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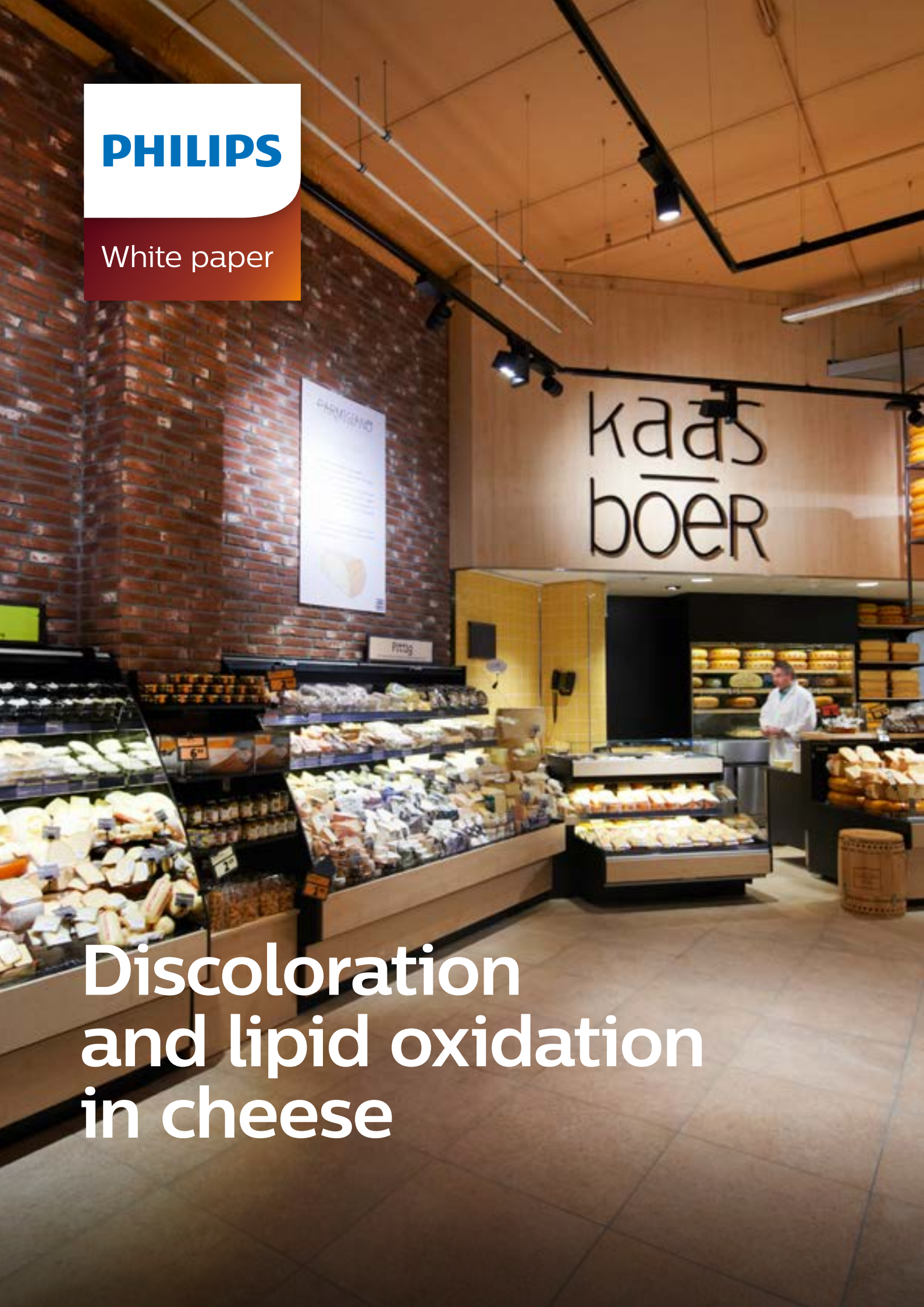
White paper



Discoloration and lipid oxidation in cheese

How could the **right lighting** help keep cheese fresh for longer?

