Designation: E2454 – 19a

Standard Guide for Sensory Evaluation Methods to Determine the Sensory Shelf Life of Consumer Products[1]

This standard is issued under the fixed designation E2454; 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 provides recommended sensory testing approaches and decision criteria for establishing the sensory shelf life of consumable products, including food, personal care, and household products to manage business risk. It describes research considerations that include: product selection and handling, appropriate application of specific sensory test methods, selection of test intervals, and data analysis techniques for the determination of a product's sensory shelf life end-point. This guide will focus on the practical considerations and approaches, risks, and criteria that must be considered in designing, executing, and interpreting sensory shelf life results.

1.2 This guide is not intended to provide a detailed description of how to conduct reliable sensory testing. It assumes knowledge of basic sensory and statistical analysis techniques, focusing instead on special considerations for the specific application of sensory testing methods to shelf life determination.

1.3 The shelf life measures in this guide refer to foods, household and personal care products stored as the manufacturer intended and do not account for changes in sensory properties occurring after opening, partial consumption/use or in-home storage. Once products have been manufactured, packaged and sent through the distribution channels, the condition of the products is not typically under study. However, a company may wish to include such variables in their shelf life studies when there is a need to evaluate the sensory quality of their products as they go through distribution channels and/or in-home storage and use.

1.4 This guide is not intended to address non-sensory issues related to the shelf life of food, including microbial contamination and chemical changes of products associated with aging, nor is it intended to address potential safety issues associated with aging food and non-food consumer products.

1.5 *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

E460 Practice for Determining Effect of Packaging on Food and Beverage Products During Storage

E1871 Guide for Serving Protocol for Sensory Evaluation of Foods and Beverages

E2139 Test Method for Same-Different Test

E2164 Test Method for Directional Difference Test

E2263 Test Method for Paired Preference Test

E2610 Test Method for Sensory Analysis—Duo-Trio Test

E3005 Terminology for Body Armor

E2943 Guide for Two-Sample Acceptance and Preference Testing with Consumers

2.2 *ASTM Manuals:*[3]

MNL 13 Descriptive Analysis Testing

MNL 26 Sensory Testing Methods

MNL 30 Relating Consumer, Descriptive, and Laboratory Data to Better Understand Consumer Responses

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this guide see Terminology E253.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accelerated storage/aging*—subjecting a product to extreme or stressed conditions, such as elevated temperatures or humidity, exposure to sunlight or other light, to speed up

[1] This guide is under the jurisdiction of ASTM Committee E18 on Sensory Evaluation and is the direct responsibility of Subcommittee E18.05 on Sensory Applications--General.

Current edition approved Nov. 15, 2019. Published January 2020. Originally approved in 2005. Last previous edition approved in 2019 as E2454 – 19. DOI: 10.1520/E2454-19A.

[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.

[3] Available from ASTM International Headquarters, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428–2959.

those changes in product characteristics that are assumed to be related to aging the product.

3.2.2 *control parameters for sensory shelf life determination (known as "control")*—specific product or data set (based on previous sensory research) designated as the one to which the data from stored products are to be compared .

3.2.3 *controlled conditions*—set of environmental parameters (including but not limited to temperature, humidity, light, and oxygen) that are maintained and monitored so that changes in product attributes can be evaluated relative to these parameters.

3.2.4 *sensory end-point (end of shelf-life)*—point at which a product no longer meets predetermined sensory attributes as defined by the set end-point criterion or criteria (for example, discrimination, descriptive, or affective, or a combination thereof).

3.2.5 *end-point criterion/criteria*—the parameter(s) that will be used to determine the end of sensory shelf life.

3.2.6 *pull out date(s)*—predetermined point(s) in time at which the product is removed from storage for evaluation.

3.2.7 *sensory characteristics*—any attributes of the products that are assessed using the sensory methods that measure the human response to that product.

3.2.8 *shelf life*—time period that a product may be stored before reaching its end-point.

3.2.9 *shelf life testing*—method(s) to determine the effects of aging or storage conditions, or both, on product(s) characteristics for purposes of determining a product's shelf life.

3.2.10 *uncontrolled ambient*—also known as room temperature, uncontrolled conditions (that is, temperature of storage location, humidity, or environmental factors, or both) which fluctuate with changes in weather, time of day, location, and so forth (see 3.2.3).

