffee samples ($n = 71$) from Australia, Colombia, India, Hawaii, Panama, Ethiopia, Honduras, and Mexico were provided and duplicated across the panels. Each panel had 1–2 replicate samples across batches to check panel consistency, with the green bean roasted freshly for each replicate.

Panel samples were roasted to a light-medium roast using a fixed roast profile (Default cupping profile, level 2.0) with a Kaffelogic Nano 7 benchtop roaster (Kaffelogic, Dunedin, New Zealand) with a roast duration of 8:22 min and average end temperature of 215°C. Roasted coffee samples were used within 24 h of roasting and allowed to rest for a minimum of 8 h before cupping. Water was provided to panelists to cleanse their palates between samples if they wished.

2.5 | Statistically analysis of character sensory descriptor terms

Data input occurred in Microsoft Excel (Microsoft Corporation, 2019) and Microsoft Access (Microsoft Corporation, 2019), with processing in R Studio (RStudio Team, 4.2.0). The packages "tidytext," "widyr," and "tm" were used for text mining, and "igraph" was used for constructing Bigrams. Hierarchical clustering was performed with the base "stats" package. Acidity, mouthfeel, and aftertaste descriptor terms were manually entered from the source material over automation due to the variety of source material and formatting. Acidity, mouthfeel, and aftertaste terms were recorded separately (Ickes et al., 2017). Each panelist and marketing descriptor was reported on a single row in the spreadsheet, and the same process was carried out for academic and industry literature to extract descriptors (reported in the Data S1).

Descriptor terms were processed in preparation for text mining. Methods from Fox et al. (2021), Hamilton and Lahne (2020), and Ickes et al. (2017) were used with adjustments to incorporate using multiple source types. Where required, terms were condensed to their root form. For processing terms with spaces, for example, "green apple" were condensed to "greenapple" removing the space to create a single term. Food terms had "like" added to the term to reflect that the acidity or mouthfeel was like the food but did not necessarily reflect the flavor of the food ("greenapple"— > "greenapplelike"). When required, words with a low occurrence used synonyms to provide links to other terms. Terms that did not relate to acidity or mouthfeel were excluded. Acidity and mouthfeel terms were processed independently.

A single word replacement pass was performed on the dataset to clean up, standardize, and add "like" to food terms. Spearman correlation provided a pairwise correlation between the occurrence of sensory descriptor terms (Calvert et al., 2023). Understanding of the correlation between multiple terms was achieved using correlation bigrams (Calvert et al., 2023). A correlation bigram is a visualization of the pairwise occurrence of terms, with the strength of the linkage dependent on the correlation between the pair of terms. A series of iterations combined terms using the correlation bigrams. Descriptor terms with low occurrence were combined into similar terms with a higher occurrence. Condensation rather than elimination was used to preserve the occurrence of like terms. The significant terms for acidity and mouthfeel were identified through iterative steps condensing terms.

Guidelines were established to direct the condensations:

- Words favored by the panelists and online sources have greater weighting over terms identified in the literature to reflect current industry vocabulary.

- Non-food related terms are weighted higher than food terms and those found on the current SCA flavor wheel to minimize cross-modal interactions.
- The final terms for acidity, mouthfeel, and aftertaste are not to be the same.
- The term with the larger correlations should be considered first as the primary term for condensing.
- Descriptors with higher occurrences are weighted higher than those with a low occurrence.
- Hedonic terms (e.g., pleasant or unpleasant) are to be avoided.

In parallel with the creation of correlation bigrams, hierarchical clustering was used to inform linkages and groupings of the sensory descriptors (Hamilton & Lahne, 2020; Spencer et al., 2016). Hierarchical clustering is an unsupervised clustering method that can group and sort attributes, providing a visual representation via a dendrogram. Initially, each attribute is treated as a separate cluster, with each step merging pairs of clusters with the shortest distance between them. Multiple methods "euclidean," "cranberra," and "binary" were used to calculate the distance matrix (Hamilton & Lahne, 2020; Spencer et al., 2016). The agglomerations methods "single," "complete," "average," and "ward.D2" were trailed for the hierarchical clustering and dendrogram construction. Dendrograms constructed with the cranberra method for distance matrix and ward.D2 for agglomeration provides the clear visualization of clustering to inform linkages and groupings for the bigrams (Hamilton & Lahne, 2020; Spencer et al., 2016).

The creation of a correlation bigram from the iterative condensation steps and hierarchical clustering created a word network illustrating the relationships between the different sensory character terms. The sensory wheel was created by combining the word network nodes with the occurrences of the terms. Terms that occurred more often and acted as node points were incorporated into the sensory wheel.

2.6 | Validation

The completed wheel was provided to an additional seven panels of semi-trained coffee panels ($n = 100$, Aged 20–60, M = 44, F = 40) for the assessment of 179 green bean samples from Australia, Brazil, Colombia, Costa Rica, Ethiopia, Guatemala, Hawaii, Honduras, India, Kenya, Malawi, Mexico, Nicaragua, Papua New Guinea, Peru, Sumatra, Tanzania, and Uganda. Feedback was received in a free-form format. Based on feedback, adjustments were made to groupings, supporting any change dependent on the literature and the collected data.

