

# DEVELOPING LEXICONS: A REVIEW

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## ABSTRACT

Lexicons are standardized vocabularies that facilitate communication across diverse audiences. Lexicons undergo two stages (preparation and development). Lexicon preparation includes selecting suitable panelists who are highly trained and capable of describing the product category, selecting samples that represent the entire product space, and developing protocols that panelists systematically follow when creating the lexicon. The development stage includes reviewing protocols before evaluation ensues, generating terms and definitions that describe the products, selecting references that clarify the terms, reviewing examples to further train the panel on important attributes, and finalizing the lexicon. Examples of published lexicons exist for foods, beverages, home care products, personal care products and fragrances. Publishing lexicons is beneficial because it promotes standardization of sensory vocabulary across multiple panels, companies and countries. Ideally, a published lexicon has the complete list of products from which it was developed, all attribute terms, definitions for every attribute and references for every attribute.

## PRACTICAL APPLICATIONS

Sensory analysts working with trained descriptive panels need well defined and documented words to consistently and correctly describe products of interest. These lexicons provide a tool for communication within the panel and allow sensory analysts to communicate with product developers, marketing professionals and suppliers. Ultimately the terminology provides a basis for understanding the differences among products in a category and is the basis for designing consumer research questionnaires.

Lexicons are prominent in the sensory literature. Synthesizing these publications and establishing best practices for lexicon development promotes consistency and reproducibility across the field of sensory science. Review of existing lexicons reveals criteria for successful and useful versions. As globalization spreads modern-day businesses to new locations, consistency in sensory evaluation becomes increasingly important to establish the success of product development.

## INTRODUCTION

Lexicons are standardized vocabularies that objectively describe the sensory properties of consumer products. Lexicons developed on scientific principles can confidently be used by several different panels to consistently describe products. The use of panels as instruments depends on calibration and validation; well-defined and documented lexicons support this level of sensory research.

The need for lexicons arose from the complex needs of industry. Manufacturers may have multiple locations in which they need to evaluate the same products and various business entities such as research and development, marketing, and manufacturing, which need to converse. Outsourcing sensory evaluation to varied ingredient and material suppliers, flavor and fragrance houses and consulting firms continues and necessitates clear communication across diverse audiences. Furthermore, the role of

sensory evaluation in business strategy is increasingly emphasized and understood; thus, sensory scientists need effective communication tools to relate to nontechnical business audiences. Lexicons establish the vocabulary that enables all of these entities to connect and communicate.

Within the research and development function, lexicons allow product developers and other product researchers to understand and study the attributes of products, which have applications in product development, product maintenance, quality control and shelf-life studies (Koppel and Chambers 2010). Lexicon development may also quantify inherent variability in a product (Civille *et al.* 2010), which is useful in specification and target development.

Once sensory evaluation began to explore approaches to trained panels (the origins of descriptive analysis), the field saw the need for clearly defined and consistent terminology. Arthur D. Little began developing the Flavor Profile Method during the 1940s, and Jean Caul described the work during the 1950s (Caul 1957). In the Flavor Profile Method, descriptive panels with 4–8 trained panelists evaluate the flavor, aroma and aftertaste intensities of products on a 7-point scale. The principles of the Flavor Profile Method were later expanded to the Texture Profile Method (Brandt *et al.* 1963), which is used to measure the mechanical, geometric, fat and moisture characteristics of food. The Spectrum Descriptive Analysis method (SDA; Meilgaard *et al.* 2007) evolved the Flavor Profile Method and Texture Profile Method by providing more points of discrimination and creating absolute intensity references. The absolute scale features universal references and precise terminology, which contribute to consistent evaluations across products and descriptive panels. The Tragon Quantitative Descriptive Analysis method (Tragon QDA) uses consumer-based language and does not standardize terminology from one panel to another. Each panel of product users creates its own consumer-based vocabulary for panel evaluation of a set product category. As such, proponents of Tragon methodology may disagree on the level of training required for panelists (Stone and Sidel 2004). Additionally, intensity references are not commonly used in QDA as they are in SDA, but both methods use qualitative references.

The American Society for Testing and Materials (ASTM; ASTM Stock #DS72 2011) summarizes lexicon development into five steps: (1) establishing the “frame of reference” from a wide array of products in the category; (2) developing and generating terms that describe the products; (3) using references that describe the terms to clarify the terms and definitions; (4) using examples so the panel more fully understands the terms; and (5) developing the final list of descriptors for the lexicon. These steps assume (1) that the appropriate panelists have been selected; (2) that the product space has been screened for products that represent the entire sensory space; and (3) that the protocol to

measure each attribute is suitable. Appropriate adherence to these principles creates well-designed lexicons; however, nonadherence creates potential pitfalls that could affect the effectiveness of the lexicon. This work will explore the benefits of good lexicon design and the disadvantages of poor lexicon design.

