Shelf Life Studies: Basics, Principles, and Concepts

Introduction

Shelf life studies are used to determine how long a product can reasonably be expected to maintain its quality, safety, and character. These studies take into account not only products' functional qualities such as safety and effectiveness, but also cosmetic qualities such as color and texture that make them appealing to customers.

An acceptable shelf life for a product is one that allows its desired end of shelf life parameters (EOSLs) to be maintained; these include a product's sensory, chemical, functional, microbiological, and physical properties. Since the EOSLs are different for every product, the test procedure for conducting a shelf life study will be unique for each product.

Test methods

There are two test methods for conducting a shelf life study. The direct method involves storing the product under specific conditions for a period of time that is longer than its expected shelf life and checking it at regular intervals to see when it begins to spoil. Two indirect methods allow for shelf life prediction without conducting a full-length storage trial, and are useful for products with a long shelf life.

The first indirect method uses a predictive model based on information from a database that predicts bacterial growth under specific conditions, which can then be used to calculate shelf life.

The second method is an accelerated shelf life study, which involves deliberately increasing the rate at which a product will spoil, usually by increasing the storage temperature.

A tool used in accelerated studies is "the rule of ten," or Q_{10}, which is the factor by which the rate of spoilage increases when the temperature is raised by 10C. Q_{10} allows for the prediction of a product's shelf life under real-life conditions based on the results of testing conducted at high temperatures. It is unitless and can be calculated with the equation $Q_{10} = (R_2/R_1)^{(10/(T2-T1))}$, where R is the time it takes for a product to spoil and T is the temperature at which the testing is conducted. For most products the Q_{10} value is 2.0, which means that for every increase of 10C, the rate of a chemical reaction will double.

In an example, a product was tested at three different temperatures to obtain the time to spoilage. Q_{10} values were obtained by comparing T_2/T_1 with R_2/R_1 and T_3/T_2 with R_3/R_2, as defined in Figure 1.

T1	T2	T3
20C	30C	40C
R1	R2	R3
15	24	38

Figure 1. Temperature and time to spoilage data.

Applying these numbers to the equation:

$$Q_{10} = (24/15)^{(10/(30-20))} = 1.61$$

$$Q_{10} = (38/24)^{(10/(40-30))} = 1.58$$

Figure 2. Calculating the Q_{10} values.

As we can see in Figure 2, the actual Q_{10} for this product is approximately 1.6, not the value of 2.0 that is generally assumed. If this product started to spoil after eight weeks, to determine the shelf life at 20C the time to spoilage would be multiplied by the Q_{10} value twice, once for each 10C change in temperature. When calculating the shelf life of this product using a Q_{10} value of 2.0, the predicted shelf life is 32 weeks (8 months), but with a Q_{10} value of 1.6 the predicted shelf life is 20.48 weeks (5.2 months).

Water activity

Water activity, abbreviated a_w, is the amount of "free" or "available" water in a system and is a measure of how much water is available to react with or attach itself to a product. It is calculated by dividing the vapor pressure of water in the system by that of pure water at the same temperature. Pure water has an a_w of 1.0. Most microorganisms grow well with an a_w between 0.91 and 0.99, and none will grow with an a_w below 0.65.

Knowing a product's a_w is important for slowing down enzymatic reactions, most of which are slowed at an a_w below 0.8. Maillard reactions, or non-enzymatic browning reactions, are also rate-dependent with a_w. Knowing a product's a_w will assist with measuring, predicting, and controlling these reactions, and therefore extending the product's shelf life.

Along with free water, a portion of the total water in a product is chemically bound to the product itself. This is referred to as "bound water," and free water and bound water together are referred to as a product's moisture content.

An example of this concept is honey. It has a high moisture content as evidenced by the fact that it is pourable, but because it has a very low free water content it has an extremely long shelf life.

Conclusion

Shelf life studies can be complex because they are product specific; the test parameters will be unique for each product because of their different EOSLs. For an example of a shelf life study, see our case study "Shelf life study: Testing to increase shelf life from 16 to 36 weeks."

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