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, requiring consideration of sensory deterioration, nutritional degradation and microbial growth. For most refrigerated products, the shelf life is relatively short and 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 on quality changes that occur in the product as it ages. Food companies want products to deliver the same high-quality sensory experience to 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 input to help 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, 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. The results commonly include color changes, loss of desirable aroma and flavor notes, the formation of undesirable aromas or flavors (Table 1) and texture changes. You can assess the point at which a product is no longer acceptable by testing with target consumers, but this is more often a business decision based on the degree of product change that your company considers tolerable. After determining the critical mode(s) of deterioration or failure, product changes can be monitored and limits can be set to identify the end of shelf life.

Measuring Product Change

Sensory Testing

Trained panelists can help 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 for each sample. These scores or descriptions are anchored to the scoresheet for comparison at later time points. Next, panelists describe or rate changes in samples that have been held under typical or accelerated storage conditions. Panelists may also offer a subjective opinion on how close the aged samples are to a refrigerated or frozen reference sample. A sensory panel leader guides the group discussion and records the consensus of opinion. However, the final decision on acceptability of the product rests with the company.

*Table 1: Common Off-Flavors*

- Oxidized
- Cardboard
- Painty
- Fishy
- Musty
- Bitter
- Metallic
- Phenolic
- Chemical
- Soured
- Browned/Cooked
See Figure 1 for output showing the sensory changes in packaged cookies 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.

**Consumer Testing**

In addition to trained sensory panel testing, consumer testing near the end of predicted shelf life ensures that overall liking remains at an acceptable level. The end of shelf life is typically chosen based on a meaningful drop in consumer liking. This protects the brand by ensuring that the product is not 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 a product.

**Chemical/Physical Testing**

Products must meet the nutrient claims printed on their labels (Figure 2) to comply with government regulations. Nutrients such as Vitamin A and Vitamin C degrade over time; sensitive compounds such as these should be assayed over 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 product quality. Color can be measured in the laboratory and you may choose to end product shelf life based on the degree of visual change.

Interpreting chemical and physical measurements is often easier and more meaningful when combined with sensory data. When you record a change in a chemical or physical measurement, you can correlate the consequence of that change in the product with a change described in the sensory evaluation. For example, if cookie moisture decreases by 10%, you want to know if the sensory panel describes that cookie as being more dry and hard.

**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 may migrate from the packaging into the food, or the packaging might scalp flavors from the food, affecting sensory characteristics. Also, 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 shelf life, consider the typical time between product production and consumption. If it takes a long time for the product to reach consumers and the product is stored for an extended period, you may need a longer shelf life and may decide to tolerate a higher degree of product change. However, if distribution is fast and a product is used quickly by consumers, a shorter “best by” date may ensure a higher quality product experience.

Storage conditions vary widely, so it is 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? You can design temperature, humidity and light exposure into shelf life experiments and consider these factors during end date decisions.
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 that changes in the product are being measured. The reference product is stored in a freezer or refrigerator to minimize product change over the course of the study.

Shelf-stable products are stored at ambient (typically 70°F) plus one or more abusive temperature conditions. Abusive temperatures accelerate changes in a product as it ages. There is not an exact or universal acceleration factor 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 help determine such factors. Typically, accelerated temperatures provide an early read on product deterioration and serve as a disaster check to show what may happen as a product ages. Take care to choose storage temperatures that do not trigger reactions that would not normally occur in the product.

During the study design phase, it is important to define what you consider the end of shelf life for your products. Some companies choose the formation of flavor off-notes at a pre-defined intensity to signal product failure while others choose a specified drop in consumer acceptance. This is a business decision based on company cultures, with shelf life dates set to keep products within the chosen limit. See examples of useful criteria in Table 2.

Design your studies with risk level, timeline and budget in mind. Examples of lower tier, mid-tier and upper tier shelf life experiments follow.

Table 2: Examples of End of Shelf Life Criteria

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

Lower Tier – Disaster Check

A basic-level shelf life study typically involves 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 panel leader records a consensus written summary 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 is not graphed because the data are non-quantitative. However, you can observe patterns of product change and gain solid recommendations 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 scoresheet 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. The rationale for these changes is recorded.

After each evaluation, you receive a table of consensus scores and an interpretation of results. Since quantitative data are collected, the results can be graphed to illustrate changes 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. These models can help set a preliminary shelf life for similar products without waiting for the end of shelf life data to be collected. It can also be used to calculate the 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 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 endpoint, 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.

Higher temperature pull times are spaced closer together so that early models can be created to estimate how long the product will last. You can update models as new data are collected to gain more accurate predictions. See Figure 3 for an example of a typical output. 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

Companies are free to determine the shelf life of their shelf-stable or frozen products as long as food safety is not in question, and a product meets all of the nutritional claims printed on its label. Shelf life philosophies vary greatly; 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. Your company will need to decide what degree of product change you are comfortable with for your brand.

Data from well-designed shelf life studies can help to determine “best by” dates. These dates can reduce consumer complaints, keep product quality within a range the company is comfortable with and ultimately maximize protection of the brand.

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