Sensory Shelf Life Study Design for Shelf-Stable and Frozen Foods

Overview

Most packaged foods and beverages come stamped with a 'use by' date to ensure consumer safety or a 'best by' date to ensure product quality. Setting shelf life dates can be challenging for food companies as many factors need to be considered, including sensory deterioration, nutritional degradation, and microbial growth. For most refrigerated products, the shelf life is relatively short and is typically dictated by microbial growth. Therefore, shelf life of products requiring refrigeration is established based upon a threshold microbial load which signals spoilage or potential safety concerns. However, shelf stable and frozen products are safe over months or years. In these cases, shelf life is based upon quality changes that occur in the product as it ages. Food companies want their products to deliver the same high quality sensory experience to their consumers at the end of a product's shelf life as when the product is fresh. Results from a well-designed shelf life study provide the input needed to help companies make the business decision of choosing a 'best by' date.

Modes of Deterioration/Failure

The first task in designing a successful shelf life study is determining the probable causes of product quality deterioration or failure. For shelf-stable and frozen products, the most common modes of failure are sensory or chemical/physical degradation. (Microbial growth is not typically a critical factor for shelf stable or frozen foods.) Modes of failure are influenced by product composition, packaging, and storage temperature and commonly include color changes, loss of desirable aroma and flavor notes, formation of undesirable aromas or flavors (Table 1), and texture changes. The point at which a product is no longer acceptable can be assessed by testing with target consumers, but is more often a business decision based upon the degree of product change that the company considers tolerable. Once the critical mode(s) of deterioration or failure are determined, product changes can be monitored and limits can be set to identify the end of shelf life.

Table 1: Common Off-Flavors

- Oxidized
  - Cardboard
  - Painty
  - Fishy
- Musty
- Bitter
- Metallic
- Phenolic
- Chemical
- Soured
- Browned/Cooked

Measuring Product Change

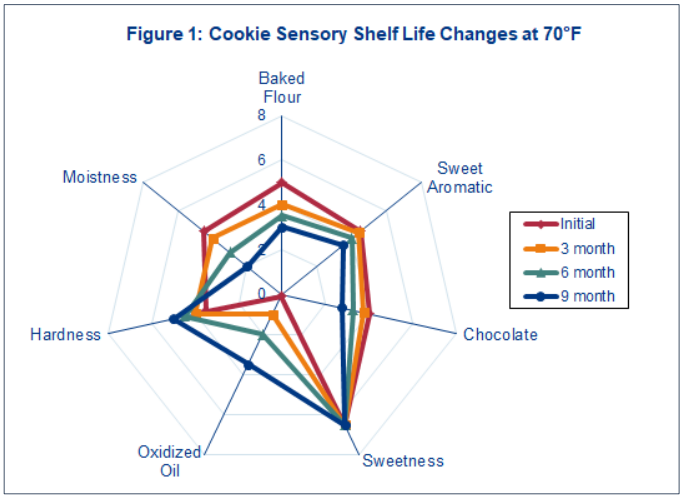
Sensory Testing

Trained panelists are commonly used to measure the sensory changes in products over time. These panelists should be highly skilled at describing the appearance, aroma, flavor, and texture of the product. For most shelf life tests, three to five trained sensory panelists evaluate the samples at each time point. During an initial evaluation, panelists describe or rate the intensity of key sensory attributes of each sample. These scores or descriptions

are anchored to the score sheet and serve as the Reference for comparison at later time points. Panelists then describe or rate the changes in samples that have been held under typical or accelerated storage conditions. Panelists may also offer their subjective opinion as to how close the aged samples are to a refrigerated or frozen Reference sample on an overall basis. A sensory panel leader would lead the group discussion and record their consensus of opinion. However, the final decision on acceptability of the product rests with the company.

One type of output is shown in Figure 1, in which the sensory changes in packaged cookies are shown over the course of ambient storage. Fresh baked flour flavor, sweet aromatic flavor, chocolate flavor, and moistness decrease, while oxidized oil flavor and hardness increase as the sample ages.

Figure 1: Cookie Sensory Shelf Life Changes at 70°F



Consumer Testing

In addition to trained sensory panel testing, consumer testing can be conducted near the end of predicted shelf life to assure that Overall Liking remains at an acceptable level. The end of shelf life can be chosen based on a meaningful drop in consumer liking. This protects the brand by assuring that the product will not be perceived as lower quality when consumed close to the 'best by' date. Because consumer testing is more expensive than trained panel testing, consumer testing is often conducted after sensory panelists have documented a meaningful change in the products.

