# ALMOND SENSORY ANALYSIS

## How to evaluate the sensory profiles of almond samples

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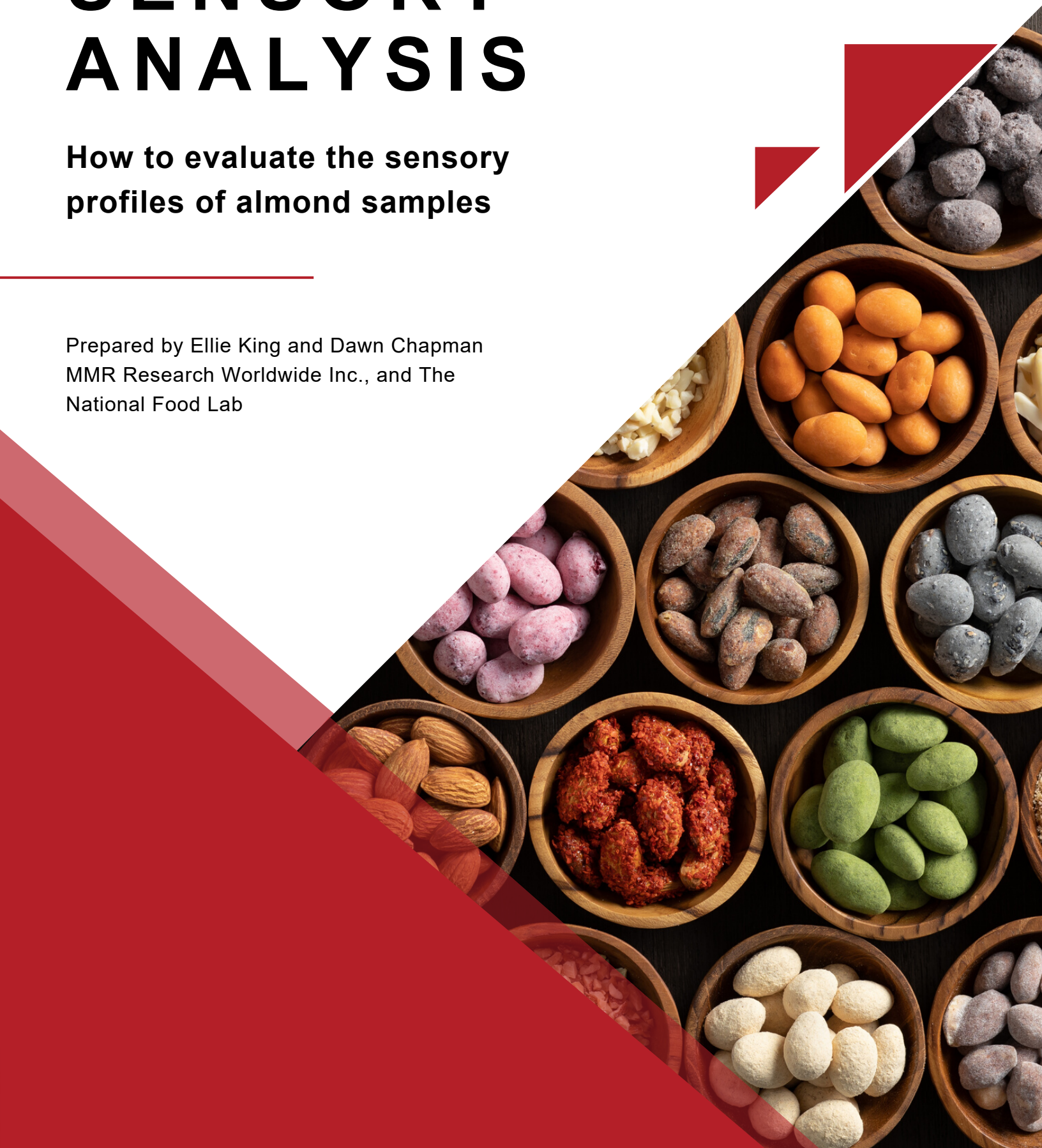


This document provides guidance for evaluating the sensory profiles of almonds. It includes suggestions for designing sensory studies, establishing a sensory panel *and** conducting various methods of sensory evaluations on almond samples.

