A Look at Accelerated Photostability Testing for Packaged Food and Drinks

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The authors discuss the effects of light and temperature on packaged food and drinks and the tests undertaken to establish correct requirements.

Today's world of packaged food and drinks is different than previous eras. Modern recipes are often more complex. With an increase in the number of available ingredients and the strong differentiation in target groups, product variety has grown considerably in recent years. Today's products are considered as multi-component systems from a laboratory point of view. In addition, food and beverage producers favor transparent plastic packaging more than ever for a lightweight, visually attractive, and low-cost presentation of their contents to the consumer. But the transparency of plastic packaging also has disadvantages; as considerable amounts of light penetrate the packaging, there is a demand for suitable light protection.

This applies both for the product formulation and the packaging itself. Stability tests under the effects of light and temperature must not be neglected in favor of product marketing, user friendliness, or appearance. The risks of undesirable chemical interactions have risen due to an increase in formulations that are now technologically possible. UV light and various ingredients in drinks can lead to extremely complex interactions which often have a negative effect on elementary properties essential to the brand [1]. (See Figure 1 for examples of exposures.) Where traditional methods for determining "best before" dates are too slow or inaccurate, faster methods are required. Until now, there have been no national or international standards for the accelerated photostability testing of food and beverages. What do exist are independently developed internal tests by individual members of the process chain, mainly the color and flavor manufacturers and compounders.

Photostability and Test Requirements

Many factors must be considered for photostability testing in the laboratory in order to handle the increased chemical and physical complexity and to test as realistically as possible. The discoloration risks to which recipes are exposed by interaction with sunlight are a primary concern.

Oxygen that gets into the product by permeation through the plastic material or through a seal can very easily be transformed into singlet oxygen by excitation and very quickly oxidize ingredients that are sensitive to oxidation. Partial or complete discoloration is possible, or even the loss of vitamins such as vitamin C. Citric acids and trace metals can lead to destabilization of the product color under exposure to UV light. While vitamin B12 by itself is relatively stable, it decomposes in contact with vitamin C and UV light [1].

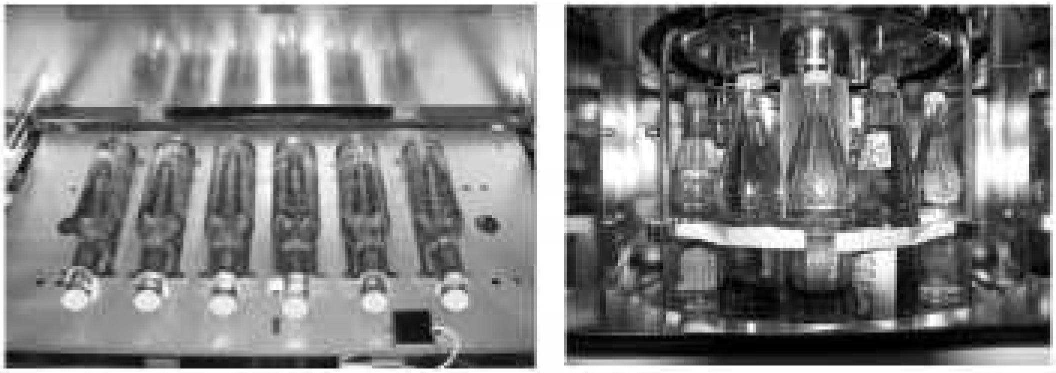


Figure 1: Xenon technology performs accelerated photostability tests under realistic conditions. Test chamber options include a flat bed (left, SUNTEST XXL+) and a carousel (right, Xenotest Beta+)

The decomposition of fruit flavor was observed in drinks filled into PET bottles [2]. In addition to oxygen permeation into the product, the permeation speed of carbon dioxide—for example, in the case of beer and non-alcoholic beverages—must also be examined. A reliable statement finally has to be made on whether the product is suitable for the intended container or whether greater packaging protection is required.

The actual temperatures that occur in the process chain also have to be considered among the stress factors. Real temperatures are largely responsible for the speed of the chemical decomposition reactions as a product moves from the manufacturer or producer to the shelf via various distribution routes, and finally to the consumer.

Packaging Materials

The plastics most frequently used for food and beverages are the thermoplastics polyethylene (HDPE), polypropylene (PP), and polyethylenterephthalate (PET). These are used to produce packaging and different bottle types by extrusion, blow molding, or injection molding processes. PET bottles are produced in different wall thicknesses, whereby types with very thin walls allow relatively strong oxygen permeation. However, processes now exist from which special barrier properties can be achieved—a cost factor that must be carefully weighed.

