OVERALL STATUS
OF SHELF LIFE STUDIES

G.L. ROBERTSON

Food Packaging Environment and University of Queensland, Brisbane, Australia
E-mail: gordonlrobertson@gmail.com

ABSTRACT

While it would be of great interest to know the status of shelf life studies in industry, such data is sadly not available. Therefore, this paper must of necessity confine itself to the status of shelf life studies that are published in the scientific literature. Regrettably, many published studies are irreproducible because key data are lacking or incomplete. This is as much an indictment of the journal referees as it is of the individual authors. This paper reviews recent published shelf life studies and highlights the important details that must be included so they can be reproduced and their findings applied by a wider audience. To preserve anonymity, the journal names and authors are omitted. Although it is unfortunate that so much published research on shelf life is not reproducible, it is also a waste of millions of dollars of research funding and time. In most cases, the missing details could have been easily supplied if requested.

Key words: Shelf life, package dimensions, surface area, volume, degree of filling.

INTRODUCTION

Despite its importance, there is no simple, generally accepted definition of shelf life in the food technology literature. In ASTM E2454, sensory shelf life is described as “the time period that a product may be stored before reaching its end point” and defines the end point as “the point at which a product no longer meets predetermined criteria as defined by test data (for example, discrimination, descriptive or affective, or a combination thereof).” A broader definition is that “shelf life is the
duration of that period between the packing of a product and the end of consumer quality as determined by the percentage of consumers who are displeased by the product.” In most cases, packaging has a strong influence on the shelf life of a food. The objective is to provide just enough protection to ensure that the food maintains its acceptability until the end of its desired shelf life. This requires detailed knowledge and understanding of the food, its packaging and the environment to which it will be exposed prior to consumption.

**DETERMINATION OF SHELF LIFE**

Shelf life can be determined from two sides: the product side or the consumer side. Determining shelf life from the product side implies investigating the deterioration of the product as a function of time and several models are available to assist in the determination. Alternatively, determining shelf life from the consumer side implies asking consumers to accept or reject food which has been stored for various lengths of time without normally specifying the reason for acceptance or rejection.

When shelf life is determined from the product side, sensory evaluation of the food is likely to be used either alone or in combination with instrumental or chemical analyses to determine the quality of the product. Many sensory test methodologies are available and can be classified into either analytical tests or hedonic tests. One of the problems with published shelf life studies is that insufficient details are given about the nature, experience and repeatability of the sensory panels employed.

When determining shelf life from the consumer side, consumer dissatisfaction can be related to the survival function, and models applying survival analysis to the sensory shelf life of foods have been published. Because quality changes in foods are very complex, it is not always possible to make accurate predictions of shelf life based on a mechanistic insight. In such situations, it is necessary to resort to a statistical description so that the mean time to failure and its standard deviation can be accurately estimated, and the probability of future failures predicted.

**OVERALL STATUS OF SHELF LIFE STUDIES**

So what is the overall status of shelf life studies? A book published in May 2012 entitled *Shelf Life Assessment of Food* and edited by Professor Nicoli may well provide the answer to this question. An earlier book entitled *Food Packaging and Shelf Life* also provides some answers. While it would be of great interest to know the status of shelf life studies in industry, such data is sadly not available. Therefore, this paper must of necessity confine itself to the status of shelf life studies that are published in the scientific literature and some recent studies are reviewed later.

**KEY INFORMATION FOR SHELF LIFE STUDIES**

**Package Dimensions**

The dimensions of the package for a given weight of food can have a significant influence on shelf life because the surface area influences permeation and the effect of exposure to light. Although a spherical shape will minimize the surface area of the package (and thus the quantity of moisture or O₂ that will permeate the package wall),
it is not a practical shape for commercial use, and in practice most packages tend to
be rectangular or cylindrical. In comparing the surface areas for a range of different
package shapes all having the same volume (~450 mL), the surface area of a cylinder
is 16% greater, a cube 24% greater, a tetrahedron 49% greater, a rectangular shape
58% greater, and a thin rectangular shape 246% greater compared with the surface
area of a sphere which is obviously not a commercially-viable shape. Extremely thin
packages have a much greater surface area:volume ratio and thus require a plastic
with better barrier properties to get the same shelf life than if the same quantity
of product were packaged in a thicker format. Regrettably, many papers omit the
dimensions of the package and therefore the research is irreproducible.