When a sensory panel starts a product evaluation, a series of attributes and reference standards (Table 1) are provided to facilitate the training. These reference standards have two purposes:

(i) to make sure that everyone in the training is aligned in their sensory language and, in some instances, scaling (some of the references have scale values), to represent low, medium and high areas on the intensity scale; and

(ii) to act as a translation device to anyone outside the panel that has not gone through the training

Throughout this guide, there are references to American Society for Testing and Materials (ASTM). technical industry standards for sensory and consumer research (Committee E18). These have been written and agreed upon by experts in industry and academia and are regularly updated. They are a useful tool for anyone who is interested in learning more about sensory and consumer research, from beginners to experts. They can be accessed through a membership or individually purchased (https://www.astm.org/get-involved/technical-committees/committee-e18/subcommittee-e18).

## Basic sensory principles

In a sensory study, the main consideration is minimizing external bias, such that the only differences among the samples are the variable(s) under consideration. Any other differences will introduce bias and are likely to invalidate the results. This is because human perception is very easily influenced by many factors, such as noises, aromatics, or visual distractions.

Where possible, all sensory evaluation sessions should be conducted in a quiet room, away from other noises and smells, with bright lighting, good ventilation and a relatively constant temperature and humidity. The discussion/testing area should also be separate from the sample preparation area.

Samples should be prepared and served in a consistent manner, and assessed blind (no external information, such as brand, variety, age, region, grade, processing type). Each panel session should be structured to avoid both mental and physical fatigue, with frequent breaks between samples and use of palate cleaners (still or sparkling filtered water and unsalted crackers). The number of samples assessed in each session should also be limited, as should the length of the session (recommended no more than 2 hours long).

Sessions should be conducted by a panel leader who remains unbiased. The panel leader should not disclose any information to the panel about the study objectives or any expected outcomes. All input during panel sessions should come from panelists, including sensory language and intensity ratings. The role of a panel leader is to be a moderator of the panel sessions, collecting information, facilitating discussion and ensuring alignment of the panel. The second consideration in a sensory study is statistical power, which is only relevant for methods that involve statistical analysis, such as ranking and intensity ratings. With these methods, it's important to ensure that enough trained panelists participate in the study, with enough replicates/repetitions, so as to find a significant difference between samples above the level of chance.

## A. Panelist selection

Ideally, each individual should fit the following criteria: over 18 years of age, has no food allergies (especially to nuts!) Panelists should not smoke/vape or have any underlying medical/health conditions that impede their sensory acuity skills.

All potential candidates should be screened using some basic sensory tasks, to evaluate their ability to detect, recognize and describe basic tastes, aromas and textures.

Panels work best when they are a consistent, long-term group of people, who are trained together. This is unlike consumer tests, where untrained consumers are recruited on an 'as needed' basis. Therefore, availability and longevity should also be part of the panelist screening criteria.

Depending on the method of evaluation, more panelists may also be needed. For instance, ranking exercise generally requires more people or replicates/repetitions (~30 answers per group of products), which could consist of 10-12 panelists conducting 3 replicates or 15 panelists conducting 2 replicates, for example), to provide enough statistical power to find above chance level of significant differences among samples.

Panelists should not eat or drink anything (other than water and palate cleaners) 30 minutes prior to and at all times during each session. They should not wear any strongly perfumed products prior to or during sessions, including hair care, skin care and personal hygiene products.

For more information on sensory panelist selection, see ASTM STP758 (Guidelines for the Selection and Training of Sensory Panel Members, https://doi.org/10.1520/STP758-EB).

