Designation: E1909 – 13 (Reapproved 2017)

Standard Guide for Time-Intensity Evaluation of Sensory Attributes[1]

This standard is issued under the fixed designation E1909; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers procedures for conducting and analyzing time-intensity (T-I) evaluations of products or other sensory stimuli. Time-intensity is the measurement of the intensity of a single sensory sensation over time in response to a single exposure to a product or other sensory stimulus. Simultaneous evaluations of multiple sensory attributes are possible, although are outside of the scope of this document. See Reference List for more information.

1.2 This guide utilizes a specially trained panel to measure the intensity of a single continuous sensation during the time from initial exposure:

1.2.1 To its extinction,

1.2.2 To a specified intensity, or

1.2.3 To a predetermined limit of time.

1.3 Applications not covered in this guide include measuring:

1.3.1 Multiple sensations,

1.3.2 Multiple exposures within a single measurement, and

1.3.3 Qualitative or hedonic changes in the perceived sensation.

1.4 This guide includes protocols for the selection and training of judges, descriptions and use of physical data collection devices, and methods of data handling, summarization, and statistical analysis. Illustration of two different data handling and analysis approaches are included in the appendixes.

1.5 This guide is not applicable to measure product shelf life or stability that require evaluations over extended time.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E253 Terminology Relating to Sensory Evaluation of Materials and Products

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:* See Fig. 1.

3.1.1 *area after I_{max}*—post-peak area under the curve.

3.1.2 *area before I_{max}*—pre-peak area under the curve.

3.1.3 *AUC*—area under the curve.

3.1.4 *I_{max} or peak intensity*—maximum observed intensity during the time of measurement.

3.1.5 *perimeter*—measured distance of perimeter of area delineated by T-I curve.

3.1.6 *plateau*—duration of peak intensity.

3.1.7 *rate of increase*—rate of intensity increase before peak intensity (slope).

3.1.8 *rate of decrease*—rate of intensity decrease after peak intensity (slope).

3.1.9 *T_{dur} or duration time*—time from onset of sensation until it can no longer be perceived ($T_{ext} – T_{onset}$).

3.1.10 *T_{ext} or time to extinction*—time from initial exposure to the stimulus (T_{init}) until it can no longer be perceived.

3.1.11 *T_{init}*—time of initial exposure to the stimulus, typically when the clock starts.

3.1.12 *T_{max}*—time to reach maximum intensity of the sensation after exposure to the stimulus.

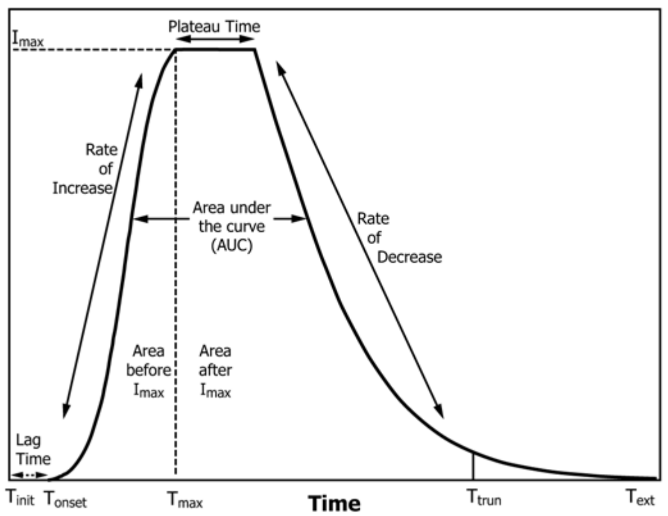
3.1.13 *T_{onset}*—time point when the stimulus is first perceived after initial exposure to the stimulus.

---

[1] This guide is under the jurisdiction of ASTM Committee E18 on Sensory Evaluation and is the direct responsibility of Subcommittee E18.03 on Sensory Theory and Statistics.

Current edition approved Aug. 1, 2017. Published August 2017. Originally approved in 1997. Last previous edition approved in 2013 as E1909 – 13. DOI: 10.1520/E1909-13R17.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



NOTE 1—Based on a figure from Ref (**1**).

FIG. 1 Representative Time-Intensity Curve with Selected Parameters Labeled

3.1.14 *T_{trun} or truncated time*—time until a specified minimum intensity or until a pre-determined time point has been reached.

3.2 The graphical illustration of a typical time-intensity curve is shown in Fig. 1. The time increment may be seconds, minutes, hours, etc., depending upon the characteristic of the particular material under study.

4. Summary of Guide

4.1 This guide describes procedures utilizing specially trained panelists to measure the intensity of a single sensory sensation as it changes with time and the possible approaches to collect and analyze such data. Details on specific procedures are given in Sections 6 – 9 of this guide. Examples of time-related evaluations are included in the appendixes.

5. Significance and Use

5.1 The purpose of time-intensity measurements is to establish the pattern of development and decline of a particular sensory characteristic under study. T-I evaluations are applicable when measurements at a single time point (an averaging process) are not sufficient to distinguish products that have very different temporal characteristics. As pointed out by Lee and Pangborn (**2**)[3], "This averaging process results in the masking or complete loss of important information such as rate of onset of stimulation, time and duration of maximum intensity, rate of decay of perceived intensity, time of extinction, and total duration of the entire process."

5.2 Products rated similarly using traditional single point techniques of product profiling may provide very different temporal sensory experiences to the consumer. Acceptability of the product may be affected, and traditional descriptive methodology does not reflect the changes in an attribute's intensity over time.

5.3 T-I has applications for a variety of products. Examples include: food products, ranging from short-term sweetness in a beverage to long-term elasticity in chewing gum; personal care products, measuring the development and longevity of shampoo lather and the residual skin feel of a skin cream; household care products, monitoring the intensity of scents over time; pharmaceuticals, monitoring skin cooling after application of a topical analgesic. Auditory signals or visual changes in products can also be evaluated by the T-I technique.

6. Time-Intensity Panel Selection and Training

6.1 *Screening and Selection of Panelists*

6.1.1 Time-Intensity evaluation is a specialized type of descriptive analysis. Therefore, use of randomly selected, naive panelists is neither appropriate nor recommended. Panelists selected for Time-Intensity studies are screened as recommended for other descriptive methods (see STP 758 (**3**)). Use of panelists with previous descriptive training facilitates the T-I training because these panelists are competent in both recognizing and intensity scaling an attribute.

6.1.2 The goal of the selection process is to identify panelists who have the ability to:

6.1.2.1 Continually focus on a single sensory attribute,

6.1.2.2 Accurately identify and quantify a single sensory attribute within a simple or complex sample,

6.1.2.3 Accurately record changes in sensations as they occur,

6.1.2.4 Perform consistently,

6.1.2.5 Perform all test procedures with appropriate motor skills (for example, ability to chew gum while manipulating the input device to indicate the intensity of the mint flavor).

6.1.3 Compared to other descriptive methods, T-I panelists require more skills to complete the time-intensity task. Due to the complexity of the method and techniques involved, final selection of panelists may not occur until after completion of the training.