The individual spectral transmission property of materials in the wavelength range between 290 nm and 600 nm is important. PET is permeable for UVA radiation, for example. The same applies for transparent PE and PP foils or bottles.

The types of plastic listed above age under the influence of light and temperature depending on the type and degree of incorporation of light protectors and their sensitivity to radiation. The result is a change in the physical properties that can have a negative influence on the protective properties of the packaging. Equally important is the migration of connections from the packaging into the product and from the product into the packaging. Even if a packaging material does not exceed the permissible limits for pollutants when it is new, harmful migratable decomposition products may evolve in the course of photo-oxidative aging.

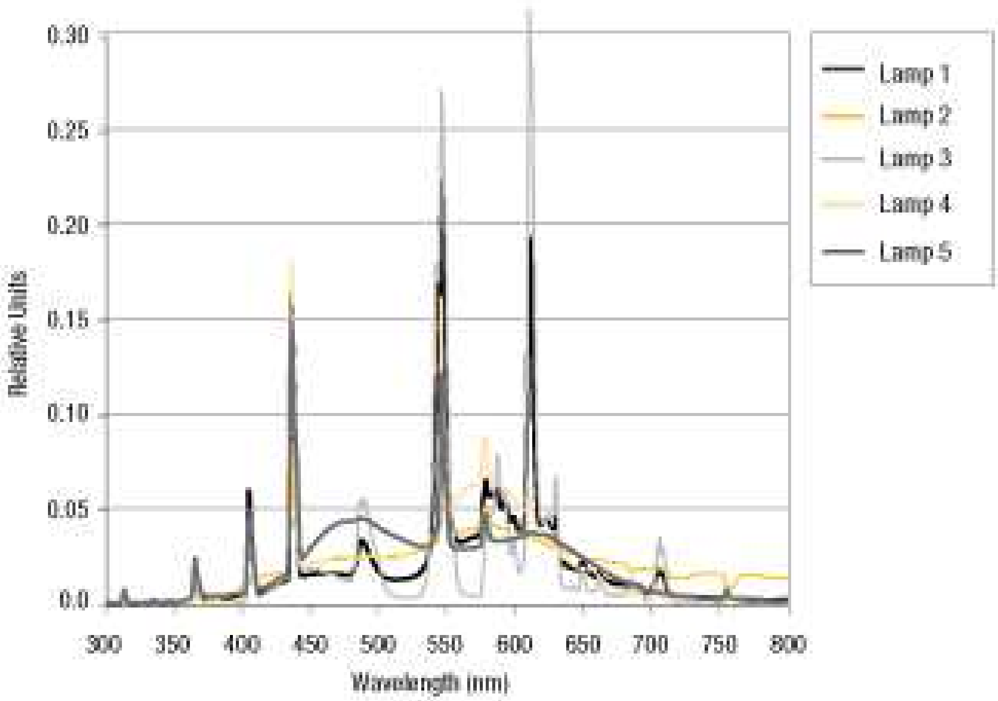
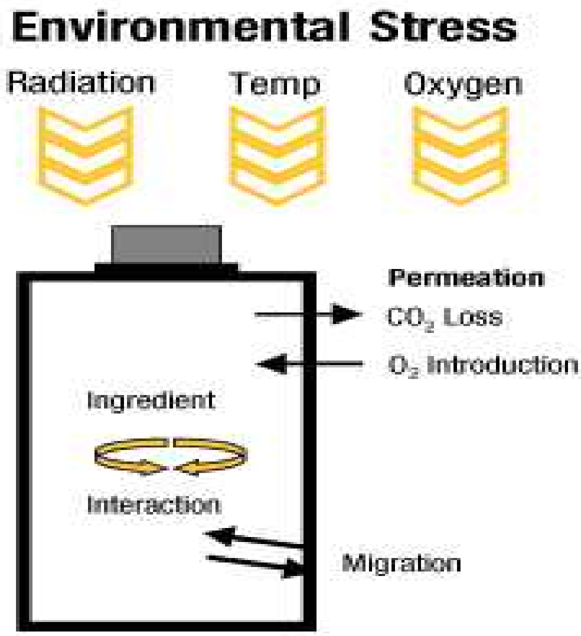


Figure 2: Typical spectra of fluorescent lamps which can affect products in the process chain in production, storage, and processing

Ambient Influences (Stress Factors)

The most important stress parameters in the food industry are radiation, oxygen, and temperature [1, 2]. At right is a closer look at the individual stress parameters in respect to their real effects in the process chain.