**Ideally, at least 8-12 panelists participate in each sensory study (8 panelists being the absolute minimum for any statistical analyses). It may be necessary to train a larger pool of panelists, so that at least 8-12 panelists are able to participate in each study, especially for employee panels.**

## B. Sample selection

Samples should be selected based on the objectives of the study. Almond samples may be raw, pasteurized, roasted, sliced, blanched, etc., and may consist of different varieties, different grades, different batches, different ages, etc.
The range of sensory profiles should also reflect the objectives of the study. For instance, comparing almond samples from different growers or regions may represent a wide range of sensory profiles, while comparing almond samples within the same batch for quality control should show less differences overall.

Larger sample sets are more difficult to evaluate and compare. It is recommended that sample sets be limited to no more than 12 samples total.

## C. Sample preparation

The amount of sample to prepare and assess in any one session should be chosen such that the panelists are able to focus, and avoid fatigue and satiety. Panelists need enough sample to reasonably complete the exercise that you are asking them to do.

Sample amount should also take into account piece to piece variability within almond samples. Assessing a larger sample amount can give panelists the ability to evaluate a more representative sample. If sample quantity is limited, the study design can be modified with this limitation in mind and trade-offs can be discussed. Ensure consistency in kernel numbers or weight across all samples throughout a single study.

**All samples in the study should be prepared and stored in the same manner for consistency.**

About 1 hour before assessment, place each almond sample in lidded cups. All samples should be blinded with random 3-digit codes. During training, samples may be served simultaneously, for side-by-side comparison and discussion.

However, during data collection, samples should be presented to panelists in a randomized and balanced order (such that every sample is seen before and after every other sample an equal number of times – an example is a William's Latin Square design). For data collection with intensity ratings, samples should also be served one at a time, however, for QC, ranking or groups, multiple samples may be served at once (in a randomized order).

For more general information on serving protocols, see ASTM E1871-17 (Standard Guide for Serving Protocol for Sensory Evaluation of Foods and Beverages, https://doi.org/10.1520/E1871-17).

## D. Panelist training

Panelists must first be trained on the basics of sensory science, and then the sensory language, references and protocols specific to almond samples. Panelists may also need to train on scaling and intensity ratings. This process can take anywhere from 2 weeks to 3 months, depending on the level of accuracy and precision required. It also depends on the range of sample sets (for example, do panelists need to be familiarized with the entire category of almonds, or only raw, fresh almonds?), and the types of sensory methods that they will be conducting.

## D.1. Introduction to Sensory science

Panelists should initially go through a series of training sessions to learn the basics of sensory science, such as objective vs. subjective assessments, differentiating modalities (i.e. sweet taste vs. sweet aromatic), eliminating their own biases and contributing to group discussion.

## D.2. Training on almond sensory language, definitions and references

Panelists then need to learn to generate and use specific sensory language, definitions, references, and potentially scaling, to describe and rate the sensory profiles of almonds. Table 1 provides a list of attributes and reference standards, to describe the appearance, flavor, and texture of raw and unpasteurized almonds (King et al. 2019) and roasted almonds throughout accelerated shelf life (Franklin et al. 2017). Panelists may also suggest additional sensory attributes to include that are relevant to the sample set of interest. For a larger list of sensory attributes related to almonds, see Civille et al. (2010).

References are used to align panelists' sensory language – they represent the character of a sensory attribute. For instance, vanilla extract to represent 'sweet aromatic aroma/flavor', which represents things that smell sweet (but not fruity), such as vanilla, caramel, dark chocolate, honey, brown sugar, maple syrup, butterscotch. References usually comprise commonly available food-grade products, but should not be the almond samples themselves (unless using an almond sample in the set as an internal calibration control, see Section D.4).

Reference foods and objects should be provided to align panelists' sensor language. Reference materials are selected to represent the character of a sensory attribute. (ie. 'sweet aromatic' for vanilla essence). They should be provided for all training sessions, so that panelists become familiar with each

attribute. Most references do not need to be made fresh each session, unless they contain fresh ingredients, and can be stored in the refrigerator overnight, to keep fresh for longer.