6.2 *Time-Intensity Panel Training:*

6.2.1 The purpose of T-I training is to demonstrate how to perform the physical, mental and psychological tasks associated with temporal profile method. Training begins with an orientation to the T-I method. Orientation to the method involves explanation and demonstration of the temporal nature of sensory properties, utilizing products having diverse temporal profiles. General time-intensity concepts may be illustrated by showing examples from alternate sensory modalities. Sound, light, odor, taste, touch/pressure or texture may all display temporal properties.

6.2.2 During training, panelists are thoroughly familiarized with all testing equipment and procedures.

6.2.3 The purpose of training samples is to demonstrate different onset, plateau, or duration characteristics. These are often best presented in contrasting pairs or sets. One example is a set of chewing gums, one with a fast flavor onset, another with a slower onset. Another example is a series of margarine products that demonstrate different textural properties, such as rate of melt.

6.2.4 References are samples that demonstrate an attribute at a given intensity. Use of references to calibrate intensity

---

[3] The boldface numbers given in parentheses refer to a list of references at the end of the text.

ratings occurs prior to the test. This is critical because in T-I analysis, attribute intensity is recorded without interruption during the test.

6.3 *Panel Performance Monitoring and Feedback*

6.3.1 Monitor panelist performance during the training and evaluation sessions. At the start of the study, determine an acceptable level of individual and group performance. This can include deviation around a scale value at a specified time point or similar indicator. STP 758 (**3**) provides statistical procedures suitable for monitoring panelist performance.

6.3.2 Panelists should be able to demonstrate consistency in their evaluations. One approach is to measure reproducibility in selected curve parameters, for example, I_{max}, T_{max}, T_{ext}, of their individual T-I curves. However, consistency with other panelists is less likely than with general descriptive analysis, as each panelist tends to produce distinctive curve shapes. In T-I analysis, within-panelist consistency, particularly in their ability to communicate relative differences among samples, is more important than panelist-to-panelist agreement. See discussion in Section 9.

6.3.3 One parameter that should show some degree of agreement among the panelists is I_{max}, particularly if reference standards for intensity are being utilized. The I_{max} value can be used to compare panelist performance with an appropriate means-separation test, percent standard deviation, or other analysis methods commonly used in monitoring descriptive evaluations.

7. Panel Protocol

7.1 Specifics of the actual management of a time-intensity panel are highly dependent upon study objectives. The following topics represent major steps or considerations in the design and execution of time-intensity panels. It is assumed that basic panel training on the product of interest and selection of the appropriate data collection device have been completed (see Sections 6 and 8, respectively).

7.1.1 *Design Considerations*—Before the panel is conducted, the following sample, experimental design, and set-up issues are resolved:

7.1.1.1 The first consideration in designing a time-intensity panel is to determine the length of time for data collection. It can be relatively short, like the meltdown of a pat of butter when placed in the mouth, or relatively long, like the longevity of mint flavor in a chewing gum.

7.1.1.2 Knowing the expected duration, and designing the study to cover critical changes in a product is prerequisite to other design considerations. The number of sampling points and the time interval between points is set to capture the changes in an attribute at the time it occurs. Factors which may affect the duration of the attribute to be measured include: sample form (crystalline versus dilute solution of sugar), sample size (larger amount of sample versus smaller amount of sample), evaluation technique (dissolving versus chewing a hard candy), and other materials (water hardness for soaps and shampoos).

7.1.2 The number of samples evaluated in a panel session is primarily dependent upon the duration of the time-intensity sensation. If the evaluation of a chewing gum is designed to measure mint flavor intensity changes over a 20 min period, one to two samples may be the maximum number panelists can evaluate without excessive physical or mental fatigue. Conversely, 5 to 6 potato chips may be evaluated for duration of crisp/crunchy attributes before fatigue sets in.

7.1.3 If the test is designed to measure the perception of an attribute to extinction, there is generally no need for lengthy waiting periods between samples. However, a longer waiting period is required when the perception of an attribute is affected by a preceding sample. Examples include: allowing mouth temperature to return to normal after ice cream evaluations, and recovery from numbing effects due to menthol or spices.

7.1.4 Sample presentation order may be randomized, fixed, balanced, or presented as an incomplete block, depending on study objectives. Typically, samples are presented in a balanced order to minimize position bias, context effects, etc. as recommended for most sensory evaluations. During training, samples may be presented in fixed order (that is, all panelists see the same samples in the same order of presentation), to facilitate discussion and learning.

7.2 *Data Collection Considerations*—In any time-intensity experiment, regardless of the type of data collection device used, the rate at which information is collected must be determined. Data recording intervals are set to capture maximum/critical change on a product's profile, with intensity ratings collected at various time points depending on the study objective (see Sections 8 and 9).

7.3 *Sample Preparation*—As with any sensory evaluation, sample preparation and presentation for T-I analysis need to be controlled to eliminate extraneous effects. Recommended guidelines are to be followed (Manual 26) (**4**).

7.3.1 *Reference Samples*—If appropriate in the test design, use of reference samples is recommended. References are evaluated prior to test samples, so that test sample evaluation is conducted without interruption. References are evaluated by the same technique as the test samples and may be used to specify an attribute's intensity at a specific point in time.

7.3.2 *Conditioning Sample*—Use of a conditioning sample, presented prior to the actual test sample, can be used to calibrate panelists to the same sensation, and to some extent, to control first position bias or context effects. Consideration should be given to adaptation, carryover, and fatigue in deciding whether or not to use a conditioning sample.

7.3.3 *Inter-Stimulus Procedures*—Specify whether panelists are to rinse, re-taste reference standards, or use a palate cleanser such as a cracker, celery, etc. between samples.

7.4 *Evaluation Procedures:*

7.4.1 Evaluation begins as soon as the stimulus is introduced to the panelist, for example, when the sample is applied, tasted, or smelled. The evaluation is completed upon reaching a predetermined time limit, intensity, or extinction of the sensation.

7.4.2 Standardized evaluation procedures such as the force and frequency of manipulations (for example, chews per second of a cookie, rubs of a hand lotion, or whether to expectorate or swallow) must be specified and incorporated into the panel training and test procedures to assure all panelists receive the same sample stimulus.

7.5 *Other Panel Protocol Considerations:*

7.5.1 *Testing Environment*—Follow recommended guidelines for physical testing facilities in MNL 60 (**5**).

8. Data Collection Techniques

8.1 *Introduction*—The two modes of data collection in time-intensity evaluation are cued and real-time. With cued techniques, panelists are instructed to report their responses at specific, predetermined points in time during the evaluation. With real-time techniques, panelists report their responses continuously over time during the evaluation. Selection of one technique over the other depends on such issues as the goals of the study, the desired time points, available resources, and economic considerations.

8.2 *Cued Techniques:*

8.2.1 This mode of data collection uses an external device or a person other than a panelist to provide an audible and/or a visual cue at the time when a response is required. Examples of cueing devices are: stop watches, visual or audible metronomes, or both, other beeping or blinking devices with adjustable timing, and computers.

8.2.2 The main advantage of cued techniques is the simplicity of the task for the panelists. Also, cued techniques often are less costly than real-time techniques. Limitations of this mode are low precision of data when short time intervals are used, possible distraction or biasing of the panelists by the cueing device and, when applicable, by viewing of previous ratings.