Drake and Civille (2002) previously outlined important considerations for lexicon development. Thus, the current review validates and updates this previous work with special emphasis placed on recent examples that support the foundation of lexicon development.

## PREPARING FOR LEXICON DEVELOPMENT

### Panelists

Typically, researchers use established panels to build lexicons because experience with numerous products enables the panelists to perceive attributes and expands the panelist's skill at describing attributes. Indeed, panelists should be selectively screened and highly trained in order to facilitate the selection of specific lexicon terms that can be supported with references.

The training and experience of the panelists who build lexicons can be significant in terms of cost and time; some studies report 120 h training time and a minimum of 500–1,200 h of experience (Drake *et al.* 2003; Suwonsichon *et al.* 2012; Vázquez-Araújo *et al.* 2012). ASTM documents recommend approximately 43 h of initial training for skinfeel panels (ASTM E1490 2011), although personal care product studies may report more (e.g., 120 h of initial training and 1,500 h of experience for evaluation of lip products (Dooley *et al.* 2009)).

At times, a highly experienced panel is not available, and it may be necessary to develop a panel from scratch. Panelist selection is important in all descriptive analysis, but particularly in lexicon development. Various published standards for selecting panelists have been published and utilized. Galán-Soldevilla *et al.* (2005) used the International Organization for Standardization (ISO) document 8586 for selecting panelists to build a lexicon for floral honey. Across sources, panelist selection criteria has common themes (ASTM STP 758 1981; Meilgaard *et al.* 2007). At initial recruitment, panelists should have high acuity (either taste or tactile depending on panel type), established abstract thinking skills (in order to execute proper scaling technique), and a positive attitude. These competencies can be tested with questionnaires, acuity tests, ranking/rating tests, and interviews, which may differ slightly across methods.

During lexicon development and consensus profiling, descriptive panelists may compromise on which attributes

should be included in the lexicon or which best describe the character of the product. For this reason, descriptive panelists should be confident in their perceptual abilities, but also be open to others' terminology. Furthermore, panelists should have a positive attitude and should be willing to work hard through the entire evaluation period.

## Samples

The sample set should be large enough to provide a fair representation of the entire product category. The appropriate size of the sample set is dependent on the category. Some categories, such as tomato-based pasta sauces, are so large that sampling every single brand and type is impractical and redundant. For categories such as this, one should collect sufficient brands and varieties to represent the sensory space. On the other hand, categories such as eye drops have fewer stock keeping units (SKUs) and more readily facilitate a sampling of all available products. Even though the sample set may cover a larger percentage of the product category, the resulting number of products sampled is lower. In addition, the analyst should consider if developmental products, products with defects, and assorted packaging types should be represented in the sample set. In practice, outlining the product space takes varying forms. In one example, during lexicon development for French cheese, 43 samples including samples of varying milk sources, geographical regions, processing methods, and maturation were included (Rétiveau *et al.* 2005). To establish a lexicon for cheddar cheese that was inclusive of various U.S. and international regions, 240 cheddar cheeses were used (Drake *et al.* 2001). Dooley *et al.* (2009) included 15 products of various price points, brands and types (balm, lipstick or gloss) when developing a lip product lexicon.

Often the combination of the products from the market place and prototypes from the product development team may include up to 50 products. These can be screened by the panel leader and a few panelists to reduce the sample set to about 20–30 samples to be presented to the panel for terminology generation.

Selecting products for *processed* fruit and vegetable lexicons (e.g., those for juiced, dried, or canned fruits or vegetables) closely resembles the process for selecting products for other commercial products and differs somewhat from selecting products for *fresh* fruit and vegetable lexicons. The selected *processed* products should represent the market space for the *processed* fruit or vegetable (e.g., pomegranate juice [Koppel and Chambers 2010] ).

Selecting products for a *fresh* fruit or vegetable lexicon is complex because of the inherent and pervasive inconsistency in *fresh* fruits and vegetables. As much as possible, a wide range of cultivars should be selected for building fresh

fruit and vegetable lexicons because sensory properties among cultivars may vary widely even within the same plant type (e.g., Muscadine grapes [Threlfall *et al.* 2007], blackberries [Du *et al.* 2010] and carrots [Szymczak *et al.* 2007] ). For some products (e.g., mangoes), including multiple stages of ripeness and storage times may also be necessary. Pre-harvest environmental and agricultural factors (e.g., agrichemicals, nutrition) may also influence sensory properties (Mattheis and Fellman 1999); the experimenter should determine whether these factors should be considered based on the project objectives. Talavera-Bianchi *et al.* (2010) included multiple families, genera, species and groups when they developed a lexicon for leafy greens, although they did not attempt to represent different harvest conditions, storage times or transportation systems. Inherent variability may have occurred because of those factors; however, the product scope was broad, which may have mitigated the sensory space not being represented by pre-consumption variability.