3 | RESULTS

3.1 | Scoping survey

The "Australian specialty coffee roasters" scoping survey identified 55 websites offering 780 types of whole roasted coffee beans (included in the Data S1). Flavor sensory terms were provided for 96% of the surveyed coffees (Figure 1). Acidity terms were defined for 38%, mouthfeel terms for 51%, and aftertaste terms for 37% of the surveyed coffees (Figure 1). The scoping survey illustrates that coffee descriptors often contain flavor information but not always acidity, mouthfeel, and aftertaste terms. However, acidity, mouthfeel, and aftertaste terms are used to provide information to assist in comparison and decision-making by coffee drinkers. The scoping survey reinforced that aftertaste terms could be split into two components: a flavor part that correlates with the SCA tasters wheel (Spencer et al., 2016) and a length part that correlates with how long the aftertaste lasts. As the flavor component of the aftertaste is covered by the SCA tasters wheel (Spencer et al., 2016), a focus is placed on refining the terms used for describing the length of the aftertaste.

3.2 | Occurrence of terms

From academic and industry literature, internet material, and coffee panels, 285 unique acidity terms, 394 unique mouthfeel terms, and 496 unique aftertaste terms were identified. The sources provided 5263 acidity, 7109 mouthfeel, and 6349 aftertaste terms. In overview, mouthfeel and aftertaste terms can be considered more fragmented than acidity due to the increased number of unique descriptor terms used. The groupings all exhibit more terms than the 110 found in the WCR sensory lexicon (Sensory Lexicon Advisory Group, 2017).

Within acidity descriptors, food terms are commonly used to describe the acidic experience of coffee (Table 2). The common use of food-related terms overlaps with the WCR coffee sensory lexicon, as does using the names of specific coffee acids (Table 2) when describing the acidic character of the coffee (Sensory Lexicon Advisory Group, 2017). Mouthfeel terms do not share the same overlap with the WCR coffee lexicon as acidity and aftertaste (Table 2; Sensory Lexicon Advisory Group, 2017). As observed in the scoping study, aftertaste shares terms with flavor, acidity, and mouthfeel (Table 2) as it describes the overall taste sensation left in the mouth after expelling the coffee.

Identifying terms that overlapped for acidity, mouthfeel, and aftertaste led to the creation of the additional major grouping of overall. The additional major grouping was inspired by the red and white wine mouthfeel wheels (Gawel et al., 2000; Pickering & Demiglio, 2008). The white wine mouthfeel wheel provides balance and overall impression and overall drying. Similarly, the red wine mouthfeel wheel has complex and drying supporting the addition of groupings that incorporate terms that can be applied to acidity, mouthfeel, aftertaste, and, more broadly, to flavor (Gawel et al., 2000; Pickering & Demiglio, 2008).

For mouthfeel, the term body had the most significant occurrence (Table 2) across the descriptors (10.42%). The large occurrence represents its use interchangeably with mouthfeel in coffee marketing material, as mouthfeel was set as the major grouping. Aftertaste exhibits a similar trend as finish (10.58%) is used interchangeably with aftertaste.

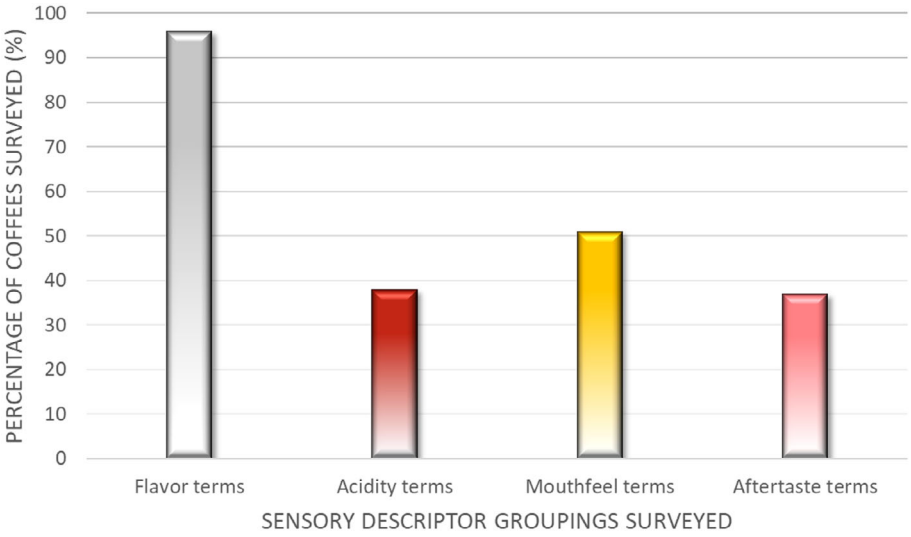

FIGURE 1 Overview of the scoping survey results, reporting the percentage of surveyed coffee that was described with flavor, acidity, and mouthfeel terms.

