Atlas Application Guide 101

# Accelerated Shelf-Life Testing

**Guidelines for fast and realistic light stability testing of ingredients, packaging, and products**

## Atlas Material Testing Technology

December 19, 2018

# Accelerated Shelf-Life Testing

## Guidelines for fast and realistic light stability testing of ingredients, packaging, and products

***"There's no simple solution to replacing synthetic colors, but consumers are demanding that they be replaced with natural colors."*** [1]

Testing for potential light exposure problems relating to this issue have been implemented over the past several years at multiple companies and with different types of clients (ingredient suppliers, packaging companies, food and beverage producers). Testing typically involves high acceleration factors up to > 50 vs real time as compared to conventional stability testingl.[2]

### 1. *Introduction*

Colors and flavors have always been some of the most important ingredients of a consumer product. Added colors are used in foods and drinks for many reasons. First, to offset color loss due to exposure to light, air, temperature extremes, moisture and storage conditions. Second, to correct natural variations in color. Finally, to provide color to colorless or "trendy/fun" products.[3]

*Nestlé USA announced plans to remove all artificial flavors and FDA-certified colors from more than 250 products.*

Consumers are very critical regarding product color, because they expect certain foods and drinks to be a specific color. If a product doesn't match the standard they expect, consumers perceive the product either of poor quality or not fresh enough.[4] Consumers also prefer that the color of a drink or food matches and indicates its flavor. The link between color and taste is logical.

Since oranges are orange, we expect orange-colored drinks to be orange-flavored, red drinks should taste like cherries or strawberries, and so on.[5] And, increasingly, consumers demand that these colors and flavors be natural and not synthetic chemicals. However, many of these natural products have poor light resistance and result in off-color, off-taste or loss of the nutrient profile.

Globally, consumers buy products mainly with their eyes, transparent packaging is todays preferred choice. Wherever there is light however, there is a risk for photo-induced reactions which can sometimes very quickly impact colors, vitamins, flavors, odor or general product appearance such as turbidity or precipitates.[6] Although the list of light-sensitive ingredients for consumer products is long, and light protection characteristics of packaging may be known, it is still a challenge to find the best accelerated shelf-life test (ASLT) for a specific packaged product.[7] Another driver for new products is based on the growing health orientation of consumers. More and more people have easy access to information via the internet and follow the trend of avoiding artificial ingredients.

Natural dyes have been used for centuries to color food or drinks. However, natural colors tend to be less light stable, and product development times can be impacted to find sufficient stabilization of the new formulas. Many manufacturers are already preparing for, or currently pursuing their transition away from artificial colors and flavors towards natural alternatives.

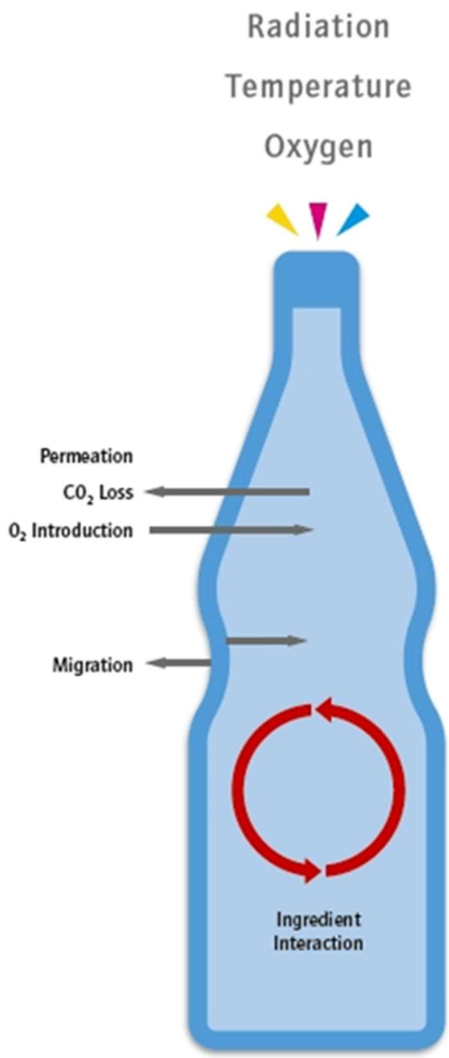
As is obvious, the fast-moving consumer goods industry is an extremely tough time-sensitive business to market environment. With a time pressure for innovations where upwards of new 100 product developments per year are common, highly accelerated test procedures are required in order to meet the time to market goals and stay ahead of competition.

