The Effects of Lighting on Product Integrity

and what can be done about it

Lighting is something that surrounds us everywhere and is often taken for granted. There are many types of lighting and strategies for its use that can be employed. Some types and uses can have many more advantages in a supermarket than others. Lighting, for instance, is a key element in product merchandising, yet merchandisers seldom are involved in choosing what lighting they use.

Lights are used in every department of a supermarket to attract shoppers and draw attention to their products. Lights are in display case canopies, on the shelves, between doors and elsewhere to illuminate everything from packaged goods, produce, cuts of meat, bottles or cans of beer, to cheese, milk and every other kind of dairy product. Just about anything in a store has some lighting trained on it.

As a result, much of the lighting in supermarkets can be described as indiscriminate. Overhead fluorescents and increasingly used skylights provide overall lighting to the store. While these can work well as a source of ambient lighting they are generally pretty poor at lighting specific merchandise. Closer to the merchandise, key lights (spots) are often aimed at products from tracks over their displays. Closest of all, case lighting is used to light display products inside the merchandisers.

But the dark side of lighting, so to speak, is the detrimental consequences it can have on product integrity. Lighting used without consideration of its effects can actually harm products. Very few lighting designers and merchandisers are aware of what these consequences can be.

The good news, however, is that there is a growing body of research pointing to solutions to these problems. Although this information has been slow to

penetrate the market, it is starting to get out. Some merchandisers and refrigeration companies are beginning to take it into consideration when deciding how to use light to enhance, and not harm, their products.

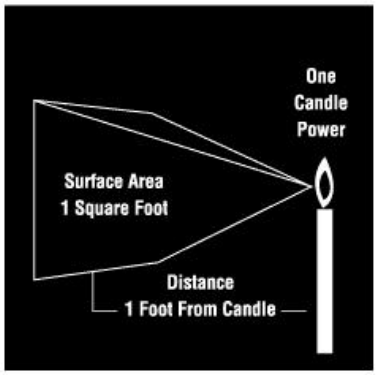
Perhaps the best way to understand how lighting can interact with product integrity – both good and bad – is, without getting to technical, to have some idea of the properties of light and how the current state of lighting used in supermarkets has come to be. From there it is also useful to know what actual harm lighting can cause to different types of food products. And finally, what are some specific steps supermarkets can take to mitigate the less than beneficial effects of lighting.

Light and its properties

Most people know that light is a form of energy that makes it possible for us to see the world around us. But as far as other characteristics of light beyond brightness and color, many of us don't know much more than that.

Since light is a form of energy, one particular aspect of how it is generated does make sense: the higher the *wattage*, the brighter the light (for any two of the same types of light). Watts are a measure of the amount of power that is generated or consumed when energy is used such as in a light blub. The more electricity used by a bulb (as expressed in watts), usually the more light the blub produces when compared to similar types of bulbs. The introduction of LED lights (see below), however, has changed this relationship opening up the gap between watts and output.

Whereas watts are used to describe the relative intensity of a light, *lumens* on the other hand, indicate a light's actual brightness. Lumens (lm) are the amount of visible light emitted by a source as measured at the source. Another common measure of brightness is *footcandles*. One footcandle is the amount of light that would be seen with a candle burning one foot away in a square foot of area.



Other characteristics of light have to do with its color. A traditional fluorescent bulb is usually not very good in bringing out vibrant colors. An incandescent bulb, on the other hand, often does very well on some colors but then not as good with blue colors. Two factors are involved here, *spectra* and *color*

temperature. Spectra refers to an area along the band of color called the spectrum. Think of a rainbow and the range of colors it has from red on one side, through orange, yellow, green, and blue to violet on the other side. These differences in color are the result of the different wavelengths of light (sunlight in the case of a rainbow) passing through a refractive substance (moisture in the atmosphere, again in the case of a rainbow) that cause the wavelengths to become visibly distinct. When either the filament of an incandescent bulb, or the gas in a fluorescent one, gives off light the color of that light will appear warmer or cooler depending on the range, or spectra of light it produces. This effect is due to the filament or gas's chemical properties.

The concept of color temperature is another way to distinguish between different types of light sources. The definition of color temperature has to do with actual temperature of something called a black-body that when heated to a certain point radiates a comparable amount of light as a particular light source. In practical terms, color temperature serves as a numerical way to characterize a light from warm to cool. Color temperature is stated in degrees Kelvin (K). Lights in the range of from 2,700 to 3,000 K are considered warm (yellow to a yellowish-white hue) and those with higher numbers are called cool (white going to a bluish white in higher kelvin temperatures).