Modified Atmosphere Packaging (MAP)
The inhibitory effect of CO₂ on many spoilage bacteria is proportional to the amount
dissolved CO₂ in the product. Thus the effectiveness of MA packaging is generally
determined by the amount of available CO₂ that can dissolve into the food, and is a
function of the partial pressure of CO₂ inside the package and the degree of filling (DoF)
(i.e., volume of product vs. volume of package (mL/mL)). The amount of gas dissolved
in a product at equilibrium is proportional to the partial pressure in the atmosphere
surrounding the product according to Henry’s law. Various reports have shown the
relationship between Henry’s law and packaging variables such as temperature, gas
composition and DoF on the amount of dissolved CO₂ in the product. However, many
of the publications on MAP do not state the DoF or the amount of dissolved CO₂, and
this makes comparison between different studies difficult and replication impossible.

Effect of Light
Determining the effect of light on the shelf life of foods is a difficult experimental
area. The major problem seems to be ensuring that all the packages have been
exposed to an even and consistent light source. Clearly, the surface area of the
package in relation to its volume is crucial in any interpretation of the results.

Recently, Manzocco et al. (2012) showed that shelf life estimation of photosen-
sitive foods (specifically sunflower and soybean oils) under actual or accelerated
conditions cannot be correctly determined if the effect of light is not taken into
account. They presented a model that predicted the shelf life based on changes in
both light intensity and temperature, although the effect of temperature as an ac-
celerating factor was quite limited. It would be of great interest if this research was
expanded to include all the common packaging materials used to pack vegetable
oils. Again, unless the surface area of the package exposed to light is specified,
then the research will not be able to be repeated.

SHELF LIFE STUDIES OF EVOO

There have been many shelf life studies on vegetable oils and in particular extra
virgin olive oil (EVOO). These oils are sensitive to both light and oxygen and thus
their shelf life is very dependent on the barrier properties of the packaging. As is
the case with many foods today, the traditional glass and metal packaging is being
replaced by plastics which do not provide the same shelf life. Cecchi et al. (2009)
critically reviewed the literature results concerning the packaging of olive oil in
glass or PET bottles (both of which are used commercially for this purpose) and
their conclusions provide a salutary message to researchers (and journal referees)
in the shelf life area. From the analysis of the cited literature, it was clear that the reliability of PET bottles as olive oil containers still needs to be demonstrated, primarily because of inconsistent results.

Their major criticisms concerned the fact that important properties of the PET bottle (O₂ permeability and thickness) were very seldom declared, and most experimental designs were performed using drinking water PET bottles with variable thickness and composition. In their view, the low self-consistency of literature results was also probably related to the use of different oxidation markers, and dissimilar methods to predict the shelf life by different research groups. Since olive oil is not a standardized reference material, they suggested that future experimental designs should make use of the same olive oil for all experiments or should carefully declare the initial O₂, antioxidant and pro-oxidant contents, which are widely known to influence olive oil oxidation during storage. They concluded that detailed, comprehensive and standardized experimental studies on the shelf live of olive oil packed in PET bottles should be encouraged.

EXAMPLES OF PUBLISHED SHELF LIFE STUDIES

To exemplify the overall status of shelf life studies, examples of recent shelf life studies published in the literature will be critically reviewed and their reproducibility estimated. To preserve anonymity, the journal names and authors are not given. However, the examples are drawn from 18 of the top peer-reviewed food science and technology journals.

A paper on the effects of MAP with gas mixtures of either CO₂ and Ar, or CO₂ and N₂, on the quality of pork sausages during refrigerated storage contained no details about the packaging materials, their dimensions or DoF and therefore the results cannot be replicated. A paper on MAP of fresh-cut pears gave the DoF but not the package dimensions and therefore the results cannot be replicated. A paper on the effect of MAP on the quality of Mozzarella contained details about the DoF but not the package dimensions. Although the WVTR and OTR were given, no temperature or humidity was specified. Thus the results cannot be replicated. A paper published on the effect of MAP on the shelf life of salami contained the package dimensions but no details about the DoF. Although the WVTR and OTR were given, no temperature or humidity was specified. Thus the results cannot be replicated.

A paper on the influence of storage temperature on the shelf life of fresh-cut strawberries stored under high-O₂ atmospheres contained details about the DoF but package dimensions were not given. The OTR and CDTR were given for the PP film at 23°C but not at the temperature of storage (4°C). Thus the results cannot be replicated. A paper on the shelf life of cherries under MAP contained details about the package dimensions but not the DoF. The OTR and CDTR were given at 23°C and WVTR at 38°C for the three films but not at the temperature of storage (0°C). The results cannot be replicated.