Manufacturers need answers to three major questions:

1. ***How can I develop stable product recipes in shortest time?***
2. ***How can I select right and most economic and protective packaging?***
3. ***How can I reliably test product shelf-life in the shortest time?***

## 2. Stress Factors

The major stress factors for package contents are primarily "light" radiation, oxygen and heat (temperature).[8,9] Further, the interaction of the ingredients (e.g. sensitizers such as riboflavin) and the potential migration processes are dependent on packaging characteristics to "keep the good in and the bad out."




The light radiation to which a product can be exposed in its lifecycle can basically appear in three different forms and amounts of energy. The first of these exposures is from direct natural sunlight. The second is window or skylight filtered daylight which removes the lowest wavelengths of ultraviolet energy. The third is purely artificial lighting which contains primarily only visible light.

In the lighting industry, illuminance is often measured in units of Lux. This applies only to the light visible to and skewed to the response of the human eye. For example, common supermarket and "big box" retail typically targets 750 - 800 Lux for store illumination. However, we can convert Lux units to a more appropriate unit of "irradiance" as used in scientific work.

Here, in the table below, energy is measured in radiometric terms of $W/m^2$ between 300 - 800 nm over the ultraviolet (UV), visible light and near-infrared range. Note that actual product temperatures have been measured with thermocouples.

1. Natural sunlight:

Irradiance: 200-550 W/m²
Product temp.*: 30-35°C

2. Indoor sunlight (window filtered):

Irradiance: 20-100 W/m²
Product temp.*: 20-25°C

3. Supermarket light (artificial):

Irradiance: 20-100 W/m²
Product temp.: 20-25°C

** Measured in 0.75 liter clear PET bottles. Interestingly, the rise in temperature and final product temperature is mostly independent of color for measured bottled soft-drinks.[5]*

*Test bottles with uncolored and dark colored soft-drink. Temperature sensors installed and sealed.*

## 3. Guidelines for Package Contents Screening

Atlas suggests to screen potentially light-sensitive ingredients (colors or flavors) or new product formulas under realistic “worst-case“ conditions. A realistic worst-case scenario is a high level of direct solar radiation, high temperatures (and presence of oxygen) – as typical of a hot summer day.

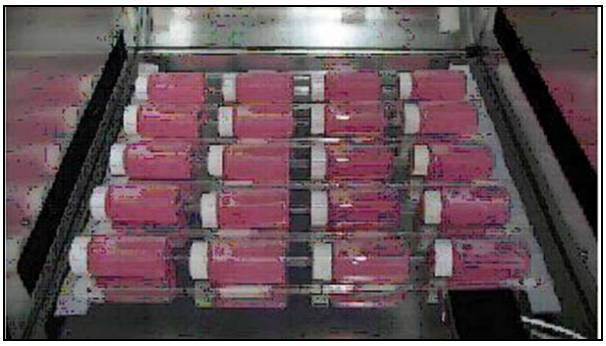
These conditions are present outdoors and could occur, for example, during short product transport and loading/unloading, open-air street sales, or even outdoor consumption. The Atlas guideline below reflects this worst-case condition with the following test setup:

**Simulation of outdoor hot summer days:**

Atlas xenon lamp chamber with Daylight filter
Irradiance level @ 300 - 800 nm: 550 W/m²
BST: 35 - 55 °C → resulting product temperature 20 - 35 °C
Test Duration: 12 h

A test duration of 12 hours simulates approximately 5 days of outdoor direct sun exposure. Atlas' experience is that light-sensitive products frequently show change after 5-10 hours.