3.3 | Sensory descriptor term correlation

The word networks (Figures 2–4) derived from bigram correlations illustrate the relationships between the sensory descriptor terms used for acidity, mouthfeel, and aftertaste. Acidity terms (Figure 2) were found to correlate with the intensity terms: low, medium, and high, and coffee acids citric acid, malic acid, acetic acid, and tartaric acid. In comparison, the coffee acids, phosphoric acid, quinic acid, and lactic acid occurred less often to describe a coffee's acidic character. Adjectives and intensifies were associated with intensity terms (low, medium, and high), while food-related terms were associated with the coffee acids (Figure 2).

Coffee mouthfeel (Figure 3) is primarily characterized by its body, broken down into weight and viscosity and along with texture (smooth, rough, and particles). Weight and viscosity share similar terms. The terms were separated with weight referring to the perceived tactile weight/concentration of the coffee in the mouth, while viscosity referred to the resistance to tongue movement of the coffee (Agorastos et al., 2020; Fernández-Alduenda & Giuliano, 2021).

After the exclusion of flavor, acidity, mouthfeel, and overall terms, aftertaste is left with length descriptors that summarize how long the sensory sensation remains in the mouth (Fernández-Alduenda & Giuliano, 2021; Technical Committee ISO/TC 34, 2018). The aftertaste length can be described as ranging from short to long (Figure 4).

The overall major group represented terms that overlapped within acidity, mouthfeel, and aftertaste. The overall group represents terms that can describe the coffee's overarching character. The overall major group is split into mouth drying, complexity, clarity, and balance.

Mouth drying terms, astringency and drying, (Figures 2 and 3) allude to a drying/puckering sensation that can linger in the mouth. These terms have been observed across all three groups (Table 2). The mouthfeel experience of drying is attributed to the acids in the coffee and is known to linger in the mouth as part of the aftertaste. The remaining terms in the overall group are commonly used in the descriptions of acidity, mouthfeel, and aftertaste (Table 2) and can be broken down into clarity, balance, and complexity (Figures 2 and 3). Currently, balance is part of the SCA coffee assessment (Fernández-Alduenda & Giuliano, 2021). Balance judges if the characteristics of the coffee are in proportion (integrated) or out of proportion (disjointed; Technical Committee ISO/TC 34, 2018). Clarity refers to the perception of a coffees' sensory descriptors and if they are clear and defined or murky and undefined (Technical Committee ISO/TC 34, 2018). Complexity is the number of characteristics, layers, or notes the coffee has. Coffee with high complexity is considered rich, while low complexity is poor (Figures 2 and 3).

3.4 | Coffee character wheel creation

The primary selection of terms for the coffee character wheel was achieved by filtering acidity terms (Table 2) above 0.2%, mouthfeel terms above 0.2%, and aftertaste terms above 0.2% occurrence. The secondary selection included those terms that linked the high occurrence terms to the central node in the word maps (Figures 2–4). The tertiary selection included terms that provided a contrast to the high % occurrence terms based on the word maps if not already present and terms that are more specific to full the second level (Figures 2 and 3). Terms that occurred under both acidity, mouthfeel, and aftertaste (e.g., soft and low) were placed where they had the most significant occurrence. The acidity, mouthfeel, aftertaste, and overall terms were then arranged by level into a condensed list of 95 terms (Table 3). For acidity, phosphoric acid, quinic acid, and lactic acid are included on the character wheel for completeness and the lack of clear links with the other coffee acids.

Terms from the condensed list (Table 3) were organized into a wheel of concentric circles to enable the easy sorting of terms and to complement the design of the SCA tasters Flavor wheel (Fernández-Alduenda & Giuliano, 2021; Spencer et al., 2016). The first level (Inner wheel) gave the board group, while the second level provided the sub-group. From the third level terms were qualitative for

TABLE 2 Top 40 occurring acidity, mouthfeel, and aftertaste terms.