As an example, consider Suwonsichon *et al.* (2012) who developed a mango lexicon based on nine cultivars of mangoes. The principal component analysis (PCA) solution for this data set had six dimensions. Three of the six dimensions were associated with ripeness (PC1 – changes occurring during ripening, PC4 – overripe characteristics, PC5 – underripe characteristics) and three were associated with cultivar distinctions (PC2 – cultivar differences, PC3 – uniqueness of some cultivars, PC6 – cultivar difference and uniqueness of some cultivars). Although the plant species was consistent, the authors revealed many variations among cultivars and stages of ripeness, which exemplified the importance of wide inclusiveness across cultivars and other variables such as ripeness, in this case.

Also consider the comparison of two beef lexicons. Adhikari *et al.* (2011) included samples with differing qualities of meat, beef cuts, animal diets, packaging types and cooking methods when developing a lexicon for intact beef muscle. Maughan *et al.* (2012) developed a lexicon for beef rib steaks based on rib cuts from six animal carcasses of different qualities and of which the animals were raised on different diets. The samples for the Maughan *et al.* (2012) study were prepared by only one cooking method. The more comprehensive sample set used by Adhikari *et al.* (2011) elicited 33 aromatics, while the more limited sample set used by Maughan *et al.* (2012) elicited just 13.

## Protocols

Protocols are necessary to maintain consistency in the evaluation process. With consistency, the sample procurement, preparation, presentation and evaluation procedure are standardized so that researchers can reproduce the panel results for the lexicon. The definition for each term or the

evaluation process often contains instructions for the precise way the panelists assess or use the product. Comparing protocols with others previously published for similar product categories should be part of the protocol development discussion as it was for Elia during protocol development for bread (2011).

Samples could potentially be procured at local retail outlets if a sufficient breadth of relevant products is available. Common products such as tomatoes are good candidates for local grocery store procurement because of the wide variety of fresh and processed tomatoes commonly available (Hongsoongnern and Chambers 2008a). Other lexicon studies of fruits and vegetables may require cooperation with horticulturists if the product is only available seasonally or if available varieties are too limited.

Consistent sample preparation and presentation is important to minimize potential bias during evaluation. Standardizing the appearance and temperature of samples should be part of good experimental protocol. For instance, processed and fresh tomatoes may be both served at room temperature in the same type of container (Hongsoongnern and Chambers 2008a).

A comprehensive protocol should include complete instructions for evaluation. Texture lexicons should include texture attributes that are key to the objectives at each stage of consumption (surface, first bite, manipulation, residue) with the specific way to feel, bite, chew or manipulate the product at that stage of consumption. For instance, the texture lexicon proposed by Bruwer *et al.* (2007) for corn chips could be expanded to include surface, manipulation and residue attributes instead of just first bite attributes (hardness, denseness, fracturability, tough/chewy).

Likewise, flavor lexicons should be comprehensive. For products in which the aftertaste may be important (e.g., diet soda), rating flavor in mouth and after expectoration should be reflected in the final lexicon.

## LEXICON DEVELOPMENT

### Correct Protocol

After the preliminary lexicon development steps have been completed, the panel leader should review the evaluation protocol and sample scope with the panel. If any changes are deemed necessary, revisions should be made before lexicon development proceeds.

For lexicons that span a wide category of sensory attributes such as those for cheese (Heisserer and Chambers 1993) or for “nutty” (Miller *et al.* 2013) products, there may be samples evaluated that have attributes not previously discussed or recorded during product orientation. In this case, the appropriate approach is to discuss, define and reference the attribute during the evaluation of the

appropriate sample (Heisserer and Chambers 1993; Miller *et al.* 2013).

