Medallion Laboratories
ANALYTICAL PROGRESS

Shelf Life Testing

By Mark Sewald and Jon Devries

What is Shelf Life?

Most dictionaries define shelf life as the length of time a product may be stored, as on a supermarket shelf or in a home pantry, without deteriorating.[1] Unfortunately, such definitions often create some misconceptions. The reality is that deterioration starts for most agricultural crops when harvested and for most manufactured foods before they are packaged. Fortunately, the rate of deterioration in many foods is slow; hence, they can be stored for some time before they become unacceptable or significantly deteriorated. If one realizes that deterioration is an ongoing process, then one can understand why it is so important to keep the *distribution time* as short as possible and avoid unnecessary stockpiling.

Relevant Factors

A better way to define shelf life is to understand the changes that occur in product quality over time. By putting an equal sign and an expression behind this definition, we have an equation. The change of quality over time is a *function of storage temperature, humidity, package protection, product composition, water activity, processing conditions, and ingredient quality.*

This equation can greatly enhance our understanding of shelf life. For example, it tells us that the shelf life of the same food stored in a warehouse in Phoenix, Arizona, will not be the same compared to being stored in International Falls, Minnesota.

The storage temperatures at the two locations are very different. Hence, shelf life can never be defined as a fixed amount of time but rather expressed as a *range* of estimated acceptable shelf time.

When a food distributor chooses to use an *open code date* ("use by," etc.) or to set maximum length of storage requirements, good judgment must be used to select the most appropriate time within the shelf life range. Selecting a value of a short shelf life could mean paying more than required for destroying over-aged product, special handling, packaging materials and, perhaps, controlled temperature storage. Erring on the other side could mean loss of repeat sales because of disappointed customers.

Testing Factors

Some food producers test their new products under a set of abusive conditions. Perhaps the conditions are those that might be encountered in a boxcar or a warehouse in Florida in July. Then they extrapolate these results to results expected under other conditions. For example, one week at the abusive conditions might equal one month of shelf life. Unfortunately, all too often such extrapolations are invalid. High temperature and high humidities are used to accelerate shelf life tests; however, the correlation between a given set of abusive condition and more normal conditions will vary greatly for different types of foods. Thus, establishing the correlation requires either testing at several conditions or significant prior experience with a given type of food.

Establishing Limits

$$\Delta PQ = f(ST, H, PP, A_W, PC, IQ$$

There are four basic factors that have to be addressed before reliable shelf limits can be established. These are understanding the innate stability of your product; how normal variability in ingredient quality, processing and packaging will impact your storage quality; understanding how your distribution will impact your storage quality

1. The American Heritage Dictionary, 1987, Houghton Mifflin, s.v. "shelf life."

understanding; and knowing the quality level at which you no longer want your product available to the consumer. Understanding the innate stability of a food product is the classical goal of shelf life testing. Does the storage quality of this product change significantly in a matter of days, weeks, three months, nine months, etc. But no matter how extensive a shelf life study is, often the test is only being run on one lot of product. Does this lot reflect typical, best or worst product quality in terms of ingredient quality, processing conditions, or package fabrication? Please consider that it is critical to understand the storage quality of any product you would be willing to sell to your consumers. This also raises the questions of understanding our distribution. In some cases, an "accelerated" storage condition such as our weather room (90°F day, 70°F night at 60 to 70% RH) may be reality for an unconditioned warehouse in the summertime. Many shelf life issues occur when marginal quality product is stored under abusive (but not atypical) storage conditions. Knowing what percent of your product will fall into this category will help you understand your risk of shelf life issues.

The typical output of a shelf life test is a plot of a quality measure vs. storage time. For some degradation reaction (lipid oxidation, microbial spoilage), a point will be reached at which the product quality will degrade markedly. In this study, defining the end of shelf life at a given storage condition is a matter of looking at the inflection of the data. Often, however, the quality of a sample will decline more gradually with changes impacting sensory attributes and not food safety. Here the question must be addressed as to what sensory quality level do we no longer want this product available to the consumers. Do we want the storage quality endpoint to be when the product is "not like fresh" or when it is "clearly objectionable" to the consumer. In these cases, the shelf life study provides the food manufacturer with the storage quality vs. storage time data. Where the shelf life of such a product is ended is a business choice that needs to be made by the manufacturer of the food product.

