PHILIPS

White paper

The best light for fruits and vegetables

A white paper for making your fresh produce look better, taste better, and last longer

The fresh produce department: **Where shopper loyalty is forged**

Online experiences can't compete with the pleasure of a well-stocked and beautifully presented produce department: the colors, the textures, the aromas. Shoppers naturally associate the look of fresh produce with its taste, and they know from experience that if food looks good, it will most likely taste good as well. For these reasons, the fresh food section is often the main reason why a shopper chooses to make a trip to the supermarket, or chooses one particular supermarket over another. There's no better place for a retailer to showcase the level of service they provide and the quality of the produce they sell.

Creating the perfect ambience in fresh food departments, however, is something of a balancing act for retailers. Shoppers want a sensory experience, and creating the right atmosphere in the fresh food areas is key to achieving this. Consumers also demand a broad assortment of ultra-fresh food as an important component of a healthier lifestyle. Retailers want to fulfill these customer expectations by offering many fresh food products, but they also need to find ways to minimize losses and waste.

Waste not

A supermarket's fresh food section offers retailers an ideal opportunity to differentiate themselves from the competition, but it can also offer challenges. One of the most significant downsides of maintaining a robust and appetizing fresh food section is the issue of food decay or deterioration that results in waste. According to a study commissioned by the Food and Agriculture Organization of the United Nations (FAO), roughly one third of the food produced in the world for human consumption every year – approximately 1.3 billion tons – is lost or wasted.[1] Converted to calories, this means that about 1 in 4 calories intended for consumption is never actually eaten!

Food waste on this scale represents a global obstacle to sustainability. In response, the United Nations and the European Union have committed to cutting food waste in half in EU countries by 2025. In France, retailers are no longer allowed to destroy produce approaching its best-before date and must donate it to charity instead, with fines of up to EUR 75,000. The group that proposed this legislation aims to extend it to the entire EU.

Fortunately, today's increasingly empowered, sustainability-conscious consumer is no longer prepared to accept food waste on this scale, and an increasing number of retailers are joining governments and other organizations to take action.

Managing change

Fruits and vegetables present specific challenges where loss and waste are concerned. To begin with, horticultural crops are susceptible to losses in quantity and quality between harvest and consumption. The magnitude of such postharvest losses ranges between 5% and 60% in developed countries, depending on the commodity.[2] To reduce such losses, producers and handlers must understand the biological and environmental factors involved in deterioration, and they must use postharvest techniques that delay senescence and maintain the best possible quality.

Because they are living tissues, fresh fruits and vegetables are subject to continuous change: maturation and ripening during growth, deterioration after harvest. Biological factors involved in postharvest deterioration include:

Respiration

All living things respire, but fruits and vegetables continue to do so after harvesting. Respiration transforms glucose (a carbohydrate) into CO_2 and water using oxygen, releasing energy which fruits and vegetables need to maintain inner processes and integrity. Once stored, organic materials use up all of their nutrients, senescence sets in, and they start to deteriorate.

Ethylene production

Ethylene is a natural product of plants that affects metabolism. It acts as a plant hormone. Exposure to ethylene accelerates senescence.

Transpiration or water loss

Transpiration is the main cause of deterioration because of direct quantitative losses (weight), losses in appearance (wilting and shriveling), and degradation of textural quality (softening, loss of crispiness and juiciness). Transpiration rate is influenced by morphological factors, temperature, relative humidity, air movement, and atmospheric pressure.

Compositional changes

Compositional changes include changes in pigments and carbohydrates during maturation or development which may continue after harvest. Loss of chlorophyll causes yellowing, while changes in anthocyanin cause red coloration.

Continued growth and development

These include sprouting of potatoes, onions, garlic, and other root-like crops.

Physiological breakdown

Exposure to inappropriate temperatures may cause cells to break down—for example, chilling of basil, or heat injury due to exposure to direct sunlight.

Physical damage

Activities such as washing and drying can cause physical damage during processing of harvested foods. Damage increases water losses and encourages infections.

Pathological breakdown

Presence of bacteria or fungi on products may result in mechanical injuries on the plant tissues, which accelerate senescence.