Acidity term	% Occurrence	Mouthfeel term	% Occurrence	Aftertaste term	% Occurrence
Low	7.63	Body	10.42	Finish	10.58
Medium	6.13	Medium	6.10	Sweet-like	4.75
Bright	5.49	Full	6.03	Long	4.69
Citric acid	4.61	Drying	4.87	Lingering	2.82
Malic acid	4.49	Smooth	4.84	Dry	2.41
Citrus-like	3.68	Creamy	4.18	Short	2.22
Sour	2.93	Light	3.64	Clean	2.20
Juicy	2.86	Syrupy	2.82	Chocolate-like	2.18
High	2.76	Heavy	2.48	Medium	1.79
Crisp	2.09	Juicy	2.44	Nut-like	1.73
Sharp	1.82	Silky	2.39	Acidity	1.61
Lemon-like	1.79	Round	2.00	Caramel-like	1.52
Soft	1.67	Rich	1.86	Bitter	1.50
Tart	1.65	Thin	1.80	Sour-like	1.48
Orange-like	1.56	Thick	1.70	Fruit-like	1.25
Mild	1.48	Astringent	1.64	Astringent	1.17
Winey	1.43	Clean	1.43	Cocoa-like	1.17
Sweet	1.37	Texture	1.39	Sharp	1.05
Tangy	1.37	Watery	1.37	Dark Chocolate-like	0.93
Balanced	1.32	Oily	1.16	Rich	0.86
Flat	1.32	Rough	1.15	Bright	0.82
Acetic acid	1.2	Coating	1.09	Smooth	0.80
Fruit-like	1.2	Viscosity	1.05	Brown sugar-like	0.70
Green apple-like	1.15	Soft	0.98	Citrus-like	0.70
Astringent	1.05	Velvety	0.98	Floral-like	0.70
Vibrant	0.94	Low	0.82	Spice-like	0.66
Mellow	0.9	Buttery	0.72	Malt-like	0.60
Apple-like	0.83	Strong	0.68	Sweetness	0.60
Intensity	0.83	Balanced	0.67	Winey-like	0.60
Tartaric	0.83	High	0.65	Earthy	0.58
Drying	0.75	Delicate	0.58	Toffee-like	0.58
Lime-like	0.7	Tea-like	0.58	Crisp	0.56
Round	0.7	Sticky	0.54	Harsh	0.54
Coffee acid	0.68	Grainy	0.52	High	0.54
Low medium	0.68	Gritty	0.50	Musty-like	0.54
Light	0.66	Lean	0.50	Tart	0.54
Clean	0.62	Mild	0.50	Papery	0.51
Pungent	0.62	Big	0.47	Tea-like	0.51
Gentle	0.6	Satiny	0.47	Woody-like	0.51
Lively	0.6	Chocolate-like	0.42	Honey-like	0.49
Vinegary	0.6	Coarse	0.41	Soft	0.49
		Plushy	0.41		

describing the coffee, with the fourth level (Outer wheel) providing increasingly specific descriptors). Acidity and mouthfeel are placed at the top of the wheel for ease of reading, with aftertaste placed at the bottom. Overall is slightly separated to provide a visual distinction that these descriptors are detached and can be used for multiple major groupings.