## D.3. Training on almond assessment protocols

At this stage, panelists also need to develop a protocol for assessing almond samples. Table 1 provides examples of references that can be adapted to the sample set of interest. Ensure that the same protocol is used by all panelists to assess all samples

**Assess each almond sample individually by following these steps in order:**

1. Record 3-digit code of sample
2. Shake cup, then remove lid and assess the aroma of the sample in the cup
3. Assess the uniformity of the color, size, shape and visual texture of the sample
4. Place at least a few kernels in your mouth
5. Bite down with front teeth and assess initial texture
6. Continue chewing with molars and rate texture during chewdown
7. Swallow / spit-out and assess particulate left in mouth (do not rinse)
8. Place at least a few more kernels in your mouth
9. Chew for at least 10 seconds and assess flavor
10. Swallow / spit-out and assess aftertaste (tastes/flavors left in mouth)
11. Rinse with water, eat an unsalted cracker and wait at least 5 minutes before assessing the next sample

Refer back to **Table 1** (Example assessment protocol for evaluating the sensory profiles of almonds. Modified from some previous work done at UC Davis by King and Heymann in 2013.)

It may seem unnatural to assess taste and texture (5), before flavor (8) in Figure 1. However, assessment of flavor requires the almond to be chewed until the flavor is released (~10 seconds). In doing this first, the texture of the almond changes (it may soften and become more cohesive), which obscures the actual texture ratings of the sample. Hence, taste and texture are rated first, followed by flavor. Panelists should not rinse between the assessments of the same sample, only between different almond samples.

**Table 1** ( Example assessment protocol for evaluating the sensory profiles of almonds. Modified from some previous work done at UC Davis by King and Heymann in 2013.)

**Attributes, terms included, and reference standards used to assess almond samples. Some references represent low (L), low to medium (L-M), medium (M), medium to high (M-H) and high (H) areas on the intensity scale (see associated references for specific scale values).† NR = Not rated or anchored to the line scale. Used as a character reference only.**

| Sensory Attribute | Scale | Reference | Definitions | Almonds/ Study Type |
|---|---|---|---|---|
| **Appearance** | | | | |
| Average Darkness of Color | L<br>M-H<br>H | White<br>Sepia Crayola<br>Black Crayola | The average darkness of the kernels, rated from light to dark. | Raw |
| Diversity of Color | | | The degree to which the kernels vary in color from all one color (uniform) to several different colors (diverse), including color contrast of ridges/veins and not including skin lesions. | Raw |
| Average Length | L-M<br>M-H | Silver Pencil Eraser<br>Quarter | The average length of the kernels, from short to long. | Raw |
| Diversity of Shape/ Size | | | The degree to which the kernels vary in shape or size from all one shape and size (uniform) to several shapes and sizes (diverse). | Raw |
| Appearance of Ridges/Veins | | | The degree to which the kernels appear to have ridges and veins, not taking into account cracks, chips, nicks or wrinkles. | Raw |
| **Aroma / Flavor** | | | | |
| Total Aroma / Flavor Intensity | | | The total intensity of all the aromas/odors or tastes/flavors in the sample. | Raw |
| Total Clean Nutty | L-M<br><br>NR†<br>NR | Trader Joes Dry Roasted, Unsalted Almonds<br><br>C<br>Walnut nut | The total intensity of clean or fresh nut character in the sample. Roll-up term includes woody, marzipan/ benzaldehyde, sweet aromatic, fruity, hay, unripe, musty, woody. Does not include roasted or off-notes. | Roasted/ Shelf Life** |
| - Marzipan / Benzaldehyde | NR | 0.75 g of Spice Island Almond Extract in 200 ml 2% milk | The aroma/flavor intensity associated with Marzipan and/or Benzaldehyde; reminiscent of maraschino cherries or almond extract.. | Raw |
| - Sweet Aromatic (non-fruity) | L | 0.75 g of Spice Island Vanilla in 200 ml 2% milk | The total aroma/flavor intensity associated with any non-fruity sweet aroma (reminiscent of products with a sweet taste such as vanilla, caramel, dark chocolate, honey, brown sugar, maple syrup, and butterscotch). | Raw |
| - Fruity / Sour | NR<br>L-M | 1 dried apricot<br>Kefir | The aroma/flavor intensity associated with fruit, such as dried apricots and fermented fruit, such as sour aromatics. | Raw |
| - Hay | NR | Alfalfa hay | The aroma/flavor intensity associated with hay or dried grass. | Raw |
| - Unripe / Beany | L (flavor)<br><br>L-M (aroma)<br><br>NR | Green banana<br><br>Fresh green beans soaked overnight in water<br><br>Walnut nut and brazil nut | The aroma/flavor intensity associated with unripe, immature, green or vegetal, such as green bean or other nuts, such as peanut and walnut. | Raw |