3.2.11 *zero time point*—time when the shelf life testing begins.

3.2.12 *use by date*—The date, usually stamped on the product by the manufacturer, indicating that the product remains consumable or usable as it delivers sensory attributes as desired by the manufacturer. In some countries, this is referred to as the 'best before date.'

3.2.13 *sampling plan*—The protocol that indicates which products are to be tested at which time intervals in a shelf life study.

4. Summary of Guide

4.1 This guide is intended to cover the basic issues and practical requirements of conducting a shelf life study designed to identify sensory end-points in a product's shelf life.

4.2 *Define Research Objective*—The purpose/objective of a shelf life study should be clearly stated before the study is implemented. The objectives are generally related to the criteria selected for defining the product's end of shelf life, which are determined prior to the study's inception. Common objectives are as follows: "determine the amount of elapsed time a product remains acceptable to consumers," or "determine specific use-by dates," or "understand the amount of time elapsed before a sensory defect is detectable."

4.3 *Identify Decision Risk*—Decision risk is defined as making an incorrect shelf life decision. There are two incorrect decisions associated with shelf life testing: (1) stating the product has reached the end of shelf life when it has not, and (2) stating that the product has not reached the end of shelf life when it has. A consequence of the former incorrect decision could be loss of potential income from the product's sale as it will be pulled from shelves and not sold when it still could be. The manufacturer will lose sales. A consequence of the second error could be consumer rejection of a too-old product, as it will continue to be sold after the sensory shelf life has been reached. Consumer repeat purchase of the same brand may be at stake. Before the researcher embarks on a shelf life study, the risk to the consumer franchise must be balanced with the risk of costs associated with pulling sensory acceptable products from the shelf, prior to the end of sensory shelf life.

4.4 *Select Criteri/Criterion to Determine the End-Point*—All products change over time. End-point criteria can refer either to the product's sensory attributes or to consumer acceptance, or both.

4.4.1 The product's overall sensory profile has changed.

4.4.2 Product attribute(s) that is (are) known or suspected to be key to consumers' perception and acceptance of the product has (have) changed, This includes decreases in the product's characterizing or expected sensory attributes or sensory signals (for example, "strawberry flavor" in a strawberry-flavored beverage or "meltability" of a processed cheese slice; for non-food products, end-point criteria may include attributes that signal product performance such as lather attributes in cleansers, including lather amount or stability, or surface feel after rinsing), increases in attributes that negatively impact the sensory perception of the product (for example, increased "red pepper heat" in a mildly spiced product), loss of functionality (a cleaning pad that no longer removes dirt), or the appearance of "off-notes", sensory properties that are not associated with the product (for example, "fish flavor" in vegetable oil, "cardboard flavor" in a box of cookies, or an off-odor in a skin care cream.)

4.4.3 The product's acceptability has decreased, either significantly or to a specific degree, compared to the fresh product.

4.5 *Select Sensory Test Method*—Discrimination, descriptive, or affective methods or a combination, can be used to determine the sensory shelf life of a product. Selection of the method depends on the chosen end-point criteria. For example, affective testing is required if a given consumer acceptance is the chosen end-point criterion.

4.6 *Define Appropriate Assessors*—Appropriate assessors are essential for the determination of sensory shelf life, depending on the chosen evaluation method.

4.7 *Select Representative Products*—Products selected for shelf life testing must be from representative production batches and production dates which are appropriately processed and packaged. In some situations, products should be subjected to typical distribution conditions (including, but not

limited to vibration, temperature elevation/reduction, temperature cycling). If testing an experimental product (for example, a product with changes in ingredients, formulation, processing, or packaging), samples should be representative of production batches of the experimental product. The amount of product required from each production batch is dependent on the estimated length of storage, number of storage conditions, methods of evaluation, and frequency of testing. Collecting products of various ages from retail establishments is generally not recommended for determining a product's shelf life, as conditions that the product has experienced may not be known and may be atypical. This does not, however, preclude collecting such samples for a product audit.

4.8 *Determine the Sensory End-point*—The end-point is selected based on the chosen end-point criteria, the type of product tested, the test method selected, previous knowledge of product changes over time, and the company's assessment of the risk/opportunities.