8.3 *Real-Time Techniques:*

8.3.1 This mode of data collection uses a computer and appropriate software that allows the panelists to report their responses continuously during the evaluations. With computers, a scale is displayed on the computer screen and the panelist manipulates an input device, such as a mouse or joystick, to position the computer's cursor on the scale to indicate the intensity of the attribute at each instant in time. The on-board clock of the computer is used to establish the time axis.

8.3.2 Several options are available for recording data obtained using real-time techniques. One approach is to measure reported intensities at a fixed number of predetermined time-points—by instructing the computer to only record or store data at selected time-points. (Note that the panelist would not be aware of the time-points actually recorded for analysis.) Another approach is to record all the data obtained in a real-time evaluation. The computer software may be instructed to record a panelist's intensity readings at a frequency that the computer allows.

8.3.3 The main advantages of real-time techniques are the flexibility afforded the analyst for controlling the collection intervals and by having all of the panelists' readings available for numerical analysis and interpretation. Another advantage of most real-time techniques is that they do not allow the panelist to view previously reported intensity values, thus eliminating the potential bias resulting from observations of the completed portion of the evolving T-I curve. Disadvantages of real-time techniques are more cumbersome or complex hardware requirements, the need for more sophisticated data handling systems, and typically higher costs.

9. Data Handling, Analysis, and Summarization

9.1 *Introduction:*

9.1.1 There are two aspects of T-I data that present challenges not typically encountered in other types of sensory data.

9.1.2 First, instead of a single response associated with each stimulus, T-I data consists of a collection of responses consisting of the intensity at each time point. The multiple values arising from T-I data can either be handled directly by special statistical analysis approaches or by data handling steps performed prior to the statistical analysis.

9.1.3 Second, T-I data typically exhibit greater panelist to panelist variability than found in other methods. This is seen in time-intensity curve shapes, sometimes referred to as "curve signatures", that are either unique for each panelist or that fall into various broad categories of shapes. Part of this variability in curve shape can be reduced by training and standardization of techniques, but it is generally believed that it cannot be completely eliminated.

9.1.4 The following section discusses several data handling techniques for T-I data. It is important to understand that there have not been a sufficient number of critically reviewed published studies to warrant setting specific guidelines or recommendations.

9.2 *Data Handling*—Several data handling techniques can be used to process the multiple-valued nature of T-I data prior to analysis. These techniques include: collecting only data relevant to the study objective, eliminating redundant data, removing data contributing to bias, smoothing noisy data, or summarizing the data by extracting curve features of interest.

9.2.1 Study objectives can determine which data points are of interest. For example, if the purpose of the study only requires information on the time to maximum intensity, then only these specific data could be collected.

9.2.2 An example of redundant data would be the collection of response values more frequently than the response is changing. This would result in a response plateau that may not be of interest in the study. In this case, the data between the start and the end of the plateau can simply be deleted from the data file, leaving two points to define the plateau.

9.2.3 Bias or data error arises when the response is influenced by factors other than the stimulus itself. Examples of such factors include variations in panelist evaluation techniques, such as expectoration prior to the designated expectoration time. If it becomes known that such actions tend to result in characteristic response patterns, that is, an extraneous curve peak, then the associated response data could be removed prior to analysis.

9.2.4 If the response data do not exhibit regular or smooth trends, but rather has noisy fluctuations around a general trend, the data can be processed by "smoothing" algorithms. Such algorithms replace the original data with transformed values that reflect the trend, but do not include the noisy fluctuations (**6**). The resulting smoothed data are typically what is used in any further analyses.

9.2.5 The T-I data can also be reduced to just a set of key curve characteristics. Each characteristic, or parameter, represents a specific feature of the time-intensity curve. Commonly used parameters include the following (see Section 3 for definitions):

9.2.5.1 I_{max},

9.2.5.2 T_{onset},

9.2.5.3 T_{max},

9.2.5.4 $T_{plateau}$,

9.2.5.5 T_{ext},

9.2.5.6 Area under the whole, or part, of the curve,

9.2.5.7 Slopes, or rates of intensity increase or decrease, and

9.2.5.8 Other parameters defined as needed, such as curve perimeter or curve shape.

9.3 *Data Analysis:*

9.3.1 Several options for the analysis of T-I data are described in the sections given below. It is important to note that not every method is applicable to every research situation. The methods vary in their complexity and the circumstances for which they are best suited. No matter what method is used it remains important to ensure that the data are accurate, that the analysis is consistent with how the study was designed, and that analysis assumptions are met.

9.3.2 Since complete details on the analyses are not given below, statistical advice or references should be utilized as needed.

9.3.3 A preliminary step for most analyses should be a visual inspection of the individual panelist time-intensity graphs. This involves plotting out specific curves to identify situations described in 9.2.1 and 9.2.2. Visual inspection will also help in making decisions regarding the most appropriate data analysis.

9.3.4 If curve parameters (see 9.2.5) are used as the "raw data" for the statistical analysis, conventional statistical techniques can be used. For example, analysis of variance (ANOVA) may be performed to compare means and form confidence intervals (see Appendix X1). These ANOVA models may include a term, or factor, for judge effects. The judge term will often be statistically significant as it has generally been found that judge signatures remain, even after extensive training (see 9.1).

9.3.4.1 Multivariate analysis of variance (MANOVA) could also be performed on the set of all curve parameters. Other multivariate methods can also be used, such as performing a principal components analysis on selected curve parameters (**7**). The principal component scores are then analyzed by analysis of variance or other methods.

9.3.4.2 The advantage of using any of these multivariate methods over the univariate ANOVAs is that patterns of differences can be detected. For example, modest differences in T_{max}, $T_{plateau}$, falling AUC, and T_{ext} may all give rise to one stimulus differing from another when looked at jointly, that is, using a multivariate method. The general pattern of longer-lasting response intensity may not be significant when each of these parameters is analyzed separately.

9.3.5 If the data consist of only a relatively small number of time points, then repeated measures analysis of variance with time and time by stimulus as model factors can be utilized. The advantage of this approach over analyzing curve parameters is that the parameter estimates may be quite imprecise when there are few time points. For example, if sweet intensity was collected on a gum only every minute, then T_{max} cannot be more precise than a minute. This approach requires examining the time by stimulus interaction term in order to assess and compare stimulus effects.

9.3.5.1 When the number of time points becomes large, say greater than eight, examining such an interaction becomes unwieldy. In addition, assumptions on how time points correlate to each other, required for what is called the "univariate approach," may not be met, particularly as the number of time points increases. This can sometimes be handled by modeling the variance-covariance structure using general linear mixed model methods (**8**).

9.3.5.2 Alternatives to a repeated measures analysis would be either a multivariate analysis of variance (MANOVA) on the set of intensity values or separate analyses at each time point. As the number of time points increase both techniques would become increasingly unwieldy. The MANOVA would also require a large amount of data, that is, judges, in order to be feasible.

9.3.6 Analyses based on time-to-event models (**9**) can also be used for time intensity data if there is a specific time parameter of interest or if the only data recorded were time parameters, such as T_{onset}, T_{max}, or T_{ext}. These models are sometimes referred to as either "survival models" in the medical field or "failure models" in manufacturing. An example "event" for T-I data would be the time when the sensation was no longer perceived, that is, T_{ext}. The collection of event times would then be the data analyzed by these techniques.