*Test conditions for simulation of hot summer outdoor daylight exposure in SUNTEST XLS+*



*New product formula screening inside SUNTEST*

## *4. Guidelines for Packaging Screening*

Atlas suggests to screen packaging under realistic “worst-case“ conditions – a hot summer day outdoors.

The above conditions are present outdoors and could happen for example during long-distance product transport or extended outdoor point-of-sale The Atlas guidelines reflects this worst-case condition with the following test setup:

**Simulation of hot summer outdoor days (extended duration):**

Atlas xenon chamber with Daylight filter

Irradiance level @ 300-800 nm: 550 W/m²

BST: 35-55 °C ➔ resulting product temperature 20-35 °C

Test Duration: 24 h

A test duration of 24 hours simulates approximately 10 days of direct sunlight outdoor exposure.


*Test conditions for simulation of extended hot summer daylight exposure in SUNTEST XXL+FD*

*Results of a glass and PET bottle screening test under worst case conditions.*

## 5. *Guidelines for ASLT of Indoor Exposure*

Atlas suggests to perform ASLT tests under realistic light and temperature conditions. Particularly with ASLT, it is important not to increase the product test temperatures beyond real life in a supermarket or similar retail location. Some colorants, such as anthocyanin dyes, can degrade and fade without the presence of light, simply due to thermal stress at 30° or 40 °C. The Atlas test setup avoids higher temperatures than normal and achieves test acceleration purely through applied light radiation energy. Atlas has developed a unique "store light" optical filter system to better reproduce the spectrum of common retail artificial lighting.

**Simulation of a typical supermarket day (24 hour operation):**

Atlas xenon lamp chamber with Store Light filter

Irradiance level @ 300-800 nm: 470 W/m²

BST: 35-55 °C → resulting product temperature 20-35 °C

Test Duration: 0.5 h

Test duration of 0.5 hours simulates approximately 1 day shelf-life in a supermarket. One year supermarket shelf-life can be tested in 7 days.


*Test conditions for simulation of artificially illuminated retail conditions*

In actual practice, architectural lighting engineering illuminance guidelines are used for determining the light exposure dose and test time.

Along with the duty-cycle of store lighting, such as on for 24-hours/day, and the target shelf life value, but the above guidelines are useful for estimating testing requirements.

As the combination of artificial and glass or plastic (e.g. skylight) filtered daylight can be complex, please contact Atlas for test recommendations.

**Three good reasons why to integrate accelerated stability testing into new product development:**

1) Reliably screen for the right ingredients and formulations in the shortest time
2) Confidently select the best packaging and product protection
3) Safely determine product shelf-life, often within 5-7 days

## 6. *Literature*


1) Jennifer Guild, global food science and regulatory manager at DD Williamson at Advances in Natural Colour, Food Ingredients Conference (London 2012)
2) Marco Schmidt, Gerhard Hübner, Joachim Tretzel, AFG Wirtschaft 4, 2002.
3) International Food Information Council (IFIC) and U.S. Food and Drug Administration, Overview of Food Ingredients, Additives & Colors, November 2004; revised April 2010
4) Teoh A.: „Predicting the stability of natural colours in food products, A review", AgroFOOD Industry high-tech, September/October 2010, Vol. 21 (5), 20-23.
5) Brian Rohrig, Eating with your eyes, ChemMatters, Oct/Nov 2015.
6) Oliver Rahäuser, Artur Schönlein, beschleunigte Photostabilitätsprüfungen von Konsumgütern in transparenten Kunststoffverpackungen, 40. Jahrestagung GUS, 2011, S.325.
7) Oliver Rahäuser, Artur Schönlein, accelerated photostability testing, PPCJ, September 2010.
8) Marco Schmidt, Gerhard Hübner, Joachim Tretzel, LVT Lebensmittel Industrie 7/8, 2002.
9) Daniel Connor, "The Harmful Effects of UV Light Exposure" Milliken Chemical. 2004.



Author: Dr. Oliver D. Rahäuser, Atlas Material Testing Technology GmbH.



Original version: September 12, 2017. Rev. 1: December 19, 2018.


---


**Atlas Material Testing Technology** |1500 Bishop Court | Mount Prospect, Illinois 60056, USA
www.atlas-mts.com