### Generating Terms and Definitions

Trained panelists should evaluate a few samples (5–10) from the whole sample set (usually 15–25 products) at a time and generate the initial list of terms from experience with the products. Selecting terms before panelists have been trained or before samples have been presented is not appropriate because the resulting lexicon could *exclude* attributes that are important to the product category or could *include* terminology not specific enough for a lexicon. The use of primary terms, that is terms that are “*elemental, rather than combinations of several terms*” are less confusing for panelists and end users of the data (e.g., product developers; Civile and Lawless 1986, p. 212). As an example, according to the authors’ experience, the consumer-oriented term “creaminess” is a combination of thickness, smoothness (lack of particulates), and dairy fat. If a product developer is told that an ice cream should be creamier, she does not know if she should adjust the thickness, smoothness or fattiness. For fabrics and paper, the term “soft” refers to a product that is not stiff (pliable), fuzzy and not gritty (smooth). Much confusion is avoided if the terms are singular/not integrated. The experience of the panel leader is critical during term generation because she can readily begin to see related, singular terms that could be combined with the panelists’ *permission and collaboration*. The panel leader distinguishes between integrated terms (e.g., creaminess and softness) and combined terms (e.g., molasses aromatic and brown sugar aromatic). For example, Panelist 1 may say that a sample of cookies has molasses flavor, while Panelist 2 says the cookies have brown sugar flavor. The experienced panel leader knows that brown sugar typically has a sensory profile similar to that of molasses, although it is generally at a lower intensity. Another example of an obvious combined term in peanuts is “woody/hulls/skins,” which describes the base elements in the flavor profile of peanuts. The elements are similar enough to be combined into one attribute. Both examples show that the panel leader can direct the panel to find the best term to describe the product and satisfy all panelists.

After all the samples have been evaluated by the panel and all the terms have been generated, organized, discussed and reorganized into a rational list, the panel then defines each term. This process is a critical part of the clarification of terms; thus, the panel must be involved. Often at this point, the panel may revise the protocol for evaluation to better approximate the way the product is consumed or used.

For instance, consider the generation of an apple juice lexicon. The first step was term generation, and the second



step was panelists testing the terms against six samples, which is not enough to represent the product space. Ideally, the process would have begun with familiarizing panelists with a broad range of apple juices to insure that all important attributes were included and unimportant attributes were excluded. Additionally, increased initial training of the panel may have revealed more singular attributes and references. For example, the attribute “apple-y” is referenced with apple juice, which is not singular enough for an apple juice lexicon (Cliff *et al.* 2000).

During term generation and discussion, vague, redundant or repetitive terms should be removed from the lexicon so that panelists consistently evaluate the same attribute. Repetitive terms may become more apparent after statistical treatment of the data (Drake *et al.* 2001).

Further evaluation by the panel may lead to rearranging terms already in the lexicon. After further discussion and exposures to additional products, Bett-Garber *et al.* (2012) made combined terms such as cardboard/musty and corn/popcorn/buttery because of the perceived interrelationships of these terms in the specific product.

### Identifying References

When identifying references for proposed lexicon attributes, an initial search in the scientific literature could reveal helpful references for attributes that cross categories. For example, parsley is a commonly reported reference for “green” (Rétiveau *et al.* 2005; Adhikari *et al.* 2011). If references are obtained from multiple sources, best practice is to record those references as Galán-Soldevilla *et al.* (2005) did in their lexicon for floral honey.

For unique attributes, a “validate, then revalidate” procedure could determine the reference’s appropriateness. For example, when panelists disagreed on the attributes present in pomegranate juice, the attributes were either re-referenced or redefined in order to reach panel consensus on the results (Koppel and Chambers 2010).

### Using Examples

Using examples increases panelists’ understanding of important attributes. Typically, examples are less singular than references, but they have a prominent component that is a specific attribute. For example, particular brands of vanilla ice cream could be examples of vanillin, but not necessarily references for it. A product such as Marshmallow Fluff could be a reference for vanillin because even though it has other attributes (corn syrup, sweet, etc.), vanillin is a highly prominent and singular component of Fluff. In cases where the other attributes (corn syrup, sweet, etc.) associated with Fluff could be confusing to panelists, vanillin crystals could be used as they represent the most singular

reference for vanillin possible. In other words, references are as singular as is practical and necessary, while examples are less restricted. Examples and references for some common attributes are included from the authors’ experience and Meilgaard *et al.* (2007; Table 1).

### Finalizing the Lexicon

**Organizing.** Once the terms are selected, the lexicon can be finalized. In many lexicons, terms are organized into complexes and sub-terms. The dairy complex may include cooked milk, soured dairy, and nonfat skim milk, and the brown spice complex may include cinnamon and clove.

Presenting the comprehensive sample set at this stage could aid the panel in clarifying and reducing redundant terms.