Food retailers face a fiercely competitive environment. As more and more people choose to do their shopping online or visit smaller, convenience store-type establishments, traditional food retailers must devise creative strategies for attracting customers to their brick-and-mortar stores. However, despite these challenges, there's one trend that has remained stable in recent years – customers are highly conscious of the diversity and quality of the fresh foods on offer. More than any other spot in the store, the fresh food section is where customer loyalty is forged.

The fresh food section offers supermarket retailers the ideal opportunity to differentiate themselves from the competition. It is where they can demonstrate the level of service they provide and the quality of the fresh foods they sell. Shoppers naturally associate the look of fresh foods with their taste, and they know from experience that if food looks good, it will most likely taste good as well.

But there's also a significant downside associated with offering a wide array of appetizing fresh food – the issue of food waste. According to a study commissioned by the UN's Food and Agriculture Organization[1], roughly one third of the food produced in the world for human consumption – approximately 1.3 billion tons – gets lost or wasted every year. Converted to calories, this means that about 1 in 4 calories intended for consumption is never actually eaten.

1 http://www.fao.org/news/story/en/item/74192/icode/

Reduction of food waste
50% by 2025 promised by UN and EU.

Source: http://www.fao.org/home/en/

Food waste on this scale is something today's increasingly empowered, sustainability-conscious consumer is no longer prepared to accept. These concerns have stimulated national governments and international organizations to tackle the problem head-on. For instance, the United Nations and the European Union have committed to reduce food waste by 50% by 2025. And in France, for example, the Parliament adopted a series of measures designed to reduce food waste.

Retailers are no longer allowed to destroy produce approaching its best-before date and must donate it to charity. The sanction for breaking this law is up to EUR 75,000, and the group that proposed this legislation hopes to persuade the EU to adopt similar legislation across member states. Denmark has also made massive strides in reducing food waste through an initiative called Stop Wasting Food – in just five years, the country has seen a 25% decline in food waste.

The amount of food lost or wasted every year is equivalent to **more than half of the world's annual cereals crop** (2.3 billion tonnes in 2009/2010).

In Europe alone, **29 million tons** of dairy foods are lost or wasted every year.

At retail level, **large quantities of food are wasted** due to quality standards that over-emphasize appearance.

Food loss and waste also amount to a major squandering of resources, including water, land, energy, labour and capital and needlessly produce greenhouse gas emissions, contributing to **global warming and climate change.**

Source: http://www.fao.org/save-food/resources/keyfindings/en/

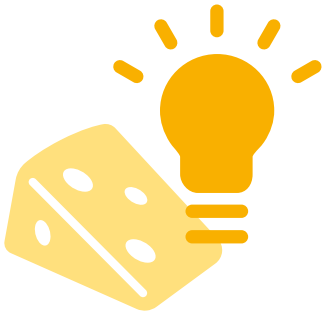
Steps to solving the problem

So how does this knowledge translate to the food retail business? How can retailers offer a variety of fresh foods that will keep customers happy while also making strides in reducing food waste?

Part of the answer lies in how retailers choose to light their fresh food departments. Let's take a deep dive into one particular area of concern – the cheese department. While there are currently different lighting recipes that help display cheese in a pleasing manner, we discovered through our own research and a review of the literature that different spectra of white light can also significantly affect the quality of cheese through a process called lipid oxidation. In other words, improper lighting in the cheese department can actually damage the cheese – making it taste rancid and sour.

This information was our starting point for investigating even further – if white light damages the quality of cheese, how do the specific wavelengths affect its quality? And is it possible to then use this knowledge to create a new, optimal recipe for both presentation and quality preservation?

What effect does lighting have on **cheese quality?**



What exactly happens when cheese is exposed to light? Generally speaking, two things occur: first, the light causes changes in the cheese's appearance – it begins to discolor, making it paler and lighter in color. At the same time, the light degrades the lipids (or in everyday parlance, the fats) in the cheese. This process is called lipid oxidation and, in a matter of only a few days, it will significantly alter the taste of the cheese.