One final characteristic of light to consider is its *intensity* (I). That is, the rate at which it spreads over a given area at a particular distance from its source. It varies by the distance from, and the power of its source. Think of sunlight on a hot day. At midday, when the sun is shinning directly, it's more intense than later or earlier in the day when it's at more of an angle. The same applies to artificial lighting. The closer a light is the more intense it is upon an object's lighting.

Lighting designers use some or all of these factors in determining how and what lights to use.

Types of Lighting

The three types of lights that are commonly all used in supermarkets are incandescent, fluorescent, and LED (Light-Emitting Diode). Of these, the use of *LEDs* has been increasing the most since their introduction over the past decade. This is due to their higher efficiency and other advantages compared to other types of lighting. Unlike the other types of lights, LEDs work on a principle called

electroluminescence. Instead of relying on heat (as with incandescent lights), or a chemical reaction (as with fluorescent lights), LEDs produce light through the action of electrons flowing through a semiconductor. Minute holes in the semiconductor allow the release of energy in the form of light as electrons flow through the holes.

Unlike some other types of lighting, LEDs do not emit harmful UV rays. They also require less energy to operate and their life expectancy is approximately 72 percent greater than traditional fluorescents when used in refrigerated environments. Over the lifetime of their use, LEDs result in less environmentally harmful waste since they do not contain any mercury, phosphors, or lead which is used in fluorescents. LEDs are also much less fragile then other types of lights. They do not require any protective sheathing. The potential for product loss from bulb breakage in a display case is greatly reduced, if not entirely eliminated.

LEDs provide maintenance savings and enhanced color compared to most fluorescents. Since their lumen quality (light level produced) does not deteriorate as rapidly over time as fluorescents do, they do not need to be replaced nearly as often (especially in refrigerated cases). They can also be used with motion detectors or other lighting controls to reduce energy consumption based on either customer traffic or store hours. LEDs perform better in cold environments, there is no "warm-up" time or flickering when they are turned off and on. Fluorescents, for example, lose 33% of their light output when installed in a 41 degree environment whereas LED's could have a 6% gain in output. In one example, where the annual bulb replacement costs for fluorescents was $4.47 per bulb, the retailer's return on investment was 11 months when switching over to LEDs. Their annual energy savings on a 60-foot lineup worked out to be $1,827.[1]

Over the past few years, LEDs have risen in efficiency by approximately 50%.[2] Compared to CFLs, LEDs only use about half as much energy: 329 kWh per year for LEDs, versus 767 kWh per year for CFLs (6-8 watt LED vs. 13-15 watt CFL). With incandescent bulbs, there is literally no comparison. A 60-watt bulb that

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[1] From Clearvoyant material 2009, /Users/williamk/Dropbox/WstrnRgnl/Case/Nu Prod

[2] LED Lighting Efficiency Jumps Roughly 50% Since 2012, CleanTechnica, Silvio Marcacci, November 2014, cleantechnica.com/2014/11/05/led-lighting-efficiency-jumps-roughly-50-since-2012/

produces an equivalent amount of light to a 6 to 8 watt LED uses more than 3200 kWh per year.[3]

As the efficiency of LEDs has risen, so has their use. More and more manufacturers are providing them and more supermarkets are switching to them. LEDs used in display case applications, typically take the place of fluorescent bulbs (usually T-8s) in shelf lighting for open deck cases and doorframe lighting for door cases. Beyond case lighting, LEDs are also finding their way into overhead and accent lighting.

Harmful Effects of Lighting

With the possible exception of outdoor farmers markets, there isn't any kind of food retailing that doesn't rely on lighting to some extent. The problem with this state of affairs is that since LED's are very efficient, many people want to use more light on the products since they are saving energy. But too much of anything can usually have can adverse effects; lighting is not exception.

Writing for the National Pork Board, Dr. Don Kropf put the problem in plain terms: "Lighting can speed up product discoloration but is essential for marketing and presentation of pork."[4] As far back as 1954, Kropf notes, Kraft and Ayres "observed a steady change in color of fresh beef from bright red to dull red during two days exposure of fresh beef to 30 to 40 footcandles of fluorescent light."

According to some estimates, U.S. retailers loose at least $1 billion annually from fresh beef sales due to discoloration.[5] But it's not just pork and beef, although photodegradation of these products can be particularly pronounced. Seafood, dairy, charcuterie and even beer are all subject to the problem. While most of the trouble lighting causes for products would at first glance seem to be due to the lights closest to the product, studies have shown that even the general overhead lighting in stores can also be a problem. In one study, for instance, the infrared radiation (IR) from

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[3] Comparison Chart LED Lights vs. Incandescent Light Bulbs vs. CFLs, designrecycleinc.com/led%20comp%20chart.html

[4] Meat Display Lighting, Dr. Don Kropf, Kansas State University, National Pork Board, 2002.