**Validating.** Lexicons can be validated by using the terms to compare two to four products in the category and determine if the lexicon allows the panel to differentiate and describe the sensory properties. Some understanding of the test products is critical to ascertain if the panel’s responses are valid when compared with the known sample characteristics and differences. For example, a trained panel, which was developing a lexicon for almonds, reevaluated six almond samples out of the previously evaluated 15. Results of the validation were used to show that the panel could discriminate among the almond samples by using the lexicon (Civille *et al.* 2010). Likewise, 23 French bread samples were evaluated to check the validity of a bread lexicon (Hayakawa *et al.* 2010b). In addition, a lexicon can be validated across panels. Lexicons for orange juice were validated through the comparison of lexicons and results from two separate panels (Lotong *et al.* 2002). Similarly, whey and soy protein lexicons developed in the U.S.A. and New Zealand produced comparable sensory spaces (Drake *et al.* 2007) as did cheddar cheese lexicons produced in the U.S.A., New Zealand and Ireland (Drake *et al.* 2005). Definitions for attributes are crucial during the validation stage because key attributes may be described by different words in different countries (Drake *et al.* 2005). This is especially important for lexicons developed cross-culturally with groups who do

**TABLE 1.** EXAMPLES AND REFERENCES FOR COMMON ATTRIBUTES

Attribute	Example
Vanillin	Marshmallow Fluff, Fudgsicle, Honey Bun (Little Debbie)
Caramelized sugar	Bordeaux cookies (Pepperidge Farm)
Cinnamon	Big Red (Wrigley)
Ethyl maltol	Nesquik, strawberry (Nestle)
Amyl acetate	Circus peanuts (Brach’s)
Toasted oat	Cheerios (General Mills)

not share the same language. One Korean and one Japanese panel each independently created a lexicon for fermented soybean, and the panels' results were compared (Chung and Chung 2007). For many common attributes, correlations were high across panels, although other variations occurred. When reporting lexicons developed by panels who do not share the same language, the term in the language of origin should be included with the definition and reference as shown by Chung and Chung (2007). Typically, as long as the vocabulary is standardized and representative, trained panels can generate reproducible sensory results even if they are from different cultures (Drake *et al.* 2005).

As an important note, when developing a lexicon for cross-cultural use, involving scientists from all relevant cultures is desirable. For example, Chambers *et al.* (2012) used a team of American and Korean scientists to develop a lexicon for kimchee and to translate the generated terms from English to Korean. The cross-panel validation procedure typically involves analyzing product means with PCA and regression vector (RV) coefficient analysis (a form of multivariate correlations). PCA results are typically presented in a two-dimensional plot, which represents the sensory space of the product category. If the distance among various products and attributes is similar across panels, then the sensory space is considered comparable. RV coefficients close to 1 reveal good agreement between two data sets. Pearson's correlations can also be applied to test agreement between two panels on specific attributes.

**Revising and Completing.** After the organization and validation steps, the lexicon is finalized. Refinements during this stage are particularly prominent for sensory wheels, which are lexicons that tend to be well-publicized and representative of a whole category.

Lexicons are never really complete. As new products, prototypes and ingredients become available, panelists may find new attribute(s) in the products/samples. When this occurs, new term(s) with appropriate reference(s) and definition(s) should be added to the attribute list.

## EXAMPLES OF DEVELOPED LEXICONS

### Food

Lexicons for food and beverage products are prominent in the literature (Table 2). Less recent examples were listed previously by Drake and Civille (2002). For ease of reference, the inclusion of definitions and references in the lexicon is indicated (Table 2).

Some lexicons further delve into specific attributes (e.g., nutty attribute [Miller *et al.* 2013], green attribute [Hongsoongnern and Chambers 2008b]) that may have different characters depending on the product. For example,

nutty-beany is not equivalent to nutty-woody, and green-peapod is distinct from green-unripe. This style of lexicon is helpful in further clarifying a complex attribute, and further additions of this lexicon style to the literature are encouraged. Other recently published lexicons include those for beverages (lemon lime soda, rooibos tea, coffee, pomegranate juice, milk, orange juice, green tea and soymilk), grain (rice and bread), fruits and vegetables (mango, sweet potato, polenta, garlic, fresh leafy greens, tomatoes, soybeans and apples), meat/fish (beef and cooked catfish), dairy (cheese, dried milk) and other miscellanea (turrón, spices and herbs, almond, honey, and soy sauce). The lexicon list represents examples developed in the U.S.A., Thailand and Japan among others (Drake *et al.* 2005; Koppel and Chambers 2010; Hayakawa *et al.* 2010a,b; Suwonsichon *et al.* 2012). Lexicon submissions from around the world enrich the literature because they clarify information that could potentially be "lost in translation."

**Sensory Lexicon Wheels.** Wheels visually represent an entire product lexicon arranged in hierarchy. The creation and organization of lexicon wheels is a fairly qualitative process. Typically, after the terms have been generated, the lead researcher assembles a group of expert panelists who discuss the similarities among a group of attributes and place similar attributes in the same category. Similar categories are grouped near each other and placed on a donut graph. The result is a visual representation of how attributes are related.