Light-induced discoloration and lipid oxidation can put customers off buying the product in the first instance, and could influence their enjoyment of the cheese if they do decide to purchase it. These issues can have a serious impact on consumer loyalty and the accelerated spoilage caused by certain spectra of light leads to more food waste, prompting supermarkets and consumers to throw away cheese that otherwise could have had a longer shelf life.

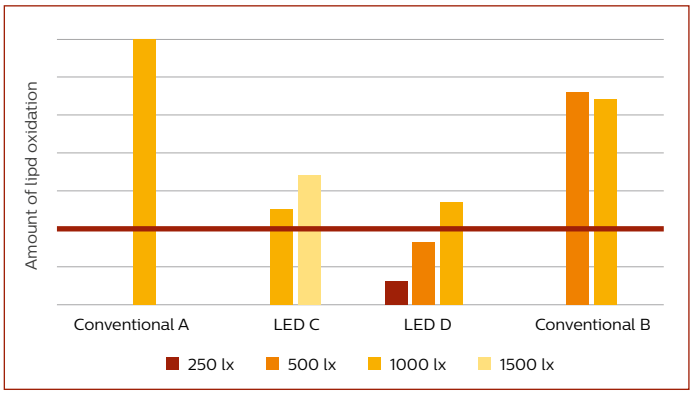
We investigated this idea more thoroughly by trying to answer the following questions:

1. How do different white spectra damage cheese quality?
2. How deep does this damage go? In other words, what is the penetration depth of the damage?
3. If different white spectra cause varying degrees of damage, which specific wavelengths of light cause the most damage?
4. If we know which wavelengths cause the most damage, can we then create an "ideal" light recipe for both optimal cheese presentation and preservation?

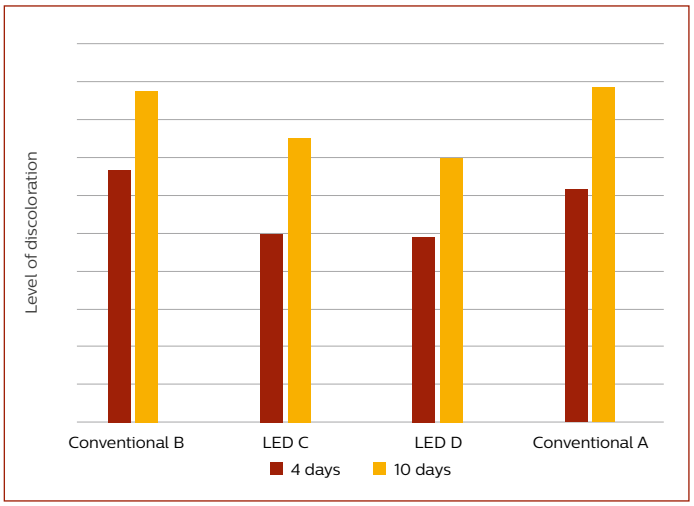
What are the effects of different white spectra on discoloration and lipid oxidation?

In the first stage of our research, we illuminated cheese samples with different white spectra while stored at 4°C. We used two conventional lamps and two different LED spectra. The lamps were placed in different closed compartments to prevent cross illumination from neighboring lamps or other light sources. Samples were also stored in a dark compartment and the refrigerator. Lipid oxidation and color changes were measured at different time points.

Effect of spectrum on lipid oxidation and discoloration



Graph 1a Amount of lipid oxidation
Effect of spectrum and illuminance on lipid oxidation. Data after 10 days illumination. Red treshold line is based on sensory evaluations in literature: above this line odor and taste affected by light.



Graph 1b Level of discoloration
Effect of spectrum and light exposure duration on discoloration. Results for illumination level of 1000 lx.

Digging deeper: what is the effect of specific wavelengths on lipid oxidation?