Stress Factor Radiation

The most important stress factor in the photochemically initiated change is the relevant radiation to which food or beverages are exposed. The entire process chain must be considered: production (processing) » storage » transport » storage » processing (consumption). The parts of the process chain that warrant special attention will certainly depend on the specific product and the protective measures used against the effects of radiation.

Conventional fluorescent lamps are normally used in production, storage, and processing (see Figure 2 for spectra). These lamps have a mercury low-pressure discharge (characteristic lines) with special coatings on the inside of the tubes. The irradiances in the wavelength range of 300 nm–800 nm at the location of the object depend on the distance between the object and the light source and are about 2–20 W/m². 100 W/m² may also be reached very close to the lamp. No relevant radiation occurs below 350 nm. The large number of spectra can be simulated fairly well by filtered xenon radiation, which blocks radiation below 360 nm (see Figure 3). The power of the xenon lamp must be reduced so that low irradiances can be achieved as well as possible, which is often possible only with additional neutral filters.

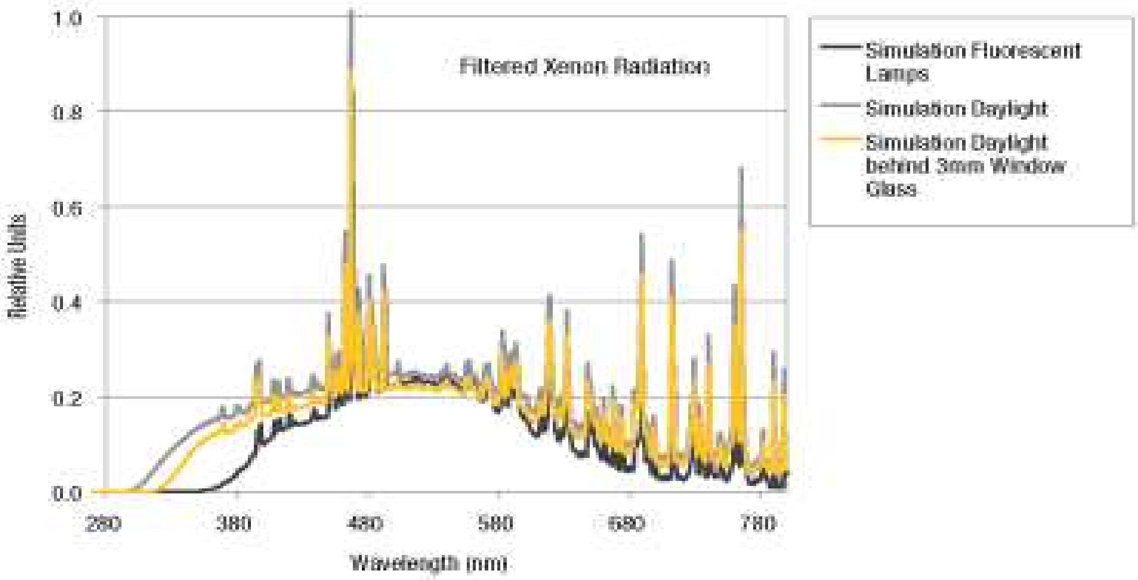


Figure 3: Filtered xenon radiation for simulation of different light sources in the process chain

Food and beverage products may also be exposed to direct sunlight or sunlight behind window glass during transport and storage (see Figure 4 for spectra). For example, products are often stored outdoors in a yard, transported on an open truck, or stored in a room with windows or a skylight. In this case, the irradiance in the wavelength range from 300 nm–800 nm will vary between approximately 200 W/m² and 550 W/m². The maximum value is usually used in the radiation simulation. These solar spectra are best simulated with filtered xenon radiation as shown in Figure 4.

Fluorescent lamps (also known as low energy lamps), halogen lamps, and normal filament bulbs may play a role in processing before consumption, whereby the color temperature for

the latter two types may fall approximately between 2000K and 3000K. The irradiances at the location of the object will also vary between 2 and 20 W/m² in these cases. The simulation can also be made with filtered xenon radiation (Simulation Fluorescent Lamps in Figure 3).