9.3.6.1 Methods that do not rely on a particular time model, that is non-parameteric methods, include the method due to Kaplan-Meier, also called the product-limit method. This approach estimates the odds of the event occurring at any given time point. For example, the particular time point when there is a 50 % chance of reaching the I_{max} could be estimated.

9.3.6.2 The advantages of using time-to-event methods depend partly on the nature of the data. The method can handle what is called "censored" data, that is, data that were truncated. For example, suppose that time-intensity values were collected for only the first two minutes, but extinction of the intensity for several panelists exceeded two minutes. In this case their T_{ext} values would be "censored" at two minutes. Standard ANOVA does not handle censored data. In addition, the event times may not satisfy other ANOVA assumptions, such as normality, that the time-to-event model does not require.

9.4 *Curve Summarization*—Since a key aspect of T-I studies is that data are collected over time, it is clearly natural to display the data with the time dimension included. Although individual time intensity curves may be plotted, it is also very useful to be able to summarize what the panel as a whole says about a given stimulus. This is particularly useful to visualize sample differences. Several techniques for summarizing individual T-I curves into a panel consensus curve are described below.

9.4.1 A natural, though simplistic, approach to combining individual time-intensity curves is to average the intensity responses at each time point, and then plot these mean values as the summarized curve. This approach will often introduce distortions unless each individual curve follows a highly similar time course pattern.

9.4.1.1 An example using just two panelists is shown in Fig. 2, below. One panelist reaches a response extinction point (T_{ext}) at 40 s and another panelist at 60 s. Although, in this two-judge example, the mean extinction time is 50 s, the plot of the simple averages at each time point would show the "consensus curve" falling to zero at 60 s. This is because the mean of the panelists' ratings will continue to be non-zero until *all* judges hit zero. In addition, even though both judges have a distinct plateau time, the mean curve does not because the plateau times of the two judges do not happen to overlap.

9.4.2 A simple approach that avoids the distortions of averaging is to connect various key curve parameters with straight line segments. The points so connected would typically be the parameters averaged over the panelists.

9.4.2.1 For example, the average onset time, peak intensity, time to peak intensity, peak duration time, and extinction time, can be connected. Such a curve, though rough, would be completely consistent with the results of conventional statistical analysis on the curve parameters (see Fig. X1.2). However, as with any curve that summarizes the entire panel, this curve is not likely to match any given panelist's typical response.

9.4.3 A curve averaging technique that creates a common intensity range for the T-I curves was first reported by Overbosch et al. (**10**), and involves four steps:

9.4.3.1 Normalize or re-scale the intensities of each curve to the geometric mean of the maximum intensities (I_{max}),

9.4.3.2 Segment each curve into "*n*" equal steps in time (20 is recommended) both before and after the point of maximum intensity,

9.4.3.3 Calculate the geometric mean on the normalized intensities for each time segment (interpolate), and

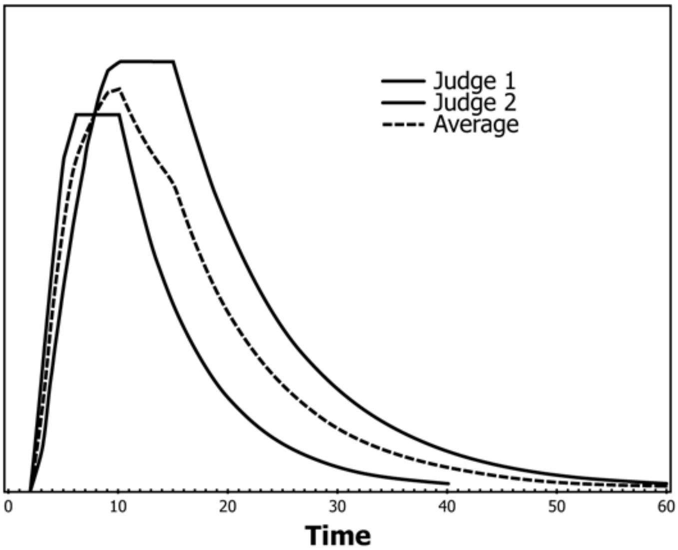


FIG. 2 Example Time-Intensity Curves Showing Two Judge Curves and the Result of "Simple" Averaging

9.4.3.4 Plot the normalized, geometric mean intensities over the time steps.

9.4.4 Liu and MacFie (**11**) suggested an enhancement to the Overbosch approach that used more curve parameters by adjusting the time axis as well (see Fig. X1.3), and consists of five steps:

9.4.4.1 Normalize the intensities of each curve to the panel mean maximum intensity,

9.4.4.2 Standardize the times of each curve in the interval T_{onset} to T_{max} to lie within the corresponding panel averages, likewise for the interval T_{max} to T_{ext}, with the plateau time mapped to the mean as well,

9.4.4.3 Split the interval from the panel mean T_{onset} to T_{max} and from T_{max} to T_{ext} into "*n*" equal time points (20 is recommended); separately for each curve, estimate the intensity at these standardized time points by linear interpolation,

9.4.4.4 Calculate the average of the interpolated intensities at each of the common time points, and

9.4.4.5 Plot the averaged intensities versus time.

9.4.4.6 In either approach, however, the normalization of the data can result in misleading information. For example, forcing the curves to fit within the panel average I_{max} intensity and time ranges will tend to shrink the AUC of judges above the panel mean and inflate the AUC of judges below the mean. After curve averaging, the AUC of the final curve will not generally match the panel average AUC. It may even occur that the AUCs of the summarized curves are not in the same rank order as the panel average AUCs; that is, the stimuli with the largest panel mean AUC may not have the largest AUC among the summarized curves. If AUC differences are not relevant to the objectives of the project, then this artifact of the method would not pose a problem. In general, when using these summarization methods, it is advisable to make sure that the summarized curves are consistent with the conclusions of the data analysis.

9.4.5 Curves can be summarized by modeling the shape of the time intensity curve (**12, 13**). In this case, a consensus curve is formed by plotting the model predictions. The model predictions are calculated using the estimated panel parameters from the model fit separately to each stimulus.

9.4.5.1 When using a modeling technique, the ideal approach would be to fit a theoretical equation that describes the mechanisms at work. Some researchers have used exponential or logistic growth and decay models fit to the rising and falling portions of the T-I curve, respectively (**14**). Further research would need to be done to establish what mechanistic models explain T-I data.

9.4.5.2 If a theoretical model is not available, empirical model fitting can be done. This might involve fitting separate regression equations to natural divisions of the time axis. For example, a separate regression could be performed on the time interval from T_{onset} to T_{max}, from T_{max} to $T_{max} + T_{plateau}$ and from $T_{max} + T_{plateau}$ to T_{ext}. The plateau interval is essentially a constant. The other intervals would require regressions of a linear, quadratic, or even higher order, depending upon the shape complexity of the T-I curves.

9.4.6 Van Buuren introduced (**15**) and Dijksterhuis (**1**) further developed a procedure using principal components analysis (PCA) to summarize curves into "principal curves." The PCA is performed with the time points as observations and the judge curves as variables.

9.4.6.1 In this approach, the first principal curve is the weighted average that best summarizes the entire collection of judge curves. Subsequent principal curves account for variability not already handled by earlier ones.