Testing Requirements

Some analytical determinations may be required to obtain a better understanding of a given food before setting up a shelf life test. Moisture and water activity (a_w) must always be known. Others, which often are desirable, are the amount and type of fat, the protein content, the type of sugars and starches, ash content and pH. For high moisture foods, microbiological tests may be needed.

The objective of most shelf life testing is to determine how rapidly microbiological, chemical and physical changes occur in the food during distribution and storage. Since different storage conditions accelerate some changes but not others, it helps to know before testing what changes are likely to occur. Knowing the a_w will provide some indication of what the major mode of deterioration will be. At water activities above 0.8, microbiological growth may occur. At a_w greater than 0.55, enzymes can be active. In the intermediate a_w (0.25 to 0.55) range, nonenzymatic browning is often the major mode of deterioration. At a_w below 0.25, rancidity often contributes to the loss of quality. Other deteriorations affected by a_w are losses of vitamins, flavors, leavening and changes in color. It is important to realize that the water activity is only a guide. Some yeast and molds can grow in foods with an a_w as low as 0.65. Enzymatic hydrolysis has been reported to occur at a_w as low as 0.2. Lipid oxidation does occur in high moisture systems. Most foods, when stored, will either gain or lose moisture unless they are contained in moisture impermeable materials. Moisture changes may directly affect the food quality, e.g., its texture, or indirectly by changing the reaction rate because of change in a_w. Some of the product changes (texture, caking, crystallization, etc.) which occur with change of moisture can be determined by placing the food in desiccators containing a variety of saturated salt solutions, which maintain a desired relative humidity (RH) and allowing the moisture in the food to reach equilibrium. By weighing the samples, one can calculate the moisture change at the different RH. By plotting the moisture against the RHs, the moisture sorption isotherm (also called moisture equilibrium or equilibrium relative humidity curve) can be generated.

Test Package Concerns

What type of packages should be used for shelf life testing? The packages in which the product will be sold may not be the best choice. As pointed out above, water activity is critical. If one tests under abusive conditions, the commercial package may not provide the protection required to maintain the normal water activity and reactions may occur which normally would not. On the other hand, sometimes one may want to know what would happen if the water activity changes greatly. In such a case, one might want to test the standard package against *packages with intentional defects*.

Rate of Deterioration

How do we measure the rate of *deterioration*? If major changes occur rapidly, the task is fairly simply. On the other hand, if the changes are very gradual, it is often difficult to differentiate between deterioration and normal quality variations after storage for a reasonable period of time, even with a control sample stored at 0°F or -40°F.

Olfactory Changes

The authors believe in smelling all, and tasting most shelf life test samples. However, because of differences in taste acuity between individuals, *sensory evaluations* are often not very reliable unless large numbers of tasters are used. If evaluations must be done with only a few tasters, it is recommended that differences be accentuated. This can be done by using accelerated storage conditions, using containers that will trap off-odors, or packages with intentional defects.

Moisture

Moisture analyses are fast and relatively cheap; however, moisture changes for many foods can often be most reliably monitored by package weight changes using empty containers as tare weights. The beauty of this method is that it is nondestructive; hence, one can determine variations between a great number of individual packages relatively inexpensively and place the product back in storage for additional testing.

Color Changes

Color changes due to nonenzymatic browning can be detected visually somewhat reliably. This can be supplemented by color measurements.

Lipid Deterioration

For low moisture, high fat foods (25% or more fat), lipid oxidation can be tracked by measuring the changes using peroxide values. For high moisture foods, thiobarbituric acid (TBA) values are often used to detect lipid oxidation. The best rancidity measure for low moisture, low fat foods is the hexanal method 22 providing that the fat contains some linoleic acid.

Microbiological Tests

For high moisture foods, *microbiological tests* are needed to track spoilage. To determine the effect of shelf life from a microbiological standpoint, there are several aspects that have to be considered. One must determine if the product will support microbiological activity. If the product does support growth, it is important to determine if this growth would result in product spoilage or present potential consumer safety issues. To answer these questions, there are several factors that have to be determined. These factors are: pH, water activity, how the product will be distributed and retailed, length of shelf life, preservatives used and type of packaging. Once the key storage factors of the product are determined, then an inoculated storage test can be designed using the appropriate combination of microorganisms, times, and temperatures.

[2] Fritsch, C.W. and Gale , J.A.;
J. Am. Oil Chemists Soc. 54:225, 1977.

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