# Table 1 (Cont.)

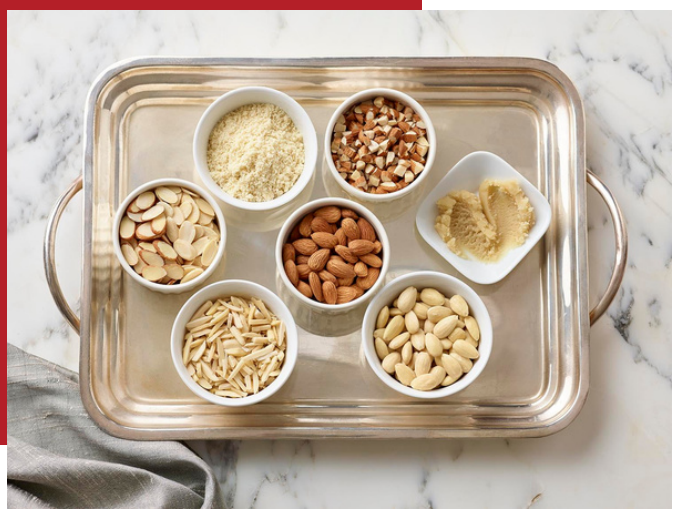
| | | | | |
|---|---|---|---|---|
| - Woody | NR | Fresh wood plank | The aroma/flavor intensity associated with wood, sawdust, pencil shavings or cut lumber. | Raw |
| - Musty / Earthy | NR<br>NR<br>NR | Raw Mushrooms<br>Humic acid<br>Dirty potato skins | The aroma/flavor intensity associated with musty, stale, dank, wet cellar, dirt, earthy, such as potato skins and mushrooms. | Raw |
| - Clean Roasted | L-M | Trader Joes Dry Roasted, Unsalted Almonds | The intensity of notes reminiscent of roasted or toasted. | Roasted/ Shelf Life |
| - Rubber / Medicinal | NR<br><br>NR | Rubber stopper soaked in warm water<br>Phenol | The aroma/flavor intensity associated with rubber, leather, medicinal, phenolic, Band-Aid, petroleum or metallic. | Raw |
| - Total Oxidized | | | The total intensity of notes associated with an old/stale oil character or oil that is oxidized. Roll-up includes painty, solvent, rancid, soapy. | Roasted/ Shelf Life |
| - Cardboard | NR | Cardboard soaked overnight at room temperature in Alhambra water | The intensity of notes associated with cardboard, stale, musty, dusty or sawdust. | Roasted/ Shelf Life |
| - Painty / Solvent | NR | Wesson Vegetable Oil, several years past expiry, stored at room temperature | The intensity of notes reminiscent of oil based paint, solvent, spoiled fish or rancid oil. | Roasted/ Shelf Life |
| - Soapy | | | The intensity of notes associated with soap, floral, ivory soap and waxy. | Roasted/ Shelf Life |
| - Sweet | L<br><br>L-M | 2.0 g Sucrose in 250 ml Drinking Water<br>5.0 g Sucrose in 250 ml Drinking Water | One of the basic tastes, common to sucrose. | Raw |
| - Bitter | L | 0.025% Caffeine | One of the basic tastes, characteristic of caffeine or quinine. | Roasted/ Shelf Life |
| **Texture (Initial)** | | | | |
| Hardness (force to break) | L-M<br>M<br>M<br>M-H<br>H | Nabisco Chips Ahoy Cookies<br>Nabisco Wheat Thin Crackers<br>Nabisco Oreo<br>Old London Melba Toast<br>Nabisco Ginger Snap | Force required to chew through the sample using the molars, from soft (left) to hard (right). | Roasted/ Shelf Life |
| Fracturability | L-M<br>L-M<br>M<br>M-H<br>H | Nabisco Regular Chips Ahoy<br>Nabisco Graham Cracker<br>Nabisco Oreo<br>Old London Melba Toast<br>Nabisco Ginger Snap | The force with which the sample breaks, includes brittleness. Generally, an increase in auditory signals results from higher fracturability. | Raw |