In a paper that evaluated the use of a chlorine dioxide release system in combination with MAP to control the growth of *S. Typhimurium* and *L. monocytogenes* on raw chicken breast during refrigerated storage, no package (tray) dimensions or details about the DoF were given. The WVTR, CDTR and OTR of trays and lid-stock were not given, and neither was their construction. Thus the results cannot be replicated. A paper on the control of *S. Typhimurium* in chicken breast by irradiation and MAP (vacuum packaging or high CO₂ + CO) contained no details
about the pouch dimensions or composition but gave the DoF. The OTR of “high barrier” pouches was given at 23°C but not at the temperature of storage (0°C). It was claimed that the pouches were “essentially impermeable to CO₂ and CO” but no CDTR was provided. Thus the results cannot be replicated.

A paper on the effect of CO on colour stability of beef steaks stored at 1°C contained no details about the pouch dimensions or composition or the DoF. The gas barrier properties of the pouches were not given and therefore the results cannot be replicated. A paper on the effects of vacuum packaging and wrapping with an edible film on the shelf life of fish at 4°C contained no package dimensions and no WVTR or OTR of the “impermeable polyethylene bags.” Therefore the results cannot be replicated.

A paper reported the effects of active and MA packaging as well as packaging materials on the quality retention of dark chocolate with hazelnuts. The dimensions of the plastic pouches were not specified, but their OTR at 25°C was. For a given pouch material, the shelf life was independent of the storage atmosphere (N₂ or vacuum). A similar paper from the same authors but focussing on almonds was published in another journal and suffered from the same omissions.

A paper on the effect of packaging on the shelf life of cauliflower stored at low temperature contained no package dimensions. Although the HDPE and LDPE bags were perforated, no details of perforation diameter or WVTR and OTR were given. Therefore the results cannot be replicated.

A paper on the effect of cartons (3 types) and PET bottles on the quality of mandarin juice stored at 4°C for up to 90 days concluded that deterioration was triggered by the rise in O₂ in the headspace of the packages. However, no details about the surface area:volume ratio of the packages or their OTRs were given so study cannot be replicated.

A paper on the effects of packaging materials on the shelf life of shelled walnuts stored in the dark for up to 12 months at 10, 20 and 30°C gave the OTRs of the two pouches. However, no details about the dimensions of the pouches were provided, thus making the results of limited value as study cannot be replicated.

A paper on quality changes in EVOO stored in PET bottles with and without an O₂ scavenger stored in the dark and under diffuse light (details not provided) at 20-22°C for up to 13 months provided no details about the surface area:volume ratio of the PET bottles or their OTRs, thus making the results of limited value as the study cannot be replicated. A paper on quality changes in EVOO stored in PET, PVC and glass bottles at 15, 30 and 40°C under fluorescent light or in the dark for 12 months gave the OTRs of the plastic bottles but provided no details about the surface area:volume ratio of the bottles, thus making the results of limited value as the study cannot be replicated. A recent paper examined changes in the chemical composition and sensory characteristics of EVOO resulting from prolonged storage at different temperatures in various containers. The results showed a gradual loss in quality during storage, and the container types related to this loss followed the order: PET bottles >glass bottles>Tetra-Brik®. Although all container types had the same surface area exposed to light and air, regrettably no details about the three packages were provided, making it impossible to replicate this study.

A paper compared the shelf life of blackberries stored at 3°C and 85% RH for 3 weeks in OPLA and OPS containers with snap-fit lids. Although the WVTR (38°C and 100% RH), OTR and CDTR (23°C and 0% RH) were given, the surface area:volume ratio of the containers was not specified, thus making the results of limited value as the study cannot be replicated.
In a paper in which whole wheat bread was stored at 22°C for up to 5 weeks in LDPE bags “with high O₂ permeability,” enrichment of bread with α-tocopherol resulted in higher degrees of rancid aroma and flavour. However, no details about the dimensions of the bags or their barrier properties were provided, thus making the results of limited value as the study cannot be replicated. A paper on the shelf life of whole wheat bread stored for up to 5 weeks at room temperature (unspecified) provided no details about the dimensions of the bags or their barrier properties, thus making the results of limited value as the study cannot be replicated.