9.4.6.2 The PCA loadings can be examined to determined how specific curves influenced a given principal curve. This might be used to spot panelist subgroups or outlying judges.

9.4.6.3 Principal curves differ from the simple average method because the weights (PCA loadings) are constructed to capture the most information possible. It is unclear, however, whether the principal curves are free of the distortions discussed in 9.4.1, nor have they been directly compared to the other methods discussed above.

APPENDIXES

(Nonmandatory Information)

X1. TIME-INTENSITY: SOURNESS IN A SALAD DRESSING

X1.1 Product development had used a number of different food grade acids in a salad dressing formula at equivalent acidity and pH. The acid levels had to be maintained to deliver safe, shelf-stable product. However, the sensory performance of these acids was quite different in the product. The product developer wanted to understand how the sourness of the three different acids and a combination of all three performed in the formula. A time-intensity evaluation was conducted to fully document the development and decline of the sour taste.

X1.2 Thirteen experienced descriptive flavor panelists were calibrated in the quantification of sour intensity and then trained in the use of a computerized data collection device (mouse) and procedures. Salad Dressing samples were prepared containing levels of acid previously determined to provide a range of sourness intensities. Reference standards for sourness intensity were prepared to deliver a range of sourness intensity values of 20, 40, and 60 on a line scale anchored at 0 and 100.

X1.3 Panelists evaluated sourness time intensity for each sample. Panelists evaluated the rate of increase and rate of decrease in sourness perception by taking one small spoon (5 mL) of dressing into the mouth, holding it for 10 s and then swallowing it when prompted by an on-screen message. Time intensity data were collected immediately upon putting the sample in the mouth. The mouse cursor was moved over the start point on the screen, and the mouse button was clicked to initiate the timing. The intensity was tracked by moving the cursor along the line scale using the mouse. The data collection continued until sourness could no longer be perceived by the panelist, or until the maximum time of 120 s was reached. The time intensity question was set to collect data every 1.0 s for a total of 120 time intervals. Three time-intensity sessions were held to collect three replicate evaluations of the four dressings An example of the complete data set collected from a single assessor (Assessor Number 1) is shown in Table X1.1.

TABLE X1.1 Time-Intensity Data for Sourness in Salad Dressings for Assessor Number 1, Replication 1

	Sample			
Time (s)	Acid A	Acid B	Acid C	Blend
0 s	0	0	0	0
1 s	2	1	1	1
2 s	6	6	5	6
3 s	11	13	11	12
4 s	16	20	19	18
5 s	21	26	26	24
6 s	24	31	32	29
7 s	27	35	38	33
8 s	30	40	42	38
9 s	33	43	45	41
10 s	36	46	49	44
11 s	37	48	52	46
12 s	37	50	54	46
13 s	35	49	55	45
14 s	32	47	55	43
15 s	31	45	52	40
16 s	28	41	49	36
17 s	26	37	45	32
18 s	22	33	40	27
19 s	19	30	34	23
20 s	16	26	28	19
21 s	14	22	24	15
22 s	12	18	21	12
23 s	10	16	19	11
24 s	8	14	16	9
25 s	6	11	14	7
26 s	4	9	11	6
27 s	3	8	10	4
28 s	2	6	9	3
29 s	2	5	7	3
30 s	1	4	6	2

X1.4 As is common with T-I data, the curves generated in each assessment are different (see Section 9). Fig. X1.1 illustrates the curves generated by one assessor over three replications. Some of the shape differences in these assessor replicates are: Rep 1 showed a single peak, with shorter duration, Rep 2 had a definite plateau and longer duration, while Rep 3 showed a larger double peak. The solid line demonstrates the Average curve obtained by combining all three replicates.

X1.5 To create a curve that is representative of the product, one approach is to average the average curves of all assessors. As illustrated in Fig. X1.2, two assessors' curves that are the average of three replicates each are combined to make an average of the two assessors. The values for the eight selected

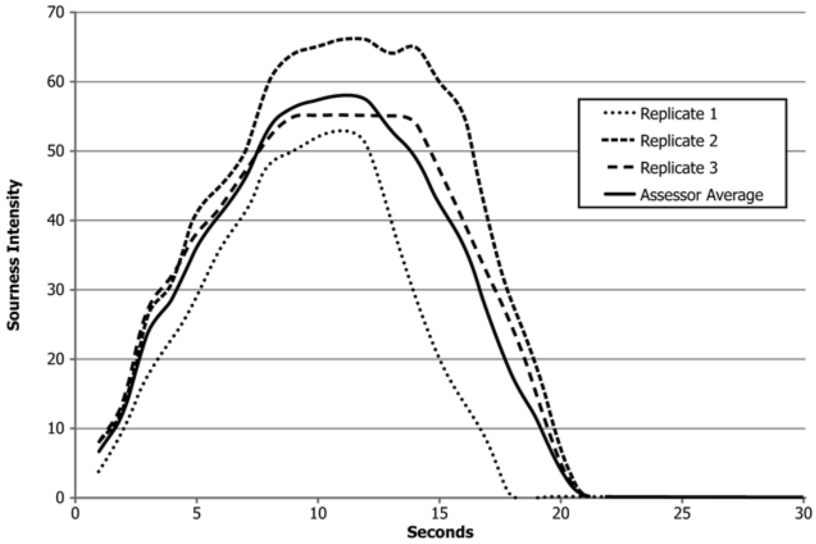


FIG. X1.1 Time Intensity of Sourness—Curve Averaging Over Replicates

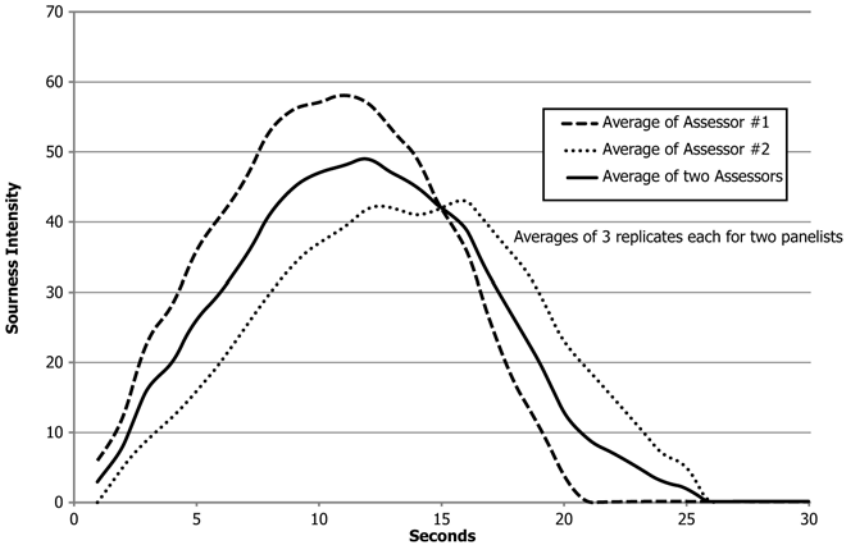


FIG. X1.2 Time Intensity of Sourness—Curve Averaging Over Assessors

parameters for Sample 1 are shown in Table X1.2. The parameters for the Average Curve are not the same as the arithmetic means of the parameters of the two individual curves. For the Average Curve, T_{max} is 12 s, while the Assessor T_{max} values are 11 s and 16 s, respectively. The addition of the curve changes the shape of the Average Curve resulting in parameters that reflect that new curve.