## D.4. Training on sensory scaling (for intensity ratings only)

Additionally, panelists may need to learn how to quantitatively rate the intensity of sensory attributes on scales. This requires additional training, as panelists need to change their perception of sensory attributes (i.e. “I can smell sweet aromatic”) into numerical values (i.e. “the sweet aromatic intensity is a 2”). It also requires panelists to understand scale values and agree on intensity scores for all attributes for all samples. This is because intensity ratings should be relative across all attributes, and comparative across all samples.

Note: Panelist intensity scoring is not necessarily indicative of consumer perception. Panelists are considered to be more sensitive than consumers, given their training, and are likely to detect some differences that are not perceptible to consumers, especially at lower intensity levels. A consumer test would need to be conducted to understand the specific relationship of panelist ratings to consumer perception for a given product category. Some notes (especially off notes) may be noticed by consumers at a lower intensity levels.

There are many different types of sensory scales, all with a different purpose of measurement. The references in Table 1 provide examples of a 15 point line scale, where 0= “None” and 15 = “Extreme”. Some of the character references are anchored on the attribute scales, to represent low, medium and high areas of intensity. This is to provide tangible examples of intensity ratings, so that panelists can compare the intensities of the character references to the almond



samples in the set and align on scores together during training.

However, not all sensory methods have anchored references. Some use a sample in the set as an anchor on the line scales, to provide an internal calibration control, while other methods use no anchors (references or samples) at all. For more information on selecting the appropriate scale, see E3041-17 (Standard Guide for Selecting and Using Scales for Sensory Evaluation, https://doi.org/10.1520/E3041-17).

## D.5. Training for specific sensory study

Once panelists are trained to evaluate almond sensory profiles, they are ready to start conducting sensory studies. For each study, panelists should first be familiarized with all the samples in the study. This provides them with the context of the study (ie. which samples are the darkest, the sweetest, the hardest and the most astringent in the set).

At this stage, the panel should also agree and finalize the sensory attributes, references and protocols relevant to the specific study. Training should focus on the key attributes of interest (ie. if the study design is related to humidity, then maybe texture is the most important modality to focus on). This will streamline the panel discussions.

Panelists should also use this training to discuss and align on key differences and similarities among the sample set, whether this be through roundtable consensus discussion, and/or by practice scoring. This helps to build panelist agreement and consistency, prior to data collection.

Depending on the objectives of the study, panelists could also conduct a "mock study" to practice data collection. This is a chance to provide panelists with feedback and determine if they need re-training prior to final data collection.

For more general information on training sensory panelists, see ASTM STP758 (Guidelines for the Selection and Training of Sensory Panel Members, https://doi.org/10.1520/STP758-EB).

## D.6. Panelist feedback

When training a panel, it's essential to provide panelists with feedback at each stage, to determine their level of progress and whether they need more training.