Chemical/Physical Testing

In order to comply with government regulations, products must also meet the nutrient claims printed on their label (Figure 2). Some nutrients, such as Vitamin A and Vitamin C, degrade over time; sensitive compounds such as these should be assayed over the course of the intended shelf life to determine when their concentration falls below the level stated on the package to set the end of shelf life.

Color change can be associated with a perceived loss of quality in some products. Color can be measured in the laboratory and food companies may choose to end a product's shelf life based on the degree of visual change.

Figure 2: Fortified Juice Drink

Nutrition Facts

1 serving per container
Serving size **8 fl oz (240 mL)**

Amount per serving
Calories **120**

	% Daily Value*
Total Fat 0g	**0%**
Saturated Fat 0g	**0%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 35mg	**2%**
Total Carbohydrate 29g	**11%**
Dietary Fiber 0g	**0%**
Total Sugars 23g	
Includes 5g Added Sugars	**10%**
Protein 1g	
Vitamin D 0mcg	0%
Calcium 40mg	4%
Iron 0.4mg	2%
Potassium 130mg	2%
Vitamin A 900mcg	100%
Vitamin C 90mg	100%

*The % Daily Value tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Interpreting chemical and physical measurements is often easier and more meaningful when combined with sensory data. When a change is recorded in a chemical or physical measurement, the consequence of that change in the product may be correlated with a change described in the sensory evaluation. For example, if the moisture in a cookie decreases by 10%, it is important to know if the sensory panel also describes that cookie as being drier and harder.

Other Considerations

Packaging

It is important to use a product's final packaging for a shelf life study, as the package influences how the food changes over time. Compounds might migrate from the packaging to the food or the packaging might scalp flavors from the food, affecting the sensory characteristics of the product. In addition, the physical characteristics of the package, including light, oxygen, and moisture permeability, influence how the sensory and nutritional properties of the product will change.

Distribution and Warehouse Storage Conditions

When setting a shelf life, the typical time between product production and consumption should be considered. If it takes a long time for the product to reach consumers and the product is then stored for extended periods of time, a longer shelf life is needed and a higher degree of product change may need to be tolerated. However, if distribution is fast and a product is used quickly by consumers, a shorter 'best by' date may be appropriate from both a financial and product quality perspective.

Storage conditions vary widely, thus it is often wise to consider worst-case storage scenarios. For example, if a product is stored in a non-climate controlled warehouse during a month-long heat wave, would the product still be acceptable within the stamped shelf life? Temperature, humidity, and light exposure can be designed into shelf life experiments and should be considered during end date decisions if there is a reasonable risk that product will be exposed to abusive conditions.

Shelf Life Study Design

Most shelf life studies involve product storage at multiple temperatures. Samples that have been stored under typical or abusive conditions are compared to a 'fresh' reference sample at multiple time points to understand how the product changes over time. The evaluation time points should be flexible dates that can be adjusted to ensure changes in the product are being measured. Reference product is stored in a freezer or refrigerator to minimize product change as much as possible over the course of the study.

Shelf stable products are stored at ambient (typically 70°F) and one or more abusive temperature conditions. Abusive temperatures accelerate changes that may occur in a product as it ages. There is not an exact or universal acceleration factor that can be used to calculate how time at one temperature directly translates to time at another temperature. Extensive testing and mathematical modeling, described below in the Predictive Modeling section, can be used to determine such factors. For most shelf life testing, accelerated temperatures are useful to gain an early read on product deterioration and serve as a disaster check to determine what may happen to a product as it ages. Care must be taken to choose storage temperatures that will not trigger reactions that would not normally occur in the product.

During the study design phase, companies are encouraged to think about how they would like to define the end of shelf life for their products. For some companies, the formation of flavor off-notes at a pre-defined intensity is chosen to signal product failure, while for others, a specified drop in consumer acceptance for the product is chosen. This is a business decision that varies widely among company cultures. Shelf life dates are set to keep products within the chosen limit. Examples of useful criteria are shown in Table 2.

Table 2: Examples of End of Shelf Life Criteria

- Descriptive Sensory Panel
  - % Quality Change Rating (of 30%)
  - Oxidized Flavor Intensity Rating (of 2)
  - Off-Note Intensity Rating (of 2)
  - Decrease in Characteristic Product Flavors
- Consumer Testing
  - Drop in Overall Liking (0.5 points on 9-point hedonic scale)
    - Difference found in Triangle Test
- Chemical / Physical
  - Drop in Nutrient Content (below value stated on label)

Studies should be designed with a company's risk-level, timeline, and budget in mind. Examples of lower tier, mid tier, and upper tier shelf life experiments are illustrated below.