A paper on the effect of light on the quality of juices in PET bottles contained no details on the surface area:volume ratio of the bottles. A bottle rotation system was used to minimize variability in light or UV exposure and temperature but insufficient details were provided to enable replication. Another paper reported the effects of MAP, O₂ absorbers, ethanol emitters and fluorescent light on 150 g of cheese packed in 500 mL plastic pouches with headspaces of 300-350 mL. The DoF and pouch dimensions were not given, and there was no indication of the surface area exposed to light. Therefore it is impossible to replicate this study.

In a further example of the difficulties of accounting for all the variables that affect the shelf life of foods, the effect of the light barrier properties of three different packaging films on the photo-oxidation and shelf life of commercial cookies containing 23.5% fat stored at 40°C under UV-light was reported. However, there were large differences in the OTRs of the three films (the OTR of the best was 25 times that of the poorest) that would have had a significant influence on shelf life, in addition to the effect of the different light transmission properties of the three films which varied by a factor of 12. Therefore, it is not possible to draw any conclusions from their results.

CONCLUSIONS

As this brief review has shown, too many published papers on shelf life contain insufficient details to enable the experiments to be replicated by others. In particular, important details related to package dimensions, surface area:volume ratios and the DoF for MAP are lacking. One of the well-established principles of scientific publishing is that others should be able to reproduce the work. The examples cited indicate that all the major food journals have permitted publication of irreproducible results and seem unaware of the need to include these details. While this is obviously unintentional, it reflects badly on the journals, their editors and reviewers. Although it is unfortunate that so much published research on shelf life is not reproducible, it is also a waste of millions of dollars of research funding and time. In most cases, the missing details could have been easily supplied if requested.

REFERENCES

For both PEF/MF and TP-treated milk an overall shelf stability of 7 days was observed based on total aerobic counts (P >= 0.05). Milk hurdle processing with PEF/MF at its most effective treatment parameters produced greater microbial inactivation and overall similar shelf stability at lower processing temperatures compared to TP. In the present study shelf life and sensory attributes of orange juice were evaluated following treatment with a combination of these technologies (TS/PEF). The juice was exposed to batch TS at 55 °C for 10 min followed by continuous PEF at a field strength of 40 kV/cm for 150 micro-s. High-temperature short-time (HTST) pasteurisation (94 °C for 26 s) was used as a control. The shelf life study can be initiated due to development of a new product, a formulation change or an alternate package evaluation. Identify mode of deterioration. End of shelf life criteria vary for different food commodities. For chilled foods, the end of shelf life is attributed to elevated levels of spoilage microorganisms. Other modes of deterioration may be oxidation of fats for fried snack foods, vitamin degradation for fruit juices, and starch retrogradation or staling for breads. This cookie is set by OneSignal push notifications and is used for storing user preferences in connection with their notification permission status. YSC. This cookie is set by Youtube and is used to track the views of embedded videos. Shelf-life is the period of time over which a food maintains its safety and/or quality under reasonably foreseeable conditions of distribution, storage and use. The shelf-life of a food begins from the time the food is produced and/or packed. It is important that food business operators include as much information as possible in this specification. Ready-to-eat status of food Food business operators should decide if the food is intended for direct human consumption without the need for cooking or other processing effective to eliminate or reduce to an acceptable level, microorganisms of concern. If this is the case, the food is considered as a ready-to eat food. Potential of Light and Temperature Exploitation for Accelerated Shelf Life Studies (ASLT) for Sauces. Emelie Elmlund. The shelf life was estimated by exposing the samples to high temperatures and light during a time period of eight weeks in Climate Chambers (Sanyo Gallenkamp Prime Incubator, INC-000- MA1.9). The light source was a LED lamp that emitted light around 680 to 770 lux and the samples was stored at 22° C, 30° C and 40° C. The samples were then evaluated by sensory analysis and by measuring pigment degradation. The sensory qualities of food is a favoured measurement for overall product quality (Heymann & Lawless, 2010) and sensory attributes is the determining factor for shelf life of foods that is not affected by microbiological spoilage. In general, long-shelf life studies do not fit with the speed requirement. Alternatively, accelerated studies have been applied. In this article, the basic concepts and kinetic reactions are discussed along with accelerated shelf life simulation. Comparison of reaction orders. Frequency of test time between tests at temperature. The overall number of samples that must be stored at each temperature value. will be calculated. Final step is that a kinetic study of the deterioration process at such levels of the accelerating factors is run. However, if the rate of deterioration is too fast or too slow, then the frequency of sampling can be increased or decreased as appropriate.