Wheels are useful because they offer a "snapshot" of a particular category's sensory world. Sensory analysts may use wheels to explain descriptive analysis to customers during business presentations or potential descriptive panelists during training (Lawless *et al.* 2012).

Published flavor wheels include the Wine Aroma Wheel, Beer Wheel, McCormick Spice Wheel (Spice Wheel), Rooibos (tea) Sensory Wheel, Spectrum Spirits Wheel and Citrus Wheels (one for orange juice and one for acid citrus; Meilgaard *et al.* 1979; Noble *et al.* 1984, 1987; Tamura *et al.* 1993; Elston 2005; Stapleton and Seltsam 2010; Koch *et al.* 2012; Lawless *et al.* 2012). Commonalities exist among these wheels. For example, all have green or vegetative, fruity, floral and earthy attributes, although the sub-attributes and the ring location differ across wheels. In contrast to the Spirits, Wine and Citrus aroma wheels, the Beer, Spice and Rooibos Wheels contain feeling factors and basic tastes. Feeling factors and basic tastes are grouped together on some wheels to establish that these attributes are perceived in the mouth rather than the nasal cavity (Lawless *et al.* 2012). The Coffee Wheel and the Gallo Food and Wine Wheel are sensory wheels commonly used in industry, although they are not formally published in the literature.

**TABLE 2.** FOOD AND BEVERAGE LEXICON EXAMPLES

General subject	Product	Definitions	References	Authors
Specific attribute	Nutty attribute	Yes	Yes	Miller <i>et al.</i> 2013
	Green attribute	Yes	Yes	Hongsoongnern and Chambers 2008b
Beverage	Lemon lime soda	Yes	Yes	Leksrisonpong <i>et al.</i> 2012a
	Rooibos tea	Yes	Yes	Koch <i>et al.</i> 2012
	Coffee	Yes	No	Hayakawa <i>et al.</i> 2010a
	Pomegranate juice	Yes	Yes	Koppel and Chambers 2010
	Milk (lactose-free)	Yes	No	Adhikari <i>et al.</i> 2010
	Coffee (brewed)	Yes	Yes	Seo <i>et al.</i> 2009
	Orange juice	Yes	Yes	Ruiz Pérez-Cacho <i>et al.</i> 2008
	White wine (mouthfeel)	Yes	Yes	Pickering and Demiglio 2008
	Green tea	Yes	Yes	Lee and Chambers 2007
	Soy milk	Yes	Yes	N'Kouka <i>et al.</i> 2004
Grain	Whole-grain rice	Yes	Yes	Bett-Garber <i>et al.</i> 2012
	Bread	Yes	Yes	Elia 2011
	Rice	Yes	Yes	Limpawattana and Shewfelt 2010
Fruits and vegetables	French bread	Yes	Yes	Hayakawa <i>et al.</i> 2010b
	Mango	Yes	Yes	Suwonsichon <i>et al.</i> 2012
	Sweet potato	Yes	Yes	Leksrisonpong <i>et al.</i> 2012b
	Polenta	Yes	Yes	Zeppa <i>et al.</i> 2011
	Garlic	Yes (Spanish)	No	Coste <i>et al.</i> 2010
	Fresh leafy greens	Yes	Yes	Talavera-Bianchi <i>et al.</i> 2010
	Tomato (fresh and processed)	Yes	Yes	Hongsoongnern and Chambers 2008a
	Soybean	Yes	Yes	Krinsky <i>et al.</i> 2006
	Apples (rose)	Yes	Yes	Vara-ubol <i>et al.</i> 2006
	Beef (rib steaks)	Yes	Yes	Maughan <i>et al.</i> 2012
Meat/fish	Beef (intact muscle)	Yes	Yes	Adhikari <i>et al.</i> 2011
	Cooked catfish	Yes	Yes	Phan and Nguyen 2012
Dairy	Cheese (Mexican añejo)	Yes	Yes	Hernández-Morales <i>et al.</i> 2010
	Cheese (processed and imitation)	Yes	Yes	Drake <i>et al.</i> 2010
	Yogurt	Yes	Yes	Coggins <i>et al.</i> 2008
	Cheese (French)	Yes	Yes	Rétiveau <i>et al.</i> 2005
	Cheese (Cheddar)	Yes	Yes	Drake <i>et al.</i> 2005
	Dairy (dried milk)	Yes	Yes	Drake <i>et al.</i> 2003
Miscellaneous	Turrón	Yes	Yes	Vázquez-Araújo <i>et al.</i> 2012
	Spices and herbs	Yes	No	Lawless <i>et al.</i> 2012
	Almond	Yes	No	Civille <i>et al.</i> 2010
	Soy and whey protein	Yes	Yes	Drake <i>et al.</i> 2007
	Honey (floral)	Yes	Yes	Galán-Soldevilla <i>et al.</i> 2005
	Soy sauce	Yes	Yes	Jeong <i>et al.</i> 2004