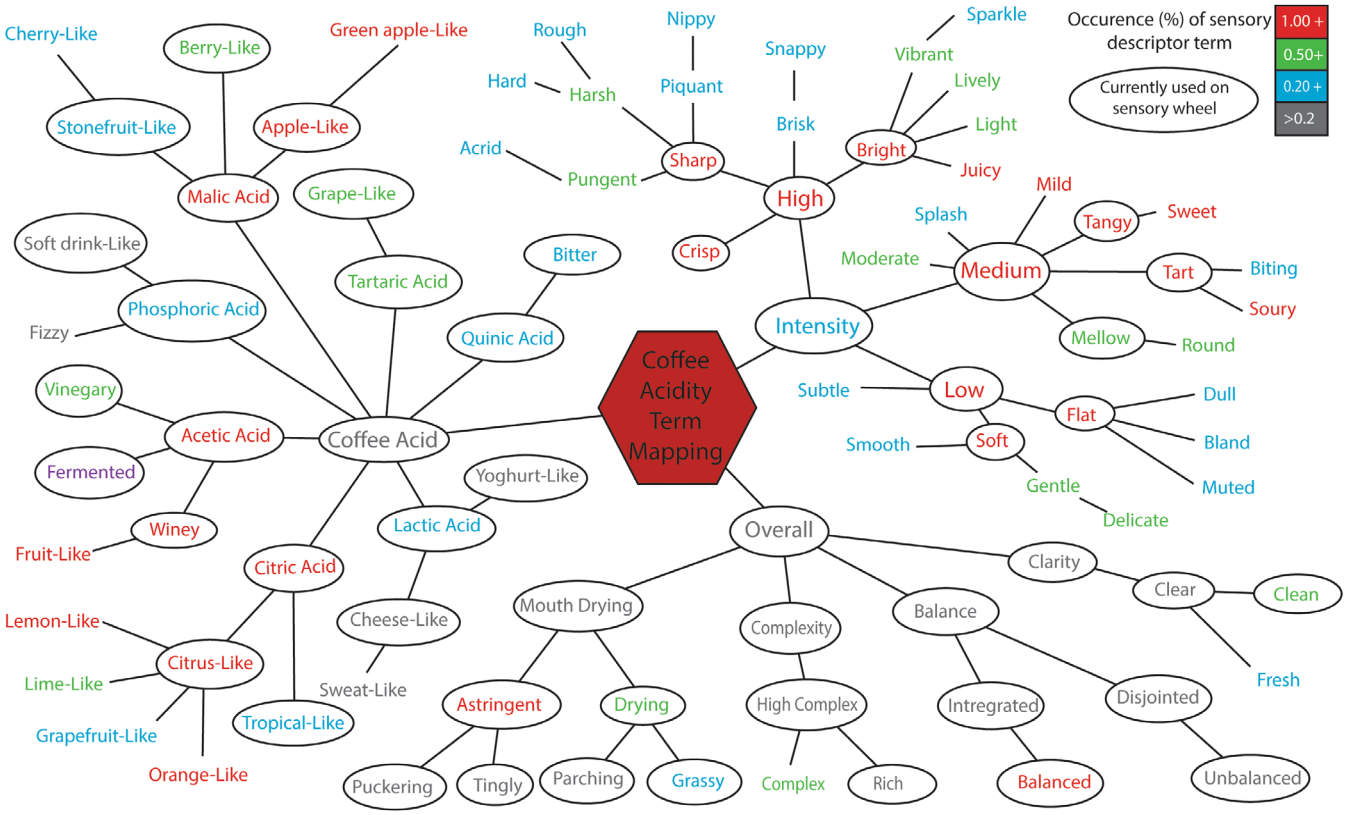

FIGURE 2 Term mapping for sensory descriptor terms that describe the acidity character of coffee. Only terms with an occurrence >0.2% are displayed in color.

4 | DISCUSSION

The scoping survey identified that flavor terms (96%) were more commonly used to describe coffee in marketing material than acidity (38%), mouthfeel (51%), and aftertaste (37%) descriptor terms, which contrasts the equal weighting applied to these categories in assessments used by the industry (Fernández-Alduenda & Giuliano, 2021; International Trade Centre, 2011; Technical Standards Committee, 2015). The lack of standardization for acidity, mouthfeel, and aftertaste terms and common terms compared to flavor (Counter Culture Coffee, 2013; Sensory Lexicon Advisory Group, 2017; Steen, 2018) could contribute to this discrepancy in use.

Our approach utilized multiple source types, published literature, cupping panels, and internet material to collate and observe the use of acidity, mouthfeel, and aftertaste sensory descriptors in coffee. Previous studies have relied upon one source type for the creation of sensory lexicons; rum (Ickes et al., 2017), whiskey (Hamilton & Lahne, 2020), coffee (Chambers et al., 2016), and beer (Fox et al., 2021; Norman, 2019). Descriptive terms derived from marketing descriptions are acknowledged to have a bias toward what consumers would perceive as favorable terms for describing coffee acidity, mouthfeel, and aftertaste (Hamilton & Lahne, 2020; Ickes et al., 2017). This bias is balanced by drawing terms from multiple sources, including literature and descriptive coffee panels that present more neutral views. Ickes et al. (2017) highlights that internet material, especially reviews and marketing material, does not define the terms used in their descriptions. To compensate, terms from published literature provided definitions and relationships, with additional support from the internet-based coffee educational material.

Suggested vocabulary was introduced during the coffee panels by prompting acidity, mouthfeel, and aftertaste terms from academic and industry sources without cross-modal interactions with the WCR coffee lexicon (Sensory Lexicon Advisory Group, 2017). Coffee panelists reported acidity, mouthfeel, and aftertaste terms outside the provided terms, including food-related terms, demonstrating the commonality of these cross-modal interactions in the coffee industry (Table 2). Web-based coffee marketing material reinforced the commonality of the cross-modal interactions with food terms and highlighted how acidity and mouthfeel terms could be confused with flavor. Aftertaste terms reflected terms used for acidity, mouthfeel, and flavor, with the length of the coffee sensation being the primary grouping accredited to the aftertaste (Figure 4).

WCR coffee lexicon suggests using solutions of acetic acid, citric acid, and malic acid for describing the different sour flavors of coffee (Sensory Lexicon Advisory Group, 2017). Using acid solutions trains coffee tasters to associate these terms with flavor without reference to the acidic character, creating an overlap between flavor and acidity and increasing the opportunity for confusion.

The initial intention was to avoid sensory terms that overlap with the WCR coffee lexicon (Sensory Lexicon Advisory