[5] Warning: Lighting May Be Hazardous to Your Food, mgvinc.com/ images/VisualStore.pdf

fluorescent overhead lights reached high enough levels to raise temperatures, causing seafood to dry out and foster the growth of bacteria.[6]

Even though the extent of the problem should at this point be clear, it is also worth noting that as more and more retailers move to offer more natural (without preservatives) and prepared foods, the potential risks only get worse. So the question then is, what exactly are the ways that photodegradation causes problems in food? In order to answer this question, it's useful to know what the food components are that light effects.

Six main components of foods are subject to deterioration from exposure to light – Fats, proteins, nutrients (vitamins), nitrites, chlorophylls and myoglobins. Fats occur in both plant and animal-derived foods and are necessary components of healthy diets. In animals, as well as people, fats form as a means of storing energy. Fresh meats exposed to oxygen typically have an attractive red color. When exposed to light in the ultraviolet (UV) wavelengths for prolonged periods, however, the fats in those meats become rancid.[7] While not a health issue per se, a perceived loss of quality from deteriorating color, odor and taste does constitute a serious threat to a product's marketability. Processed or cured meats, such as luncheon and deli items like ham, are affected more rapidly. The nitrites found in these products give them their characteristic pink color, but when exposed to light, they combine with oxygen to produce a brownish-grey color. Like the change to fats in fresh meats caused by light, this deterioration of quality in processed meats will also impact a retailer's sales.

Meat isn't the only product in which the potential affects of light on fats are a concern. Studies have shown that certain UV wavelengths can also cause milk fats to oxidize. Dairy products turn rancid when the milk fats in them oxidize.[8] As trends continue towards fresh and natural products, this effect can worsen by package style and lack of preservatives. For instance, the clear glass bottles used in dairy will oxidize quicker than that of those that block visible light.

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[6] Ibid

[7] Foodsafetysite.com | Describe the different ways that food spoils. http://www.foodsafetysite.com/educators/competencies/general/microbiology/mic6.html

[8] Warning: Lighting May Be Hazardous to Your Food

Proteins, like fats, are likewise required for proper health and can be obtained from both animal and (some) plant sources. With respect to dairy products such as cheese, proteins in them have also been found to oxidize with exposure to light.[9] As with fats, the consequences of photodegradation on proteins are anything but beneficial; their taste and appearance are affected. This problem is most pronounced on soft cheeses.

Vitamins are present in fruits and vegetables as well as meat and fish. Certain ones, such as vitamins A, C and E along with thiamine and riboflavin have been shown to be particularly sensitive to light.[10] In one study, for instance, exposure to daylight resulted in up to 80% loss of vitamin A in a nutrient mixture.[11]

Chlorophylls and myoglobin in foods are generally associated with color; chlorophylls in green fruits and vegetables and myoglobin, which is a particular type of protein, in meats. These compounds are largely responsible for giving those foods their characteristic colors. When they dissipate, as a result of photodegradation, the foods that contain chlorophylls and myoglobin turn to less desirable colors such as various shades of browns and greys.

While these effects are familiar to most people as general consequences of food spoilage (as opposed to specific results of photodegradation), another less known outcome of exposure to light is on beer. Sometimes called "sunstruck," too much light can cause certain constituents of the hops that are used to make beer, produce sulfur-containing amino acids that diminish the beer's flavor and aroma.[12] Most beers are packaged in brown or green bottles in order deter that effect and some companies are packing more in aluminum cans to block light entirely.

Given the challenge that light poses to successfully marketing food, the question is, what can retailers do to lessen the negative effects of light on the food they sell?

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[9] Light-induced protein and lipid oxidation in cheese: Dependence on fat content and packaging conditions, Trine Kastrup Dalsgaard, et al., April 2010, dairy-journal.org

[10] The effect of light on the vitamin C of milk in different containers, J. Huston, et al., June 2009, journals.cambridge.org

[11] The photodegradation of vitamins A and E in parenteral nutrition mixtures during infusion, MC Allwood & HJ Martin, September 2000, Clinical Nutrition

[12] Foodsafety.com

Mitigating Lights' Harmful Effects on Product Integrity

Two approaches to reducing the harmful effect of light on products are available to retailers. One has to do with the way products are packaged and the other with the lighting itself.

Packaging – The optical properties of packaging materials, and the chemical makeup of the air they contain, can significantly affect the impact of light on the integrity of the product within the packaging. As already pointed out, photodegradation of many types of products accelerates in the presence of oxygen. For instance, cured meats turn brown and red meats become rancid with prolonged exposure. Using solid light blocking packaging can prevent these adverse effects. But, since shoppers are not used to purchasing fresh meat or even cured or processed meats that they can't see, this particular solution isn't practical. Another possible solution, instead of keeping light from reaching and interacting with oxygen inside of a package, is to adjust oxygen levels in the package. Deoxygenating, or Modified Atmosphere Packaging (MAP), replaces the air inside of a package with a protective mixture of gas that can prolong the shelf life of fresh or minimally processed foods.[13] MAP still allows the use of a transparent packaging material but reduces the amount of oxygen inside the package to a level where photodegradation is significantly reduced.