Our research begged the question: if different white spectra cause different amounts of damage, which wavelengths areas are causing the most damage? We investigated this by dividing the visible part of the spectrum into nine individual wavelength areas and examining their effect on cheese quality. Based on this knowledge, we could describe our "damage function," allowing us to calculate a "damage factor" for any white spectrum. Simply said, we've created a formula that estimates the impact of any white spectrum on the process of lipid oxidation.

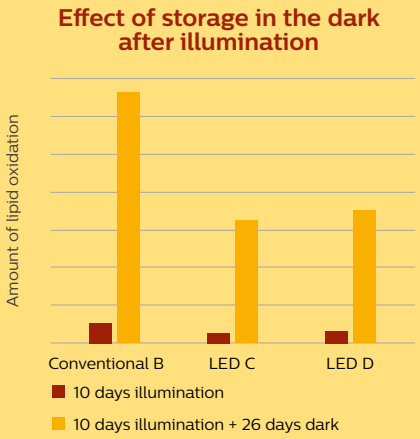
Our next task was to use this research to go one step further. Because we discovered the effect of each of these nine wavelength areas we were able to define an optimum white spectrum – one that makes use of the damaging wavelengths as little as possible.

What did we learn?

1 There is a large effect of spectrum on the amount of lipid oxidation. The amount created by the conventional lamps is much higher than when illumination took place with either of the LEDs.

2 The penetration depth of the lipid oxidation is up to 0.5 cm.

3 Surprisingly, we discovered that once cheese is exposed to lighting, the process of lipid oxidation continues in the dark. An example of this would be when a customer purchases the cheese and puts it in their own refrigerator. The spectrum of the light illuminating the cheese in the store determines how fast the process of lipid oxidation continues in the refrigerator of the customer. If the store uses traditional lighting, the increase in the dark is greater than when LEDs are used.



Effect on lipid oxidation of storage in the dark after illumination. Effect of spectrum shown. Data for illumination level of 1000 lx.

4 At illumination levels relevant for application, the effect of spectrum is larger than of illumination level. The amount of lipid oxidation is relatively low in the first days of illumination, but increases very rapidly from one week onwards. This process is just the opposite for color changes – the most significant color change is measured in the first days and reaches a sort of saturation level after longer illumination.

In the end, we've found that the right light spectrum can reduce lipid oxidation up to 50% compared to conventional lighting, making cheese taste fresh longer.

Cheese presentation: perception benefits of LED Champagne – preference and memory color

We commissioned an earlier study with the University of Leuven which investigated, among other things, how customer preferences and color memory play a role in their perception of fresh foods. The study demonstrated that in terms of perception, the saturation of color is of key importance. Interestingly, people remember the colors of fresh foods as being more saturated, and the color they prefer is even more saturated still – effectively an enhanced version of their memory. This is consistent with previous studies on other types of fresh food done at KU Leuven and with the 2012 study conducted by us and the Independent Retail Institute in Cologne, Germany, in which it was found that lighting can have a positive impact on sales in a supermarket's fresh produce department.

To reiterate, we've learned that the effect of spectrum is greater than the effect of illumination levels on lipid oxidation in cheese. This knowledge combined with an extrapolation of the above information means that an optimal lighting recipe could positively influence presentation and freshness. In other words, not only does the right LED lighting reduce chemical degradation of cheese but could also be employed to enhance its presentation to match consumer color memory

Final outcome: a new LED Champagne light recipe

In conjunction with our research into wavelengths, the color perception studies, and customer feedback, we developed a new LED Champagne lighting recipe, one that both displays cheese attractively and – most significantly – plays a major role in helping to preserve its freshness.

As you can see in Graph 2a and 2b, all white spectra will eventually have an effect on the quality of cheese, our new light recipe has a lower damage factor than traditional lighting sources and other LED white spectra by employing the wavelengths found to be the least impactful on lipid oxidation. And also important for retailers - the LED Champagne light recipe pleasingly presents their product to customers.