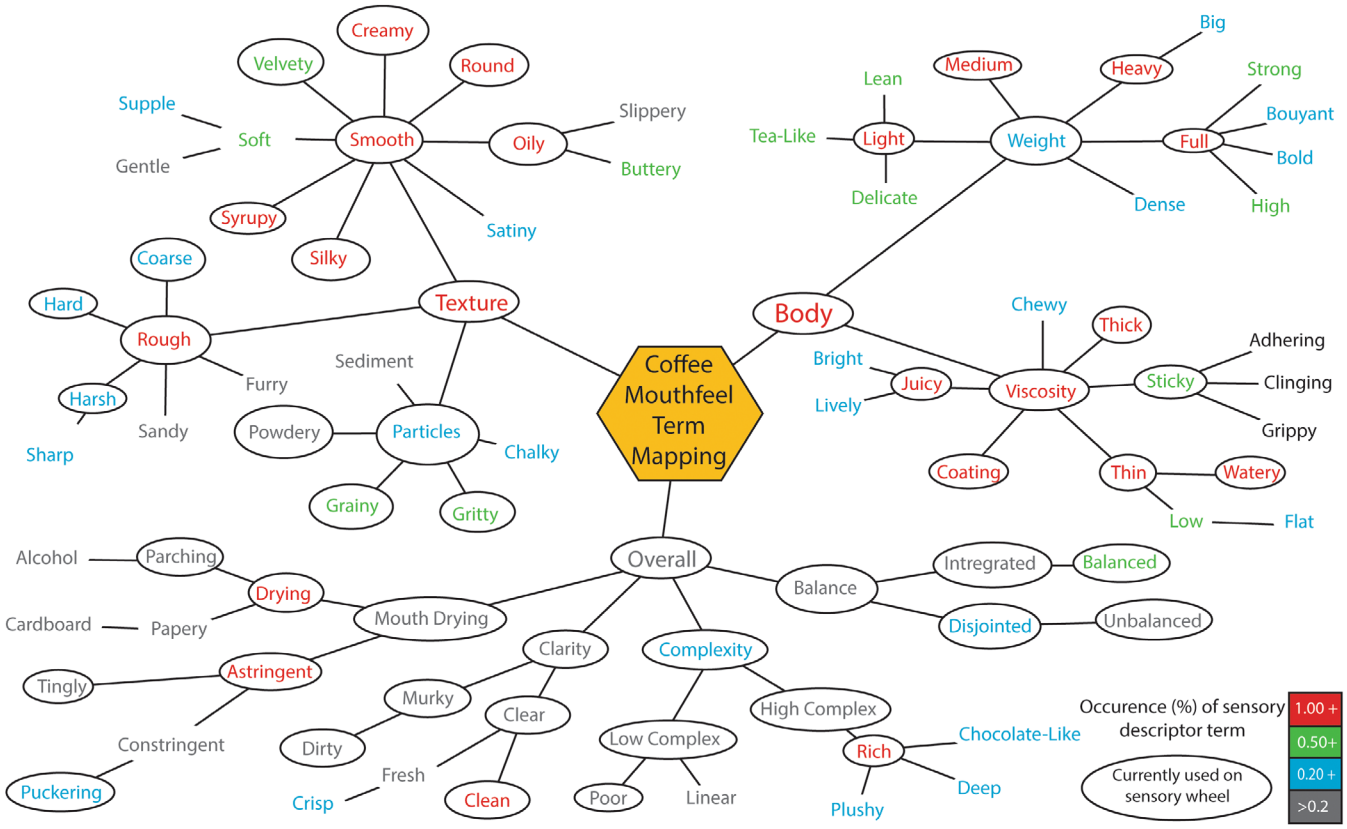

FIGURE 3 Term mapping for sensory descriptor terms that describe the acidity character of coffee. Only terms with an occurrence >0.2% are displayed in color.

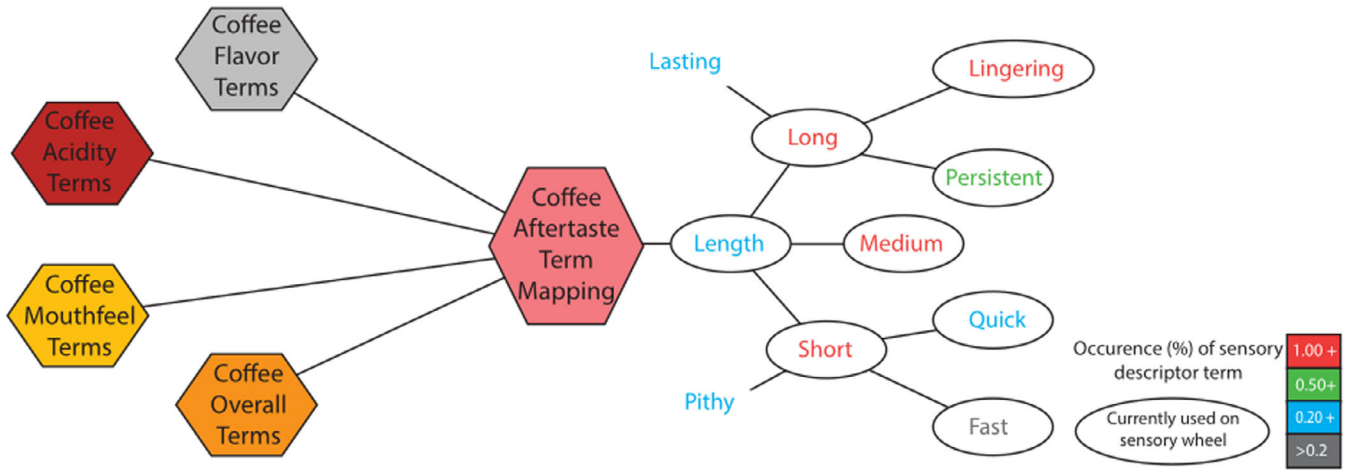

FIGURE 4 Term mapping for sensory descriptor terms that describe the aftertaste character of the coffee. Only terms with an occurrence >0.2% are displayed except where required as a linkage or to fill out a grouping. Coffee flavor, acidity, mouthfeel, and overall terms are summarized as blocks for simplicity.