X1.6 In this study, with 13 assessors and three replicates, the product average curves are comprised of 39 individual assessments. The average curves for the four Salad Dressings are shown in Fig. X1.3. Data analysis of eight selected curve parameters was chosen to illustrate the T-I differences between the salad dressings. Analysis of variance may be performed on the parameter values for each individual assessor, or on the

TABLE X1.2 Time-Intensity Curve Parameters by Sample for Assessor's 1 and 2 (Average of 3 Replications) and the Parameters of the Average Curve of the Two Assessors as Shown in Fig. X1.2

Assessor	Sample No.	T_{max}	I_{max}	Dur	AUC	Inc. Angle	Inc. Area	Dec. Angle	Dec. Area
1	1	11	58	21	711	79.1	387	80.5	324
2	1	16	43	25	621	69.7	415.5	76.6	205.5
Average Curve	1	12	49	26	658	76.5	343.5	74.5	314.5

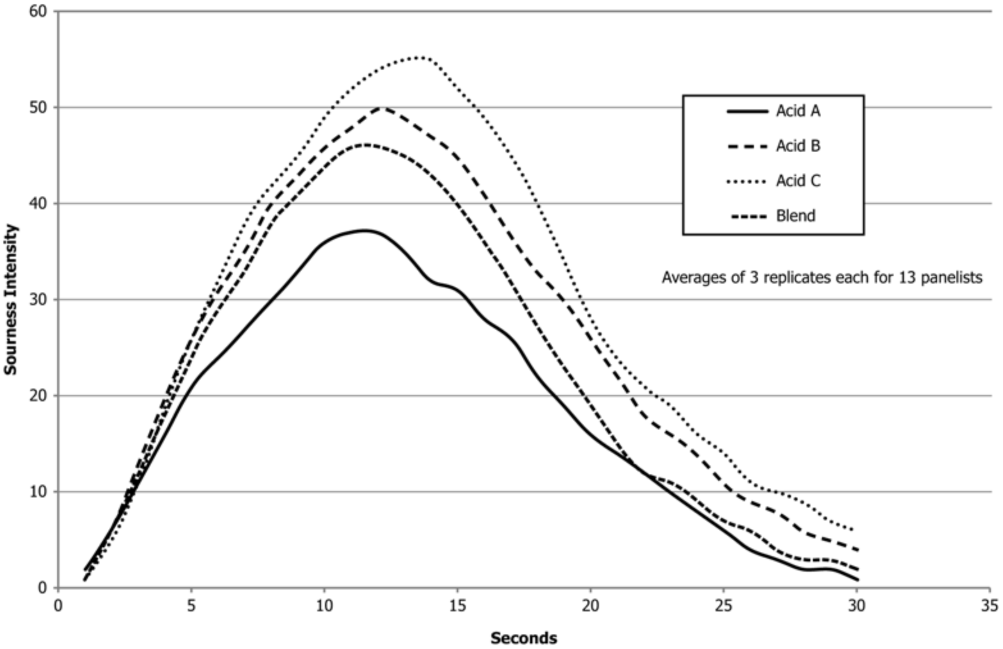


FIG. X1.3 Time Intensity of Sourness—Curve Averaging Over All Assessors

assessor average replicate values or on the product by replicate average values. Since T-I data is highly variable, significant differences are often missed unless the data from curve averaging is used, which results in a loss of degrees of freedom in the analysis.

X1.7 Although the T_{max} values for each of the Acids being studied were very similar, there was a large difference observed in I_{max} and the AUC values. The Product identified as Acid C was the strongest in delivery of temporal sourness, both in

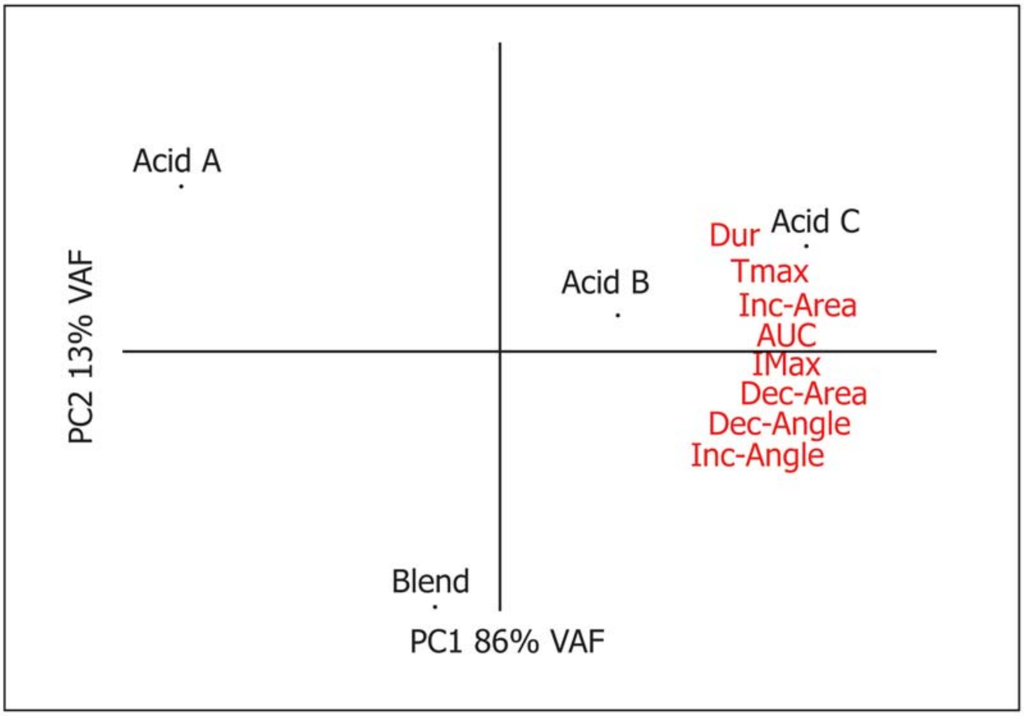


FIG. X1.4 PCA of Time Intensity Parameters of Salad Dressings with Four Acids magnitude and overall impact. It is difficult to make conclusions with univariate data or with intensity curves by themselves, Fig. X1.4 is of a Principal Components Analysis (PCA) of the mean parameters for four products. The first Principal Component (PC1) accounts for 86 % of the variance and we can see the attributes all located on the right-hand side of the plot near Acid C. The second Principal Component (PC2) accounts for 13 % of the variance and is anchored at the bottom by the product identified as the Blend. The Blend is characterized by a rapid increase, similar to Acid B and C, but with a sharper decrease angle and smaller area under the curve like Acid A. This information provides the Product Developer with guidance in the blending of the acid ingredients to give a reduced impact of sourness in the salad dressing, while maintaining the levels of acidity required for product safety.

X1.8 The I_{max} of the two sweeteners was noted to be the same, which concurs with previous testing for equivalent sweetness intensity. However, the T-I method was able to capture the differences in the linger of the sweet taste after I_{max} was reached. This information proved useful in explaining the variable consumer response to the lemonade's sweetness, and will guide further reformulation efforts.