**There are three main measures of panel performance commonly used within sensory panels (these will differ, depending on the sensory method):**

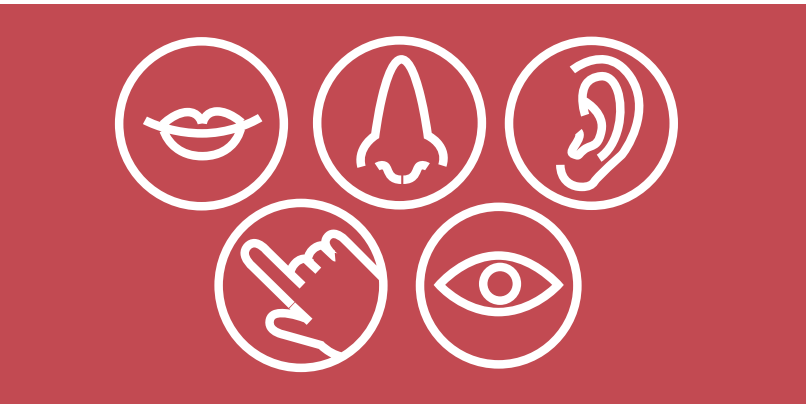
- discrimination (can they differentiate among the samples in the set)
- agreement (is their sample rating aligned with the rest of the panel)
- repeatability (can they repeat their own ratings across multiple evaluations of the same sample)

For more information on how to provide panelist feedback, see ASTM E3000-18 (Standard Guide for Measuring and Tracking Performance of Assessors on a Descriptive Sensory Panel, https://doi.org/10.1520/E3000-18).

## E. Types of sensory tests

Panelists can provide evaluations of almond sensory profiles using a number of different methods, from more qualitative approaches, like grouping and group discussions, to more quantitative approaches, like ranking and intensity ratings. Study methods should be chosen to address business needs.

Outputs from the panels can be paper forms on which the panelists write their evaluations or on-line questionnaires.



Depending on the business need, replication or repetition may be required. This is a way to measure the repeatability of each panelist (how well they can rate each sample the same way over multiple evaluations). It also provides more robust data, as it is a measure of variability within each sample (how much samples differ within the same batch). Ideally, replicates are assessed on separate days, but this is not always logistically possible. Be sure to use different 3-digit codes for each replicate, so that panelists cannot automatically recognize samples between replicates.

## E.1. Small group evaluations

There may be situations where there are not enough trained panelists available, there is limited sample quantity or resources, or the objectives of the test are more informal. In these situations, it may be suitable for a small group evaluation, also known as a "bench top tasting," "team tasting," "cutting" or "screening". These types of tests are often used for shelf life studies and QC programs.

The outputs of these roundtable consensus discussions can be either qualitative, such as providing written sensory descriptions and/or product selections, or quantitative, where panelists rate the intensity of key attributes and generate a single score per product per attribute agreed on by the group. It generally does not involve replication, and the results are not used for statistical analysis, given the low statistical power.

For more general information on small group evaluations, see ASTM E3093-20 (Standard Guide for Structured Small Group Product Evaluations, https://doi.org/10.1520/E3093-20) and for more information on shelf-life testing, one common use of these consensus methods, see ASTM E2454-19a (Standard Guide for Sensory Evaluation Methods to Determine the Sensory Shelf Life of Consumer Products, https://doi.org/10.1520/E2454-19A).

## E.2. Quality Control program

Manufacturing companies often establish quality control (QC) or quality assurance (QA) programs to ensure that their products are within certain specification limits, whether they be physical, technical, chemical, or sensory. QA/QC programs can cover incoming and stored raw materials, as well as in-process and finished goods.

For sensory QA evaluations, sensory attributes of samples are evaluated against target sensory specifications or quality standards. These target specifications or standards are generally established by the company and/or the panel.

QC methods generally involve comparison to a “gold standard” that represents the ideal sensory profile, or a set of products that are considered “in spec”. It can be a simple discrimination test, such as Same-Different: “Is this test sample the same as the Gold Standard, or not?”. Or panelists can provide more in-depth information using intensity ratings.