Group, 2017) for the coffee character wheel. The prevalence of overlapping terms, especially for acidity (Table 2), meant a compromise approach was required to align with current industry practice. For acidity, food-related sensory terms could be correlated to the acids that occur in coffee, leading to the creation of the coffee acid grouping. The restriction of food-related terms to the fourth level allows the wheel (Figure 5) to reduce terms to the less associated with food terms on the third level and below. The arrangement applied to acidity could assist in reducing the overlap between flavor and the coffee acid grouping by encouraging the panelists to shift to just using the intensity grouping to describe the coffee's acidic character.

TABLE 3 Each coffee character attributes with groupings and qualitative levels.

Attribute (first level)	Character (second level)	Third level	Fourth level
Mouthfeel	Texture	Smooth	Velvety
			Creamy
			Round
			Syrupy
			Oily
			Silky
		Rough	Coarse
			Harsh
			Hard
		Particles	Powdery
			Grainy
			Gritty
	Body	Weight	Full
			Heavy
			Medium
			Light
		Viscosity	Coating
			Sticky
			Thick
			Juicy
			Thin
			Watery
Aftertaste	Length	Long	Persistent
			Lingering
		Medium	–
		Short	Quick
Overall	Balance	Integrated	Balanced
		Disjointed	Unbalanced
	Clarity	Clear	Clean
		Murky	Not Clean
	Complexity	Low Complex	Poor
		High Complex	Rich
	Mouth Drying	Drying	Parching
			Papery
		Astringent	Puckering
			Tingly
Acidity	Coffee Acid	Quinic Acid	Bitter
		Lactic Acid	Yoghurt-Like
			Cheese-Like
		Acetic Acid	Vinegary
			Fermented
			Winey
		Tartaric Acid	Grape-Like
		Phosphoric Acid	Soft drink-Like
		Malic Acid	Apple-Like
			Berry-Like
			Stone Fruit-Like
		Citric Acid	Citrus-Like
			Tropical-Like
	Intensity	Low	Soft
			Flat
		Medium	Tart
			Tangy
			Mellow
		High	Bright
			Crisp
			Sharp

(Continues)

Revision of the coffee character wheel occurred during the validation step. Adjustment of the mouthfeel section saw the term mild removed from the smooth group, along with the terms strong and high from the weight group due to overlapping with intensity in the acidity section. The aftertaste term persistent was originally residual based on academic and industry literature and changed based on panel feedback, with panelists using the term persistent more. The overall section underwent multiple revisions. A temperature grouping was initially present within the overall section with the terms cooling and burning derived from the literature (Gawel et al., 2000; Pickering & Demiglio, 2008; Steen, 2018). The temperature group was removed based on feedback and lack of use. The separation of the overall section from the main wheel resulted from panelist feedback due to it being associated with aftertaste based on position. Inserting a separation broke the association based on position by adding space.

Though sensory definitions and references help grasp the accurate perception of a characteristic, not all sensory wheels contain definitions of their terms (Hamilton & Lahne, 2020; Ickes et al., 2017). A sensory wheel gives coffee panelists a choice of words, encouraging agreement and reducing the burden on the panelists to generate their terms from memory (Ickes et al., 2017). This wheel reflects suggested terms for acidity, mouthfeel, aftertaste, and overall descriptors based on correlation.

Even though a range of sources was used in this analysis to describe the acidity, mouthfeel, and aftertaste character of coffee, it is expected that there will be a need to modify the wheel with time, similar to the case with beer mouthfeel (Fox et al., 2021; Langstaff et al., 1991) and coffee flavor (Sensory Lexicon Advisory Group, 2017; Specialty Coffee Association of America, 1995). Additionally, the coffee character wheel was created using English and may not reflect the usage of terms in non-English speaking countries.