X2. TIME-INTENSITY MEASUREMENT AT DISCRETE TIME POINTS: TIME-INTENSITY OF THE HARDNESS OF THREE SAMPLES OF CHEWING GUM

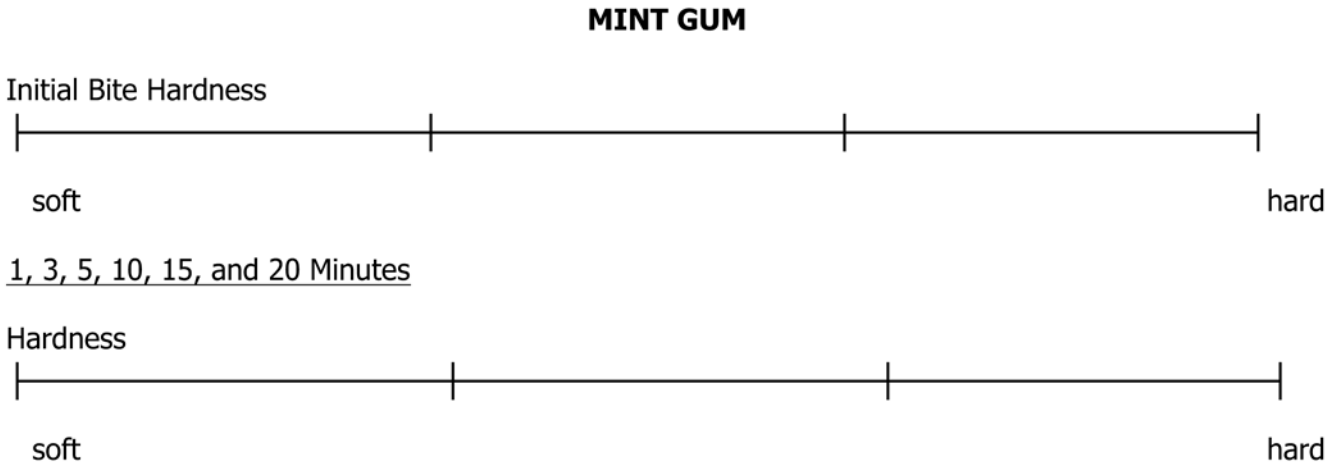
X2.1 A discrete time point time-intensity technique was used to assess the changes in hardness of three chewing gum samples over time. For this simplified, non-continuous measurement, the hardness of the gum was measured initially upon the first bite, then at 1, 3, 5, 10, 15, and 20 min during chewing.

X2.2 Ten trained assessors participated in an orientation session to review the samples, the evaluation technique, and applicable references. The ten assessors completed two replications for each sample. The serving order was balanced, with products seen approximately an equal number of times in each possible position. Samples were served in 2-oz. plastic cups with lids and were coded with three digit random numbers. One piece of gum was served per evaluation. A 20-min break was given between samples. Three samples were evaluated per day. Data was collected via computer on a 15 point line scale. Timing for the evaluations was cued by the computer.

X2.3 Assessors scored the hardness of the samples upon the first bite, then at 1, 3, 5, 10, 15 and 20 min after chewing. Hardness was defined as the force required to chew the gum to a normal degree of deformation. Panelists were instructed to chew at a constant rate of approximately one chew per second.

X2.4 The mean intensities were calculated for each time point. Analysis of Variance and Duncan's Multiple Range Test were used to determine significant differences among the samples at each time point.

X2.5 Sample 591 was harder than the other two samples at all time points. Sample 267 was harder than Sample 854 in initial bite. Samples 267 and 854 did not differ significantly in hardness beyond the initial bite.



MINT GUM

Initial Bite Hardness

soft hard

1, 3, 5, 10, 15, and 20 Minutes

Hardness

soft hard

FIG. X2.1 Scoresheet

TABLE X2.1 Gum Hardness Means at Discrete Time Points

QUANTITATIVE DESCRIPTIVE EVALUATIONS OF 3 GUM SAMPLES
n = 20 (10 Panelists, 2 Evaluations Each)

	267	854	591	Conf. Level
Texture:				
Hardness:				
Initial	7.5	6.5	8.4	95 %
1 Minute	4.0	4.1	4.6	95 %
3 Minutes	4.4	4.2	4.8	95 %
5 Minutes	4.4	4.3	4.8	95 %
10 Minutes	4.6	4.5	4.49	95 %
15 Minutes	4.6	4.7	5.0	95 %
20 Minutes	4.8	5.0	5.4	95 %

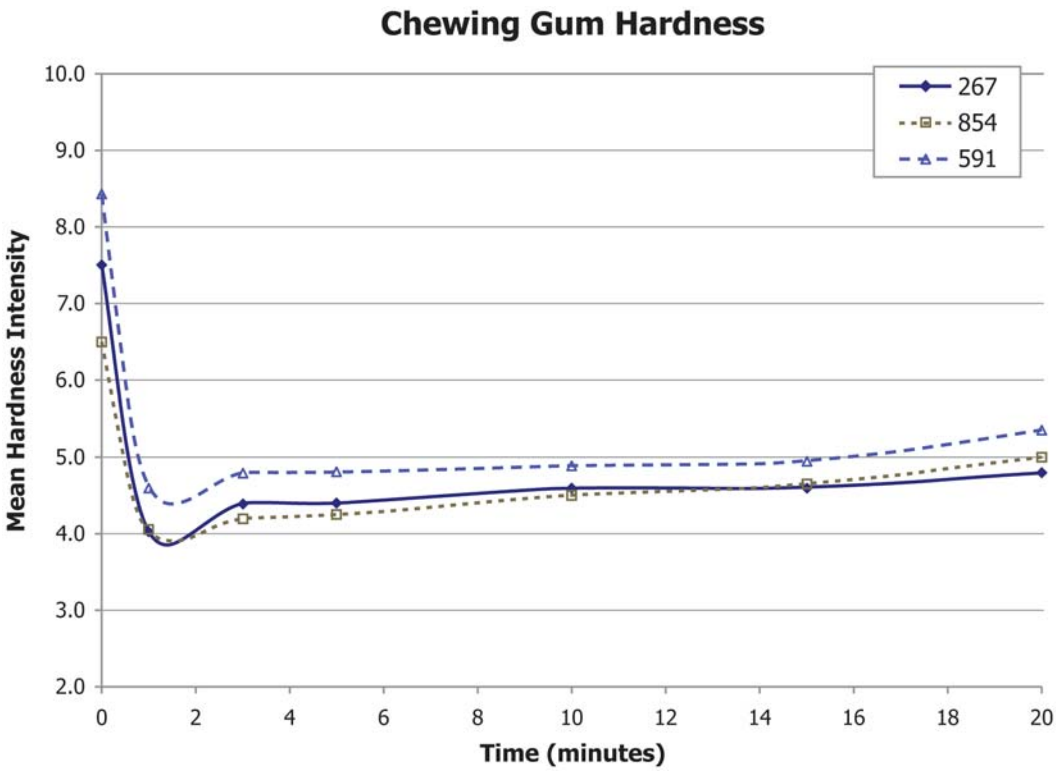


FIG. X2.2 Graph of Hardness Means at Discrete Time Points

REFERENCES

(1) Noble, A.C., Matysiak, N.L., and Bonnans, S., "Factors Affecting the Time-Intensity Parameters of Sweetness," *Food Technology*, Vol 45, No. 11, 1991, pp. 121-124 and 126.