5. Significance and Use

5.1 Sensory shelf life is the time period during which the product's sensory characteristics and performance are as intended by the manufacturer. The product is consumable or usable during this period, providing the end-user with the intended sensory characteristics, performance, and benefits. After this period, however, the product has characteristics or attributes that are not as intended, or it does not perform the same functions as fresh products or those consumed or used before the end of shelf life.

5.2 The goal of all shelf life determination is to estimate the time at which a consumer product is no longer usable, unfit for consumption, or no longer has the intended sensory characteristics.

5.3 Prior to the commencement of sensory shelf life study, the criteria/criterion that are/is used to define shelf life end must be defined. The criterion or criteria could be sensory attributes, consumer acceptance or product performance. Once the criteria are defined, the test methodology for measuring the sensory shelf life can be selected. The criterion operationally defining the end of shelf life is generally chosen based on one or more of the following changes in the product's sensory and/or functional parameters: 1) the aged product is perceptibly different from the fresh product overall, 2) the aged product has changed in specific sensory or functional attributes, either increasing some, decreasing others, or the appearance of new attributes compared to the fresh product, or 3) product acceptability of the aged product has decreased to a specific degree from that of the fresh product. The determination of these sensory end-points is a function of the criteria selected, the test method used, and sampling and statistical risks chosen by the researcher.

5.4 The three following test methods are most commonly used for the three end-point criteria cited above: (1) discrimination, (2) descriptive, and (3) affective. Researchers have to select criteria and methods that best suit the business risks associated with the selection of a final shelf life end-point.

5.5 Once a product is made, underlying chemical and physical processes continue: Time, temperature, oxygen, humidity, or light are some of the variables that can contribute to these chemical changes. The interaction of the product with the packaging may also impact the sensory shelf life of the product. These are often the independent variables included in a shelf life study. However, research techniques designed to identify the causes of sensory shelf life changes or to develop predictive models of shelf life are beyond the scope of this document.

5.6 Previous sensory research with similar products, marketing research, product technology, manufacturing considerations, marketing objectives, consumer comments, and other business criteria can all play a part in determining sensory end-point criteria.

5.7 The decision risk, end-point criteria, and shelf life testing procedure should be reviewed and agreed to by stakeholders, such as Marketing, Market Research, R&D, Quality Assurance, and Manufacturing.

6. Procedures

See Figs. 1-4 for flowcharts of the procedures needed to conduct a sensory shelf life evaluation.

6.1 *Select Criteria to Determine the Sensory End-point*—Determine the specific type of shelf life sensory end-point that will be used. There are three common criteria used to define operationally end of shelf life – a difference is detected between the fresh and aged product (discrimination failure mode), a descriptive attribute(s)is/are changed so that sensory experience/sensory signals of the product is/are no longer as intended (descriptive attribute failure mode) or the product acceptance lowers to a pre-determined level (acceptability failure mode). Inputs from quality and manufacturing staff as well as review of consumer complaint data for specific feedback on sensory attributes can be helpful in deciding the criteria for shelf life end. (See Fig. 1.)

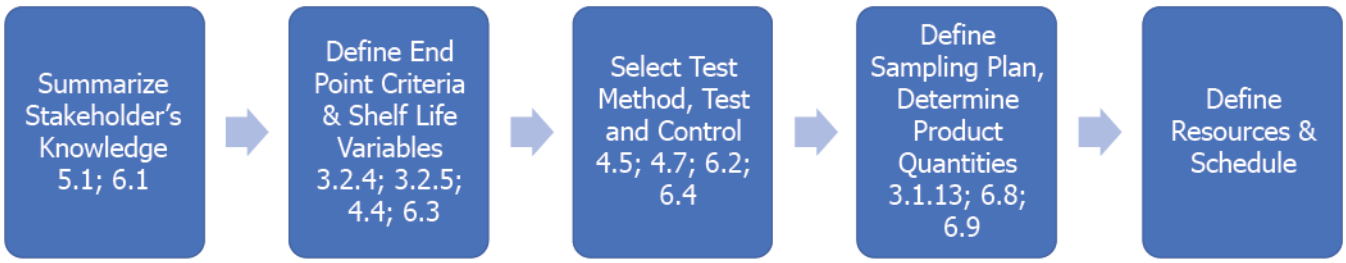

FIG. 1 Planning for Shelf-Life Evaluations—Process Flow Determination with Section References