The coffee character wheel condensed 679 acidity, mouthfeel, and aftertaste terms to 95 terms (Figure 5), reducing the complexity for a human sensory panel to describe the coffee character. To avoid time-consuming human sensory analysis, Chang et al. (2021) utilized

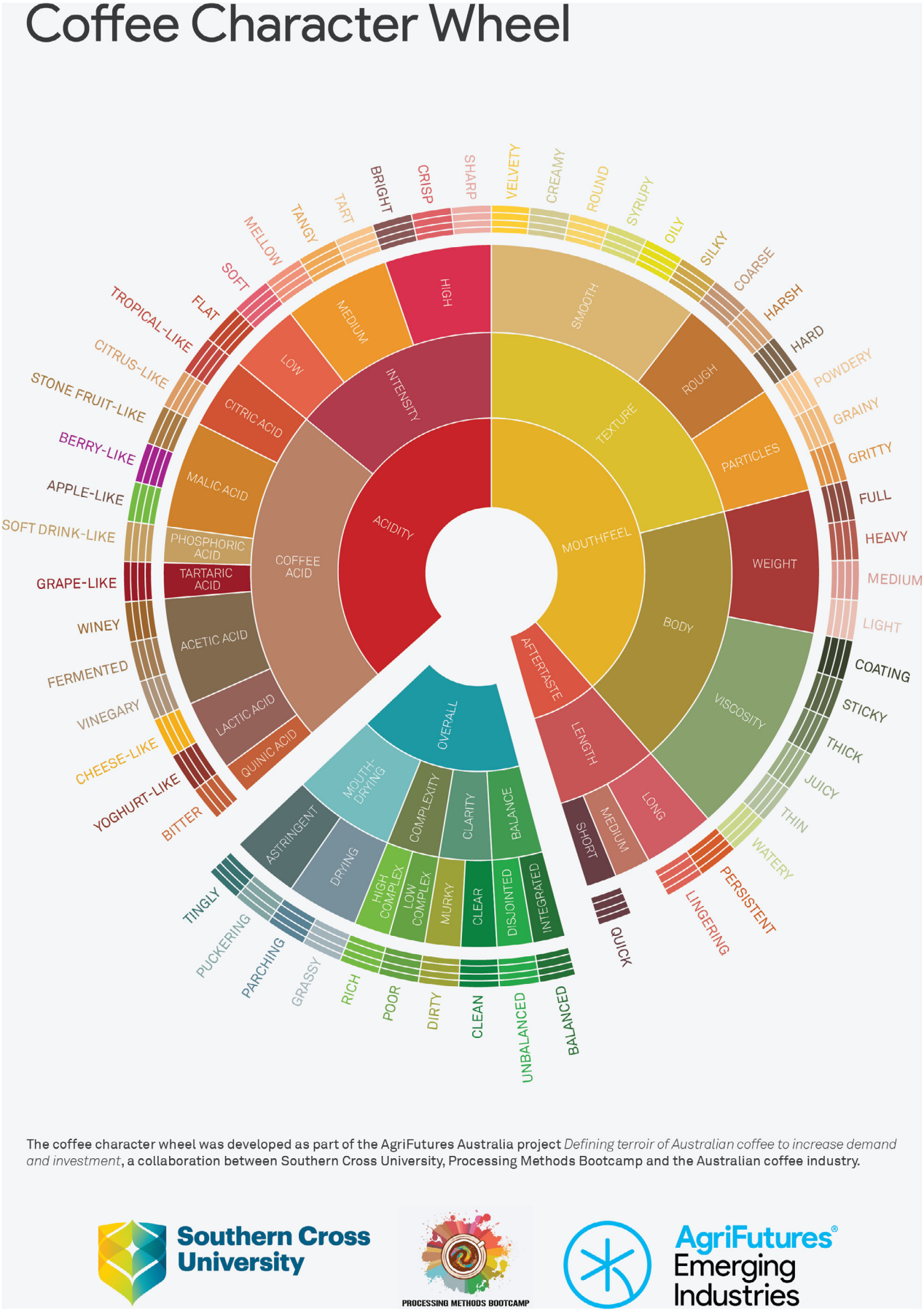

FIGURE 5 Coffee sensory character wheel for acidity, mouthfeel, aftertaste, and overall descriptors.

near infrared spectroscopy and machine learning trained by human sensory panel results to predict coffee flavor. The coffee taster's flavor wheel (Spencer et al., 2016) has a condensed list of flavor descriptors and was crucial in establishing the machine learning to predict coffee flavor (Chang et al., 2021). Our coffee character wheel also has a shortened list of terms and can be used with chemical analysis and machine learning to predict the coffee character.

5 | CONCLUSION

Coffee is more than flavor, but the lack of common terms for acidity, mouthfeel aftertaste, and other coffee characteristics limits the expression of these sensory traits. Combining information from coffee panels, literature, and internet resources led to the creation of a coffee character sensory wheel that reflects sensory terms currently used by researchers and coffee professionals. A sensory wheel provides a means to describe a reduced list of terms from broad to specific and presents a format that coffee professionals are familiar with through the SCA coffee tasters wheel. The constructed coffee character wheel is intended to be used in parallel with the SCA coffee tasters' flavor wheel to assist coffee researchers and professionals communicate the entire coffee sensory experience in alignment with current standard industry assessment protocols. Further research on coffee sensory descriptors would allow alignment of the flavor and character wheel to minimize cross-modal interactions.

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CONFLICT OF INTEREST STATEMENT

The authors declare the project funder, AgriFutures Australia, has no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript. The authors declare that the project funder, AgriFutures Australia, has a role in the final decision to publish the results.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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