Stress Factor Temperature

The second factor for the photostability test is temperature. The speed of chemical reactions can be described by the Arrhenius equation: generally, the higher the temperature, the faster the chemical reaction. To what extent process temperatures need to be considered in manufacturing for realistic testing will have to be decided by the manufacturer depending on the product.

In most cases, cold aseptic filling has been implemented in Europe. Realistic temperatures in storage and processing are usually below 22°C, and during transport above 22°C. Where solar radiation is effective, temperatures quickly rise above 22°C because visible and infrared radiation can be absorbed by the product. In these cases, the product temperature will be well above the ambient temperature, perhaps as high as 30–35°C. Therefore, the temperatures to be assumed in realistic conditions will have to be examined in careful tests.

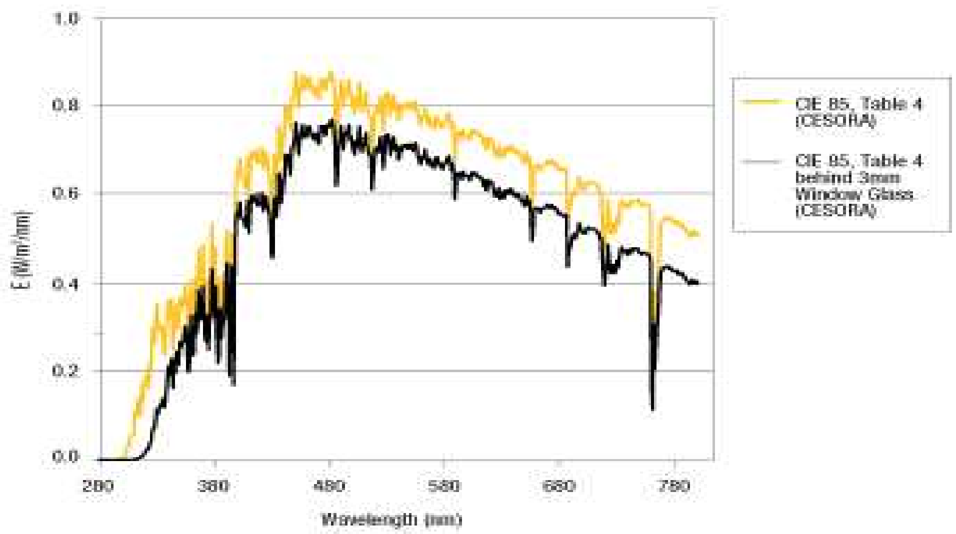


Figure 4: Solar spectrum according to CIE No. 85, Table 4 [3] calculated with CESORA [4]

Test Method

The test method depends on the stress factors that need to be considered (see Table 1 for a summary). The question of whether the entire process chain or only parts of it are to be simulated must also be answered. If the entire process chain appears to be relevant, an already standardized test procedure could be applied, for example ISO 4892-2 [5]. However, the test temperatures, air, and black standard temperature will probably need to be adapted. The usual wet/dry cycles that simulate the effects of rain and humidity can be omitted. The choice of instrument technology, flat bed or rotating rack, is determined by user demand for accuracy and the specimen geometry.

If the influence of solar radiation is ruled out during storage and outdoor transport, the filtered xenon radiation shown in Figure 3 could be used to simulate fluorescent tubes as a light source ("Store Light" conditions). The air temperature should then be selected so that the product temperatures are not above 30°C, and the relative humidity should be controlled constantly.

Quick tests with good results in the Atlas SUNTEST (flat bed technique) have been implemented recently with similar test setups—partly, as desired, with very high acceleration factors of >50 in comparison with the real time test [6]. The importance of the tests is uncontested and it will be exciting to watch how other test methods develop to ultimately confirm the large variety of food and beverages and their appropriate packaging with regard to photostability.

Process Chain	Production, Storage, Processing	Transport, Storage
Spectra	Fluorescent lamps Halogen lamps Filament bulbs	Solar spectrum directly and behind window glass
UV Limiting	Blocking below 360 nm	Blocking below 295 nm and below 310 nm
Simulation radiation	Filtered xenon radiation, neutral filter	Filtered xenon radiation
E (300–800 nm) in W/m²	20–100 nm	200–550 nm
Product Temperature in °C	20–25°C	30–35°C*
Relative Humidity in %	20–50%	20–50%

**Realistic product temperature must still be examined carefully*

Table 1. Requirements for a realistic test method for testing the photostability of packed food and drinks

References
[1] Plastverabeiter (55) Nr. 5, Jahrgang 2004
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