The Mouthfeel Wheel focuses on in-mouth sensations of red wine (Gawel *et al.* 2000). The Mouthfeel Wheel was derived from the input of wine experts and statistical analysis, although potential improvements and clarification would widen its applications in formal descriptive analysis. For example, the complex category is defined as “a positive hedonic grouping consisting of an amalgam of pleasing astringency sensations, flavour and balanced acidity” (Gawel *et al.* 2000, p. 204). While trained tasters may evaluate balance and blend, they are too biased to consider hedonic characteristics. Some of the terms used on the wheel such as “green,” “soapy” and “resinous” are associated with flavor terminology and not solely texture, which could lead to potential confusion when

evaluating across modalities. The evolution of wheels is common as the Wine Aroma Wheel, Beer Wheel and the Spice Wheel endured multiple iterations (Clapperton *et al.* 1976; Meilgaard *et al.* 1979; Noble *et al.* 1984, 1987; Lawless *et al.* 2012). Gawel *et al.* (2000) acknowledged that the lexicon terms may not be comprehensive and that the wheel may need revision. Examination of the White Wine Mouthfeel Wheel identified potential improvements for the Red Wine Mouthfeel Wheel. Pickering and Demiglio (2008) provided more in-depth explanations and justifications for the terms that appear on the White Wine Mouthfeel Wheel. Similar applications to the red wine Mouthfeel Wheel could enhance that wheel's efficacy.

The Apple Juice Wheel was not developed from a standard lexicon procedure; thus, there are potential caveats with the resulting wheel. For example, the “fresh apple” section contains “fruity” and “other fruit;” these attributes could have been combined during the term reduction stage of lexicon development. Furthermore, the preliminary terms were based on a brainstorming session rather than the evaluation of a wide range of products (Cliff *et al.* 2000); thus, the wheel may not reflect the terms most important for describing actual apples, but rather the words cognitively associated to apple flavor. Like the red wine Mouthfeel Wheel, the Apple Wheel could be improved with further revision.

### Home Care, Personal Care and Fragrance

Standardizing panelists and protocols in nonfood sensory evaluations yields reproducibility and accuracy, just as it does in food evaluations. Sensory scientists can then correlate descriptive data to instrumental measures or use it to decode consumer data. Many of the protocols for evaluating nonfood products were originally based on a combination of the Texture Profile Method (Brandt *et al.* 1963) and Spectrum Descriptive Analysis method (Meilgaard *et al.* 2007). Published lexicons for home and personal care products are fewer than those for food (Table 3). Many of the published works available are authored by ASTM subcommittee E-18, which periodically reviews protocols for evaluating personal and home care products (e.g., skinfeel, shampoo, cleaning products, etc.; Table 3). Additional authors have made contributions for lip products and paper/fabric (Civille and Dus 1990; Dooley *et al.* 2009).

The protocols to examine the tactile and sound properties of paper and fabric (Civille and Dus 1990) mimic those of food products in that each attribute term on the lexicon should correspond to one specific characteristic. Some texture attributes on the paper/fabric lexicon such as thick-

ness, grainy and gritty are familiar from food lexicons while others such as tensile stretch, tensile extension, and fabric friction are unique, yet still related to applied forces and products' reactions to those forces. When preparing to evaluate paper and fabric, there are a few concerns specific to this genre that should be emphasized.

(1) During panel selection, the panel leader should be particularly sensitive to the condition of panelists' hands. Panelists should have no “callouses on the hands and fingers, impaired circulation in the hands and fingers, central nervous system disorders, and dry and/or chapped skin.” (Civille and Dus 1990, p. 25)

(2) Panels must prep the evaluation surface (i.e., their hands) in a uniform way. Buffing their hands with the light side of the emery board, conditioning with the same lotion, and protecting their hands between sessions are all ways to reduce the variability from panelist to panelist and thus reduce experimental noise.

Similar considerations are important for selecting panelists for skin care product evaluations. Individuals with sensitive skin (e.g., those with eczema, allergies, etc.) should not be selected as evaluators. Panelists should prepare their skin uniformly by avoiding lotions and creams for 4 h prior to evaluations and uniformly cleansing their sample sites (ASTM E1490 2011). The scale for evaluating skin care products is similar to the SDA scale for food in that the scale is universal and anchored by references. For example, the scale for firmness includes references for 0 (baby oil) and 98 (lanolin AAA) among others (ASTM E1490 2011).