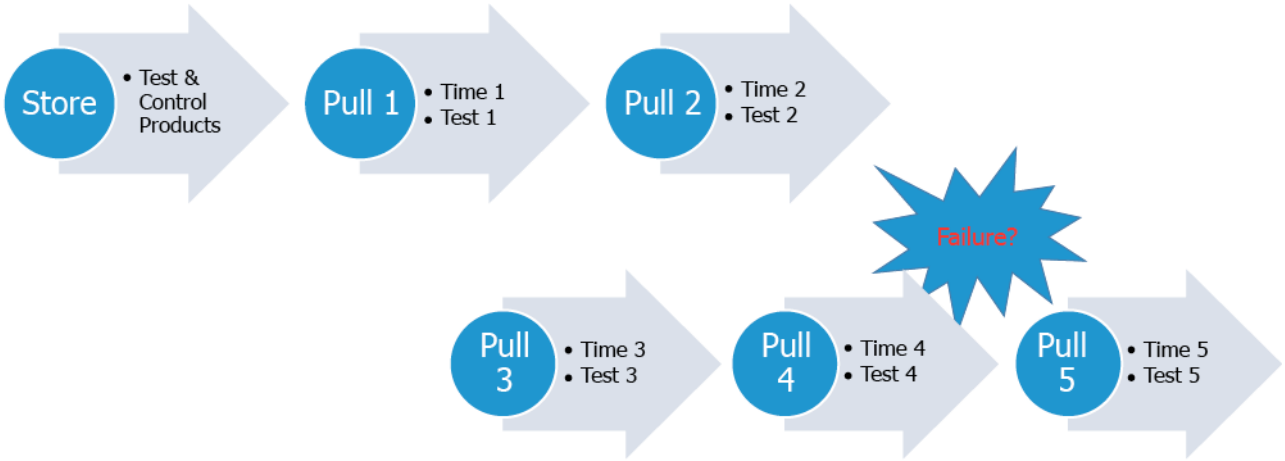

FIG. 2 Multi-Point Evaluations

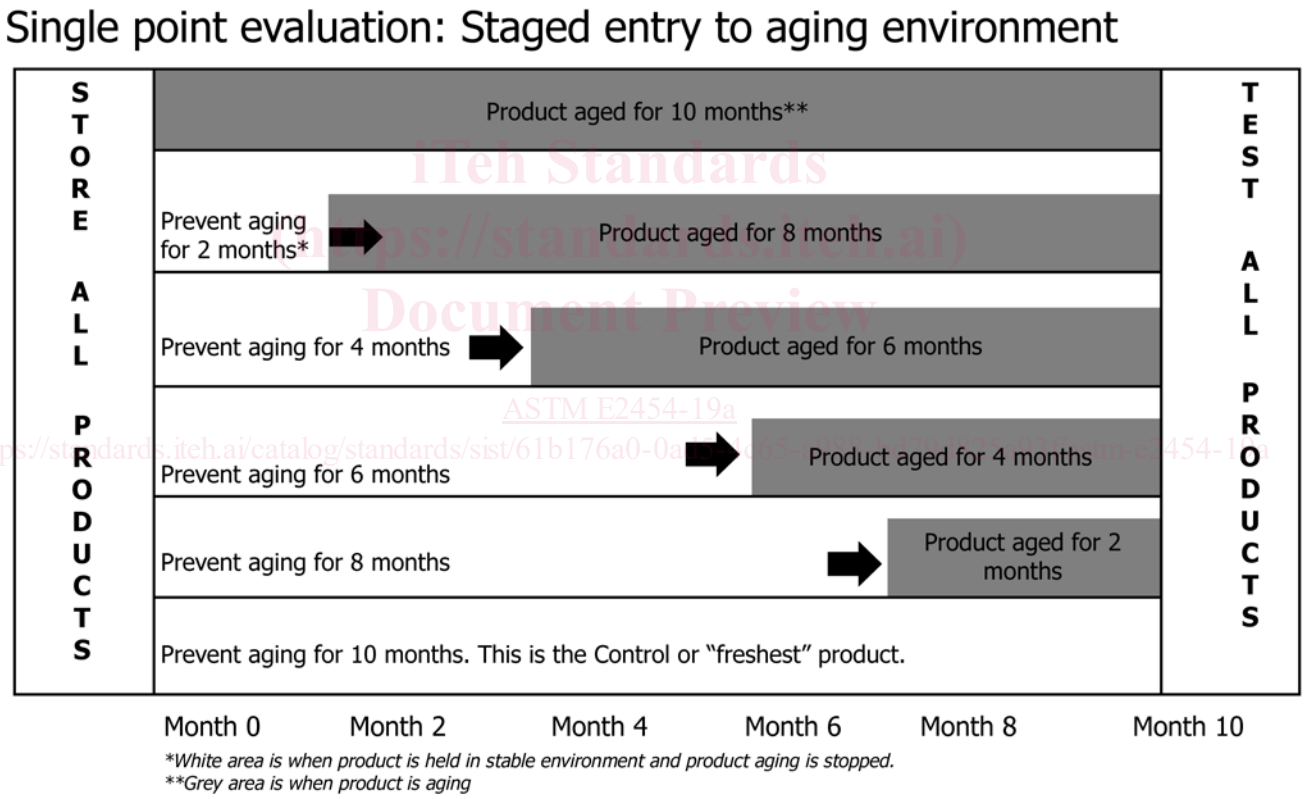

FIG. 3 Single Point Evaluation: Staged Entry Design

6.2 *Identify the Test Method to be Used*—The testing method is chosen based on the end-point criteria. Discrimination testing, descriptive, or affective testing methods are the three major test method options. Combinations of these methods may also be used.

6.3 *Determine the Sensory End-point*—The sensory end-point is established as a significant overall difference from the control based on a pre-stated degree of sensory difference, a significant or pre-determined level of change in the intensity of one or more critical product attribute(s) or the appearance of specified 'new' attributes, or a predetermined level of decrease in acceptability. The statistical criteria for measuring significance should also be included in the end-point definition (that is, α, β, and the size of the difference desired to detect) along with the number of panelists needed at each testing interval.

6.4 *Select Control*—Choose the type of control product that will be used for the study. A common comparison product might be a freshly made product, or one stored in refrigerated/