One other type of packaging that can mitigate the harmful effects of light and prolong product shelf life is filtered packaging. An example of this approach is a type of material that filters out particularly harmful UV wavelengths. UV light, as previously mentioned, is especially harmful to the fats in meats and dairy products. UV filtration can be added to the polymers used in certain types of packaging where it has been shown to be effective. Concerns, however, for its own health effects have been raised so it may not be the best solution.[14] Also, products that are affected by certain bands of light waves not in the ultraviolet range would still not be protected.

Lighting – The most straightforward solution to dealing with the problems lighting causes products is to make changes to the lighting itself. Two basic

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[13] dansensor.com/solutions/modified-atmosphere-packaging-food-and-beverage-industry

[14] foodpackagingforum.org/food-packaging-health/uv-filters-in-food-packaging

approaches that are available are to reduce the intensity of the lighting and to choose different types of lighting than are commonly used.

There are different ways to reduce lighting intensity and sometimes it can even be done in a way that gives off the appearance of more light. Reducing glare, and using the correct light sources and placement where they can provide good light on the product being illuminated, for instance can accomplish this. One way to reduce the light intensity that falls upon product is to reduce that of the lighting around display cases. Lighting designers sometimes point stores toward creating bright, highly lit spaces on the theory that shoppers will be drawn into and through them. The problem with going this route, however, is that the brighter the surrounding areas are, the brighter the product displays will need to be draw shoppers' attention since there will be a lack of contrast. As pointed out, the higher the intensity of the light hitting the product, the bigger the problems there are for the product. A solution is to lower the overall intensity of the lighting around display cases and to control the light properly on the product inside the display case. This doesn't mean to reduce department lighting to the point where it seems dark, only to lower it enough to where greater intensity isn't needed on the product. Although this seems like a simple approach there are many variables that come into the equation such as considering all light sources, product shapes and sizes, case styles, packaging, for instance.

Skylights are increasingly being used for general overhead lighting during the day for either energy savings or energy mandates. While skylights can provide energy savings and natural light, they can also pose some merchandising problems. Skylights are usually in noticeable locations and human nature draws the eyes towards brighter light sources, and in this case, away from the merchandise and up to the ceiling. Whether a customer is looking at the skylight or not, their eye is adjusting to it because it is a bright light source. To get a sense of how much this can affect merchandise, one need only try looking at their favorite store that has skylights at 2:00 pm on sunny day and then go back and see it later that evening. In most cases, it will feel very different due to the different light sources in play.

A Case Study

The overall effectiveness of various types of lights in reducing effects on product integrity can be seen in the results of a study conducted by Hillphoenix. In

the study, packages of Prosciutto – a cured deli meat, were subjected to three different types of lights at a variety of distances. The lights tested for their effects on the product included: two types of LEDs and one type of fluorescent; all of which are available for display case lighting applications. Along with varying the distances at which the different types of lights were tested, the effect of the lights was also compared on product in both MAP and non-MAP, transparent packaging.

The major results of the study were that MAP definitely makes a difference regardless of the type of lighting. There was little difference in altering the wavelengths of light versus adjusting the light intensity when the MAP packaging wasn't present. In all lights tested, there was photodegradation observed with the prosciutto in one hour when light levels exceeded 45 footcandles if oxygen was present. There was not, however, a noticeable visual difference to the prosciutto in the modified atmosphere packaging even at 600 footcandles. In comparing the effects of the different types of lights, the fluorescent light used in the study produced approximately a third less light than a comparable LED. Of the LEDs tested, one variety was specifically designed with different wavelength spectrums chosen for product integrity in meat. Even with the different spectrum discoloration showed when the product had oxygen exposure and higher light levels.

As illustrated in this study, it was evident that packaging made a significant difference for the integrity of the products exposed to light. These results, in combination with the increasing knowledge of how lighting affects products, shows convincingly just how seriously lighting has to be taken. The fact is that for many supermarkets, what has at best only been a general appreciation for how lighting can benefit their merchandising efforts, and at worst an afterthought if thought of at all, is actually a critical area of concern that can have major consequences for their operations and profitability. The importance of working with knowledgeable experts and manufacturers cannot be understated.

As consumers express a growing desire for fresh and natural products, and as supermarkets continue to look at more and more aspects of their operations that impact their bottom line, lighting and packaging are going to be more important factors. It affects product appearance, taste, nutritional values, and ultimately consumer satisfaction leading to sales revenue and profits.