(2) Lee, W.E. and Pangborn, R.M., "Time-Intensity: The Temporal Aspects of Sensory Perception," *Food Technology*, Vol 40, No. 11, 1986, pp. 71-82.

(3) *Guidelines for the Selection and Training of Sensory Panel Materials, ASTM STP 758*, ASTM International, West Conshohocken, PA.

(4) *Manual 26 Sensory Testing Methods*, ASTM International, West Conshohocken, PA.

(5) *Physical Requirement Guidelines for Sensory Evaluation Laboratories, ASTM STP 913*, ASTM International, West Conshohocken, PA.

(6) Velleman, P.F., "Definition and Comparison of Robust Nonlinear Data Smoothing Algorithms," *Journal of the American Statistical Association*, 1980, pp. 609-615.

(7) Lundahl, D., "Comparing Time-Intensity to Category Scales in Sensory Evaluation," *Food Technology*, Vol 46, No. 11, 1992, pp. 98-103.

(8) Littell, R.C., Milliken, G.A., Stroup, W.W., and Wolfinger, R.D., *SAS System for Mixed Models*, SAS Institute, Inc, Cary, NC, 1996, pp. 87-134.

(9) Lee, E.T., *Statistical Methods for Survival Data Analysis*, Lifetime Learning Publications, Belmont, California, 1980.

(10) Overbosch, P., Enden, J.C. Van Den and Keur, B.M., "An Improved Method for Measuring Perceived Intensity/Time Relationships in Human Taste and Smell," *Chemical Senses*, Vol 11, 1986, pp. 331-338.

(11) Liu, Y.H. and MacFie, H.J.H., "Methods for Averaging Time-Intensity Curves," *Chemical Senses*, Vol 15, 1990, pp. 471-484.

(12) Dijksterhuis, G.B. and Eiler, P., "Modeling Time-Intensity Curves Using Prototype Curves," *Food Quality and Preference*, Vol 8, 1997, pp. 131-140.

(13) Overbosch, P., "A Theoretical Model for Perceived Intensity in Human Taste and Smell as a Function of Time," *Chemical Senses*, Vol 11, No. 3, 1986, pp. 315-329.

(14) Eilers, P. H. C., and Dijksterhuis, G.B., "A Parametric Model for Time-Intensity Curves," *Food Quality and Preference*, Vol. 15, 1990, pp. 239–245.

(15) Buuren, S. Van, "Analysing Time Intensity Responses in Sensory Evaluation," *Food Technology*, Vol 46, 1992, pp. 101-104.

Bibliography

(1) Bloom, K., Duizer, L. M., and Findlay, C. J., "An objective numerical method of assessing the reliability of time-intensity panelists," *Journal of Sensory Studies*, Vol. 10, 1995, pp. 285–294.

(2) Clark, C. C. and Lawless, H. T., "Limiting response alternatives in time-intensity scaling: an examination of the halo-dumping effect," *Chemical Senses*, Vol. 19, No. 6, 1994, pp. 583–594.

(3) Cliff, M. and Heymann, H., "Development and use of time-intensity methodology for sensory evaluations: A review," Food Research International, Vol. 26, 1993, pp. 375–385.

(4) Cliff, M. and Noble, A. C., "Time-intensity evaluation of sweetness and fruitiness and their interaction in a model solution," *Journal of Food Science*, Vol. 55, No. 2, 1990, pp. 450–454.

(5) Dijksterhuis, G. B., "Concluding Remarks Part IV: Time-Intensity Data Analysis," in *Multivariate Data Analysis in Sensory and Consumer Science*, 2008, pp. 268–272.

(6) Dijksterhuis, G.B., "Principal Component Analysis of Time Intensity Bitterness Curves," *Journal of Sensory Studies*, Vol 8, 1993, pp. 317–328.

(7) Duizer, L. M., Gullett, E. A., and Findlay, C. J., "The Effect Of Masticatory Patterns As Measured By Time-Intensity And Electromyography On The Perception Of Bovine Muscle Tenderness," *Journal of Sensory Studies*, Vol. 9, No. 1, March 1994, pp. 33–46.

(8) Hyvönen, L., Linner, M., Tuorilla, H., and Dijksterhuis, G., "Perception of melting and flavor release of ice cream containing different types and contents of fat," *Journal of Dairy Science*, Vol. 86, 2003, pp. 1130–1138.

(9) Lallemand, M., Giboreau, A., Rytz, A., and Colas, B., "Extracting Parameters from Time-Intensity Curves Using a Trapezoid Model: The Example of Some Sensory Attributes Of Ice Cream," *Journal of Sensory Studies*, Vol. 14, No. 4, 1999, pp. 387–399.

(10) Larson-Powers, N. and Pangborn, R. M., "Paired comparison and time-intensity measurements of the sensory properties of beverages and gelatins containing sucrose or synthetic sweeteners," *Journal of Food Science*, Vol. 43, 1978, pp. 41–46.

(11) Leach, E. J. and Noble, A.C., "Comparison of bitterness of caffeine and quinine by a time-intensity procedure," *Chemical Senses*, Vol. 11, No. 3, 1986, pp. 339–345.

(12) Le Révérend, F. M., Hidrio, C., Fernandes, A., and Aubry, V., "Comparison between temporal dominance of sensations and time intensity results," *Food Quality and Preference*, Vol. 19, No. 2, 2008, pp. 174–178.

(13) Meilgarrd, M. C., "Current Progress in Sensory Analysis. A review," *ASBC Journal*, Vol. 49, No. 3, 1991, pp. 101–109.

(14) Palazzo, A. B. and Bolini, H. M., "Multiple Time-Intensity Analysis and Acceptance of Raspberry-Flavored Gelatin," *Journal of Sensory Studies*, Vol. 24, No. 5, Oct. 2009, pp. 648–663.

(15) Peyvieux, C. and Dijksterhuis, G., "Training a sensory panel for TI: a case study," *Food Quality and Preference*, Vol. 12, 2001, pp. 19–28.

(16) Pineau, N., Schlich, P., Cordelle, S., Mathonnière, C., Issanchou, S., et al., "Temporal Dominance of Sensations: Construction of the TDS curves and comparison with time-intensity," *Food Quality and Preference*, Vol. 20, No. 6, 2009, pp. 450–455.

(17) Reinbach, H. C., Toft, M., and Møller, P., "Relationship between oral burn and temperature in chili spiced pork patties evaluated by time-intensity," *Food Quality and Preference*, Vol. 20, No. 1, 2009, pp. 42–49.

(18) Swartz, M., "Sensory screening of synthetic sweeteners using time-intensity evaluations," *Journal of Food Science*, Vol. 45, 1980, pp. 577–581.

(19) Szczesniak, A.S., "Classification of Textural Characteristics," *Journal of Food Science*, Vol 28, 1963, pp. 385–389.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org). Permission rights to photocopy the standard may also be secured from the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, Tel: (978) 646-2600; http://www.copyright.com/