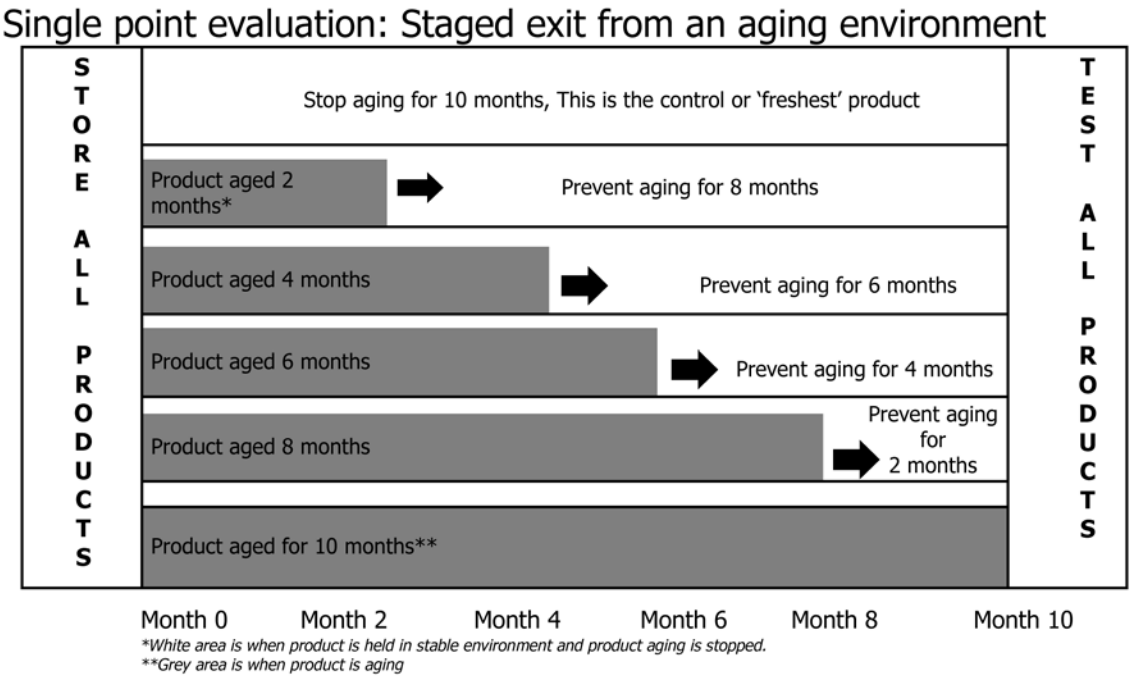

FIG. 4 Single Point Evaluation: Staged Exit Design

frozen conditions, or held under controlled light or temperature conditions. In the first case, the freshly made product represents the product at its best; in the case of the refrigerated/frozen product, the product is expected to represent a product that has had aging stopped or slowed down significantly. While the presence of a control product or control data is recommended, shelf life can still be determined without a physical control product, as long as specific end of shelf life parameters are chosen prior to the beginning of the shelf life study. When comparing a fresh product with an aged product, batch to batch product variations must be considered.

6.4.1 *Option 1—Stable Control*—This is a typical product that is held under conditions that minimize changes over time, such as frozen or refrigerated storage or specified environmental conditions (e.g., temperature, light, humidity, oxygen exposure).. If no storage condition is known to keep sensory changes to a minimum, this type of control cannot be used.

6.4.2 *Option 2—Statistical Control*—This is a set of numerical values obtained from sensory testing at zero time. Sensory data can be a degree of difference (d-prime) for discrimination testing, descriptive analysis attribute ratings or acceptance scores, depending on the chosen testing method.

6.4.3 *Option 3—Fresh Control*—If none of the above controls are feasible, a fresh control may be obtained at each pull out date. However, this type of control can only be used if the difference between separate batches is demonstrated to be minimal prior to the study, or if product variability is well understood and can be accounted for.

6.5 *Select Test Product*—Choose the test product(s) for the study. The product used for the study should be representative of the intended product. If a control product is used, the test products should be obtained from the same batch of ingredients, where possible, as the control product. Additionally, the test and control products should be as close in production as possible (that is, same production date, same product location, etc.). If this is not feasible, this added variability may obscure the differences between the control and test product. Furthermore, at the start of the storage period, an initial sensory test should be conducted to establish the relative sensory comparability of the test and control products.

6.6 *Select Storage Conditions:*

6.6.1 *Typical Life Cycle*—The typical life cycle of the product and the conditions to which it is exposed should be taken into consideration when a shelf life test is designed. Shelf life test designers may be aware of those conditions or not, but must gather as much information as possible before setting up a shelf life study. Shelf life storage conditions should reflect those real-world exposure conditions as much as possible to ensure the test outputs are relevant. Estimates of environmental extremes and time spent in the various stages of distribution can help determine appropriate conditions. Verification of test storage conditions through the use of sensory or monitors us suggested, especially if ambient storage conditions are selected.

6.6.2 *Controlled Storage Conditions*—Products selected to be representative should be stored under defined environmental conditions that may include variations in temperature, humidity, light, atmosphere, air pressure, and environmental cycling (freeze/thaw, elevated temperature conditions, etc.). Environmental conditions typical of distribution can also be considered.

6.6.3 *Accelerated Storage Conditions*—Accelerated tests attempt to achieve changes in product characteristics in a shortened period of time compared to non-accelerated storage

conditions. Such tests can be valuable time savers if appropriately selected. However, these tests are only approximations of how a product may behave under normal storage conditions.

6.6.3.1 Uses of accelerated conditions are often based on untested "rules of thumb" or beliefs rather than empirical data. During accelerated storage, product changes may take place, or characteristics may develop that would not occur during non-accelerated storage conditions. Elevated temperatures or exposure to humidity or light sources may cause different reactions than would ordinarily occur under more typical storage conditions. Before determining shelf life end-points based on accelerated conditions, one should establish the sensory, chemical, and mathematical relationships between accelerated conditions and typical storage conditions to ensure the utility of using accelerated conditions to establish Sensory Shelf life (see ASTM MNL 30).