Lower Tier – Disaster Check

A basic level shelf life study would typically involve two to three storage temperatures (frozen/refrigerated, typical, and abusive) and several evaluation time points. At each time point, sensory evaluations are conducted using a narrative descriptive method. Three panelists verbally describe the appearance, aroma, flavor, and texture of the samples and a consensus written summary is recorded by a panel leader at each time point. Physical or chemical data are also collected, if needed. Recommendations on product acceptability are made at each time point.

This output cannot be graphed because of the non-quantitative nature of the data. However, patterns of product change can be observed and solid recommendations can be made to help set shelf life dates.

Mid Tier – Quantitative Data Collection

A mid tiered shelf life study typically involves at least three storage temperatures (frozen/refrigerated, typical, and abusive) and multiple time points. At each evaluation time point, panelists rate the intensity of key appearance, aroma, flavor and texture attributes on a 15-point intensity scale. Scores from the refrigerated/frozen reference sample are anchored to the score sheet for comparison. At the end of each evaluation, panelists provide an overall percent quality change score and a subjective opinion of how close the aged samples are to the reference on an overall basis. The rationale for these changes is recorded.

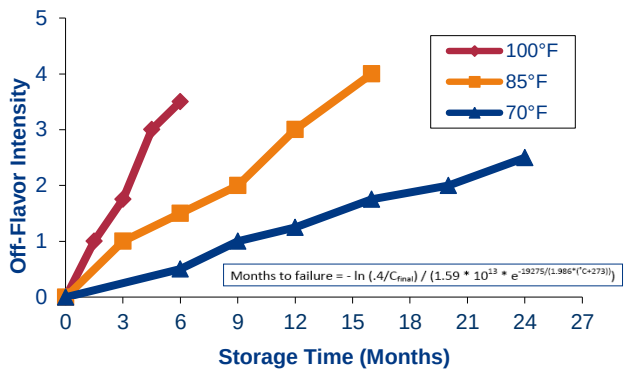
After each evaluation, a table of consensus scores and an interpretation of results is provided. Since quantitative data are collected, the results can be graphed to illustrate changes that are happening in the products over time.

Upper Tier – Predictive Modeling

Mathematical models can be created to help predict product shelf life under a range of conditions. This can be very useful to help set a preliminary shelf life for similar products without waiting for end of shelf life data to be collected. It can also be used to calculate loss of shelf life if product lots are unintentionally exposed to abusive conditions, such as a hot warehouse during a long heat wave.

Many data points are needed to create shelf life models. A common design includes four temperatures, each with approximately six evaluation time points. Sensory panelists evaluate the products at each pull time and rate the intensity of key sensory attributes. Chemical and physical data can also be collected. The Arrhenius model is used to predict how long samples will take to reach a critical end point, such as an off-note flavor intensity of 2.0. Multiple key attributes can be modeled to help make an end of shelf life decision.

Figure 3: Graph of Arrhenius Shelf Life Model



The higher temperature pull times are spaced closer together so that early models can be created to estimate how long the product will last. Models can be updated as new data are collected to gain more accurate predictions. An example of a typical output is shown in Figure 3. In this case, if the end of shelf life is reached when the off-note flavor intensity reaches 2.0, the product would last 21 months at 70˚F.

Choosing a Shelf Life Date – A Business Decision

As long as food safety is not in question and a product meets all of the nutritional claims printed on its label, companies are free to determine the shelf life of their shelf-stable or frozen products. Food companies vary greatly in their shelf life philosophies; some companies are very conservative and choose to end shelf life when there is a perceivable difference between aged product and fresh product. Other companies accept more sensory variability within their stated shelf life. Companies need to decide what degree of product change they are comfortable with being associated with their brand.

Once a company has decided how much product change it is willing to accept, data from well-designed shelf life studies can help to determine 'best by' dates. This can help reduce consumer complaints, keep product quality within a range the company is comfortable with, and ultimately maximize protection of the brand.

The Eurofins Partnership

Eurofins recognizes the need for solutions across the product lifecycle continuum, from development to processing, packaging, and testing. We offer a wide breadth and depth of services and are committed to our clients' success.

For more information, please contact:
Regan Javier at ReganJavier@EurofinsUS.com or
Dawn Chapman at DawnChapman@EurofinsUS.com