Common fragrance terms used to describe skin care products are also included (ASTM E1490 2011). These terms are supported by previous work, which associates molecules to the sensory perceptions they elicit (Jeltema and Southwick 1986). However, occasionally, the nature of personal care, home care and fragrance products are such that references cannot be practically used. Verriele *et al.* (2012) encountered this issue when evaluating the odor of

**TABLE 3.** HOME CARE, PERSONAL CARE AND FRAGRANCE LEXICON EXAMPLES

General subject	Product	Definitions	References	Authors
Home care	Hard surface cleaning products	n/a	n/a	ASTM E2346 2009
	Fabric and paper	Yes	Yes	Civille and Dus 1990
Personal care	Skinfeel	Yes	Yes	ASTM E1490 2011
	Shampoo performance	Yes	No	ASTM E2082 2006
	Lip products	Yes	Yes	Dooley <i>et al.</i> 2009
Fragrance	Car cabin	(Lexicon based on molecular nomenclature)	(Lexicon based on molecular nomenclature)	Verriele <i>et al.</i> 2012
	Skinfeel	Yes	Yes	ASTM E1490 2011
	Shampoo/conditioner fragrance	No	No	ASTM E2049 2006
	Fragrance	Yes	Yes	Rétiveau 2004

n/a, not applicable.



Attribute	Definition	Reference	Anchors/examples
Fishy	Aromatic associated with trimethylamine and old fish.	(1) 300 ppm trimethylamine. (2) HU55 Fish Flavor Artificial #738 "K" from Virginia Dare, 882 Third Avenue, Brooklyn, N.Y. 11232.	Trimethylamine, cod liver oil, kelp; HU55 Fish Flavor

**TABLE 4.** AMERICAN SOCIETY FOR TESTING AND MATERIALS EXAMPLE OF COMPLETE ATTRIBUTE INFORMATION

car cabins. To bypass the issue, they developed their lexicon using the "field of odors" methodology (Jaubert *et al.* 1995), which uses formal chemical nomenclature for attributes such as decadienal, acetic acid, cedryl acetate, styrene, methyl cyclo-pentenolone (MCP), benzothiazole and H<sub>2</sub>S. The panel related these terms to more commonly encountered substances. For example, fat described decadienal, vinegar described acetic acid, woody described cedryl acetate, solvent describes styrene and MCP, tire-like describes benzothiazole, and sulfur-like describes hydrogen sulfide.

The field of odors methodology may be suitable for building lexicons for products with no previously published attribute list. Consumer focus groups were used to create possible descriptive attributes for lip products when the product had no previously published lexicon (Dooley *et al.* 2009). Involving consumers at this stage establishes which attributes are important, although consumer terms may need to be edited to reflect more precise descriptive attributes. For example, consumers recommended that the descriptive panel measure the "shimmer" of lip products, although shimmer could be a combination of gloss and glitter.

The literature for specific home care, personal care and fragrance product lexicons is relatively sparse compared with lexicons for food and beverages, although general information about how to evaluate these products is provided through organizations such as ASTM. This phenomenon is at least in part due to the proprietary nature of much of this information. Additions by academic institutions such as (Dooley *et al.* 2009) help to expand the literature.

## CONCLUSIONS

Lexicon development should follow the procedure outlined by ASTM. First, a sample set large enough to represent the sensory space must be established. Then, terms must be generated, defined, attached to references and finalized.

Published lexicons should contain several key factors of information.

- (1) List of products from which the terms were developed;
- (2) All attributes;

- (3) Definitions for every attribute; and

- (4) References for every attribute.

This format follows that of ASTM's published lexicon (Table 4, ASTM Stock #DS72).

Including the list of products enables readers to make a judgment about the suitability of the lexicon for their products or prototypes of interest.

Published lexicons should include the terms elicited during the term development procedure. However, one should clarify to the reader that the list is not absolute and could accommodate further inclusions.

Definitions should be included so that the reader understands the terms, and results can be compared across cultures, regions or facilities. Lotong *et al.* (2002) used attribute definitions to compare the sensory space of orange juice as determined by two different panels using different products. Including the definitions for both panels enabled the authors to cross validate the sensory results.

If references are generated from a literature search, the original references should be cited, which allows researchers to cross-reference attributes across studies. At times, more than one reference may be suitable for an attribute. Including all possible references is helpful for broader application of the lexicon in case one of the references becomes less readily available. The best references are those that are economical and common across a wide range of geographic regions.

Lexicons are scientific vocabularies that facilitate communication among varied entities such as sensory scientists, product developers, technicians and their business partners. Continued publication of lexicons expands the standardization of sensory science protocols, which benefits the discipline through increased reproducibility. The development and publication of lexicons should be encouraged in the sensory community to foster increased communication.

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