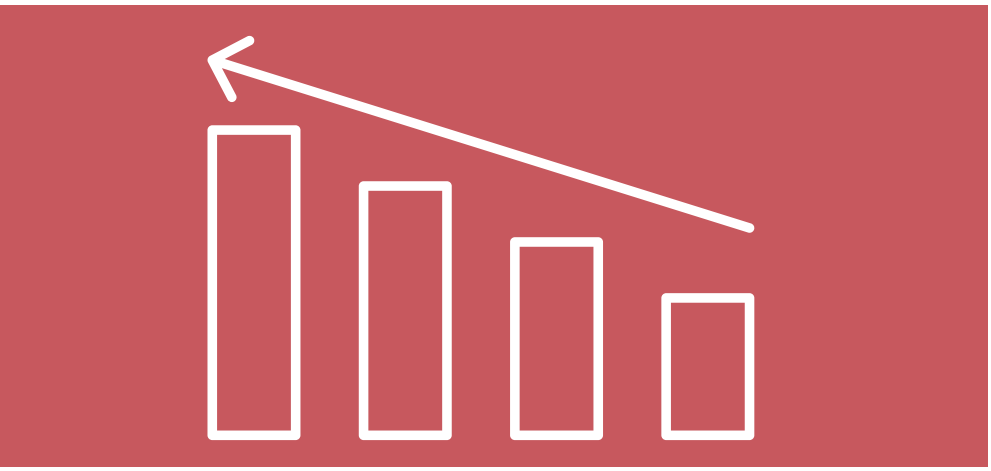
For more detailed information on developing and maintaining a QC program, see ASTM MNL14 (The Role of Sensory Analysis in Quality Control, https://doi.org/10.1520/MNL14-EB).

## E.3. Grouping

Grouping is a qualitative assessment of how similar/different almond samples are to one another based on their sensory profiles. Panelists taste all samples and then group or sort them into groups of samples with similar sensory profiles. It is possible to generate a maximum of N-1 groups (N=total number of samples).

Panelists can be asked to group samples based on their entire sensory profiles, or to focus on specific modalities, such as “group samples based on texture only”. It is useful for panelists to also describe the sensory profiles of each group (i.e. Group 1 is ‘soft and cohesive’ or ‘hard and crunchy’).

Panelists may perform the grouping task individually or together as a whole panel, using roundtable discussion and consensus agreement. Panelists may be asked to perform the grouping more than once, to confirm the robustness of each group.



## E.4. Ranking

Ranking is an order-sorting task, where panelists order products from lowest to highest based on one specific sensory attribute. For instance, “rank products in order of rancid flavor.” Ranking cannot be done on the overall sensory profiles of almonds, it must be specific to a sensory attribute, which must be clearly understood by the panel using definitions and references, where possible (see Table 1 for examples).

There should be no more than 5 samples in each ranking task.

Panelists may perform the ranking task individually or together as a whole panel, using roundtable discussion and consensus agreement. It is recommended that panelists perform the ranking more than once for each set of samples (up to three times is recommended), for statistical robustness.

## E.5. Intensity ratings

Intensity ratings are used to quantitatively compare the intensity of two or more samples for a given attribute. It is the most robust form of sensory evaluation, with 2-3 replicate evaluations and statistical significance between samples. For this reason, intensity ratings can be used in more formal, hypothesis-driven business decisions, such as launching new or re-formulated product, comparing to competitors, making a marketing claim (see ASTM E1958-20 https://doi.org/10.1520/E1958-20) or publishing research.

For more general information on collecting and analyzing intensity ratings, see ASTM MNL13 (Manual on Descriptive Analysis Testing for Sensory Evaluation).

Intensity ratings are used to Establishing a sensory panel can be a large investment of time, money and resources, but if done correctly, it can provide critical insights on product quality and development for the almond industry. On the other hand, there are some simple ways in which companies can conduct a sensory test, to get a quick read on almond sensory profiles.


## Acknowledgements

Additional contributions in reviewing this by Guangwei Huang and the Almond Board of California for funding and resources. We also thank all sensory panelists for their participation.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