6.7 *Determine Sampling Plan and Evaluation Points*—Sampling plans are drawn up at the start of a shelf life study to indicate how many products are needed, which lots, the storage conditions under which each sample will be held, and the time intervals a specific quantity of product will be tested. A sampling plan is needed in a shelf life study to ensure sufficient quantities of each product is available for testing at each interval. Lot to lot variability should be considered when establishing a sampling plan.

6.7.1 *Determine Zero Time Point*—The first step in developing a sampling plan is to establish a baseline or "zero time" point. Choice of an appropriate zero time is determined by the nature of the product(s) and by the research objective. Examples of zero time points include:

6.7.1.1 The date the product is manufactured,

6.7.1.2 The date the product reaches the retail shelf (the youngest product consumers would purchase),

6.7.1.3 The date the product is typically purchased, and

6.7.1.4 The date the product's sensory profile reaches a steady state.

6.7.2 *Determine Study End-point*—The second step is to set the expected end-point of the product's shelf life using one or more of the following criteria:

6.7.2.1 Historical data from current or similar products,

6.7.2.2 The declared shelf life of the product or of competitive products,

6.7.2.3 Advertising or label declaration requirements,

6.7.2.4 Distribution requirements,

6.7.2.5 Expected shelf life based on predicted stability of the formulation considering the product's ingredients, formulation, processing and packaging, and

6.7.2.6 The age at which consumer complaint levels about sensory attributes reaches above normal levels and are focused on sensory attributes or product functionality.

6.7.3 *Minimum Evaluation Points*—Considering the zero time and end-points as defined above, to be 100 % of the shelf life period, choose appropriate time points for evaluations. A minimum of four evaluation points is recommended, for example, 0 % (zero time), 50 %, 100 % (end-point), and one or more time points a percentage beyond the sensory endpoint, that is, 125 %. Evaluation points beyond the end-point are included in the event that the product achieves the expected shelf life and there is the possibility that the shelf life could be extended. It is best to include a time point where product failure is likely to occur.

6.7.4 *Additional Evaluation Points*—Additional evaluation points over the shelf life period are recommended. These additional evaluations should be timed at points where significant changes in the product are expected to occur. The following examples demonstrate three sampling plans that could be used for specific product applications. These examples are designed to illustrate that sampling plans should be developed and customized based on the objectives and requirements of the study, as well as the resources available to conduct the evaluations. In all cases of shelf life studies where end-points for testing are planned, product safety is also a consideration. In no case should a product sensory shelf life test be conducted when a product may be unsafe to consume or use.

6.7.4.1 For a product predicted to change most early in the shelf life period, emphasis is placed on earlier evaluations: 0 %, 15 %, 30 %, 50 %, 100 %, and some percentage beyond.

6.7.4.2 For a product predicted to change later in the shelf life period, emphasis is placed on later evaluations: 0 %, 50 %, 65 %, 80 %, 100 %, and some percentage beyond.

6.7.4.3 For a new product with little, if any, prior shelf life history, more frequent evaluation points are recommended to assure that the time of significant changes in the product are captured in evaluation. A minimum of 0 %, 25 %, 50 %, 75 %, 100 %, and one or more points beyond the expected shelf life should be planned.

6.7.4.4 It is incumbent upon the researcher to determine whether evaluations at all planned time points should occur. The researcher may choose not to continue planned shelf life evaluation points if:

(1) the product has reached the failure point prior to the anticipated end of shelf life, or

(2) the product has not reached the failure point but the decision to set the shelf-life at a point prior to failure has been made.

6.8 *Determine Product Quantities:*

6.8.1 To determine the total amount of product needed to complete a shelf life study, one must take into consideration the sampling plan test intervals, the storage temperature conditions desired, the experimental design, and the sensory test methodologies best able to determine end-point criterion or criteria. Product quantities must be calculated to allow for all possible combinations of testing needs.

6.8.2 It is often useful to include additional test product in each storage condition in case, for example, the product is more stable than expected or unexpected changes occur that warrant more in-depth study. An overage of 20 % to 50 % is common practice.

6.9 *Determine the Evaluation Plan: Multi-Point versus Single-Point Evaluation Plans*—Multi-point and single-point evaluation plans are two different evaluation plans. Each has its own advantages and disadvantages and may suit specific situations.

6.9.1 *Multi-Point Evaluations*—Multi-point evaluation plans involve conducting the shelf life testing at multiple times,