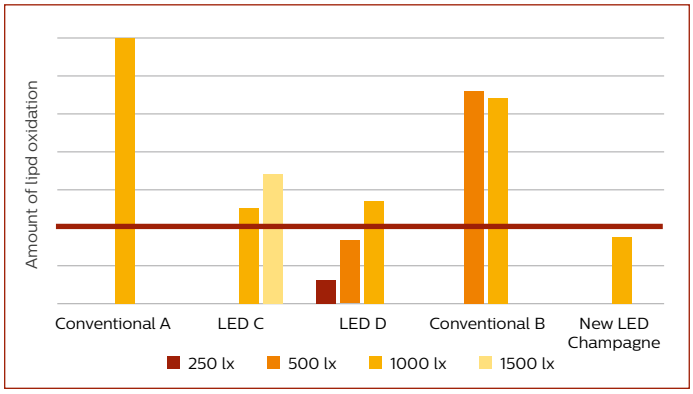
Graphs 2a and 2b show the results of the new LED Champagne on lipid oxidation and discoloration respectively. As the process of discoloration is fast in the beginning and then reaches a saturation level, the beneficial effect of the new Champagne is clearly visible after 4 days (see Graph 2b). After 10 days it can be seen that the saturation level is (almost) reached for all spectra.

Lighting application guidance

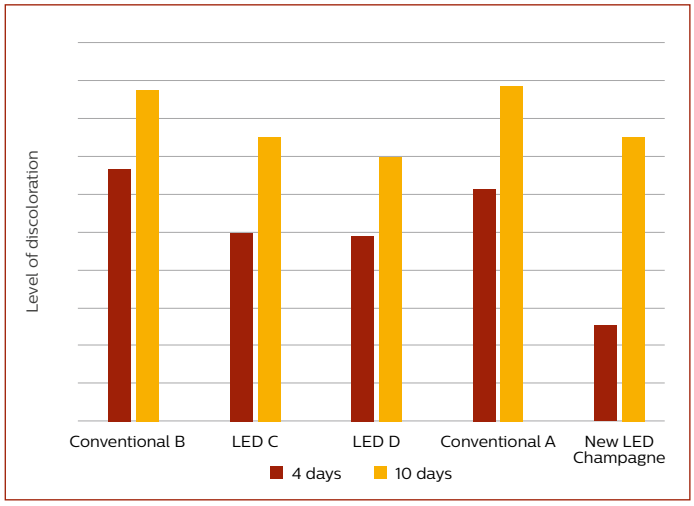
Because visible light causes discoloration and lipid oxidation in cheese, the best thing to do is to keep cheese in darkness. Of course, that's not an option for food retailers who need to expose cheese to lighting in order to display it to customers.

The spectrum of light has a much more significant impact on the quality of cheese than the amount of light used. In addition, the spectrum of the light also influences the appearance of the cheese. Yellowish cheese as well as a large variety of gourmet cheeses, look most appealing under soft, warm, yellow-enhancing light.

Effect of spectrum on lipid oxidation and discoloration



Graph 2a Amount of lipid oxidation
Effect of spectrum and illuminance on lipid oxidation. Data after 10 days illumination. Red treshold line is based on sensory evaluations in literature: above this line odor and taste affected by light.



Graph 2b Level of discoloration
Effect of spectrum and light exposure duration on discoloration. Results for illumination level of 1000 lx.

Lighting design recommendation **for cheese displays**

Use products with the Philips Fresh food LED lighting recipe Champagne. This recipe enhances presentation and reduces lipid oxidation which results in a longer shelf life.

Create an average light level (E_{ave}) of around 750 - 1000 lux on display.
The amount of light, in this illuminance range, is not that determinative for the quality of the cheese since the spectrum of light has the biggest impact. Although the right amount of light is needed to create a pleasant atmosphere in the fresh produce area and to attract the customer's attention.
Assuming a spacing of 1.8m between luminaires:
For mounting height ≤ 3 m use luminous flux ~ 1700 lm
For mounting height ≥ 3 m use luminous flux ~ 2700 lm

Create evenly-distributed light without harsh peak illuminances.
Uniformity (E_{min}/E_{ave}) > 0.6. Therefore, use an oval or wide beam.

www.philips.com/FreshFood