Postharvest deterioration can't be stopped, of course, but it can be slowed down. Temperature control is one of the most important means of slowing deterioration. Modified atmosphere packaging (MAP) can help control respiration and decay by controlling exposure to oxygen and CO_2.

Recently, light has been shown to be an important influencing factor in slowing the deterioration of certain food products. Certain uses of light during the postharvest phase may slow the breakdown of several nutritional compounds (including sugars, vitamins, proteins, glucosinolates, and carotenoids), delay senescence, and prevent enzymatic and non-enzymatic browning processes. Light can improve some quality attributes of fresh fruit and vegetables in store, and may also act as a natural defense against pathogens.

What growers can do with light

How can growers use light to directly extend shelf life and improve the quality of fresh fruits and vegetables? We ran a series of experiments on leafy green vegetables and tomatoes to find out.

LED light can influence the taste, shelf life, and coloration of leafy green vegetables
Quality and food safety are especially important considerations for leafy green crops, which are usually brought to market with a minimum of processing. Appearance, especially color and texture, are also important aspects of quality for specific crops, as are taste and nutritional content (vitamins, flavonoids, carotenoids).

Anthocyanins are blue, red, or violet flavonoid pigments found in lettuce and other plants. These pigments act as antioxidants and antibacterial agents. Since they also affect coloring, they also play an important role in increasing the aesthetic appeal of different lettuce varieties. Low light levels in greenhouses and supermarket displays can reduce anthocyanin levels in lettuce, compromising their quality and appearance.

A recent publication[3] shows that particular LED lighting recipes can cause anthocyanin accumulation, helping to preserve the health and improve the aesthetic appeal of lettuce for a period of up to seven days.

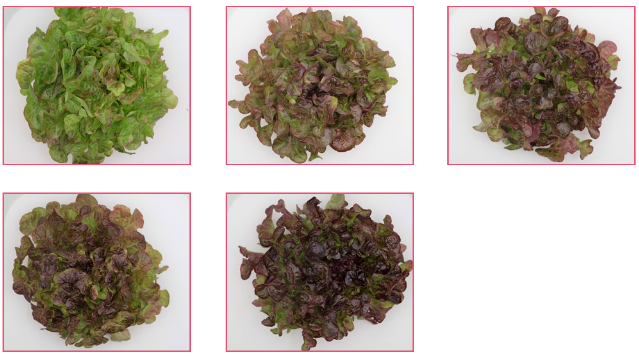


Figure 1: Red oak lettuce under different proportions of red and blue light

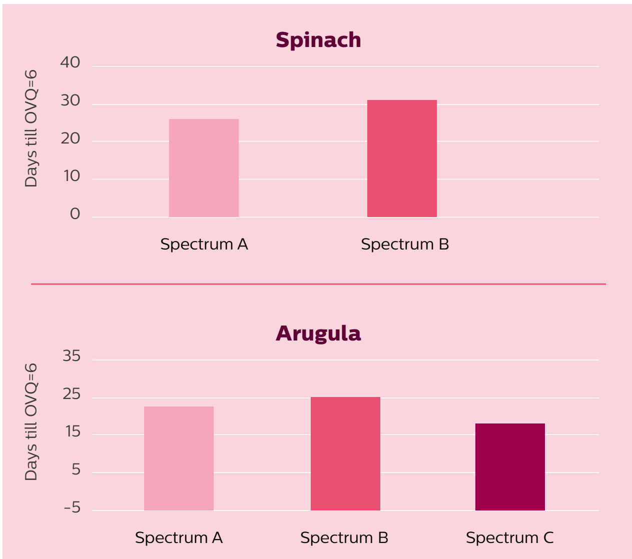


Figure 2: Improved post-harvest shelf life after pre-harvest light treatment. Bar chart represents the consumer acceptance over shelf life days after harvest as a function of light quality. Data are measured on stored baby leaf spinach and arugula at 4 deg C. OVQ (Overall visual quality)=6 represents limit of consumer acceptance.

Light intensity, total amount of light exposure, and light quality may influence the shelf life of baby leaf spinach and arugula leaves.[4] Our light recipe research has shown that LEDs may be effective in improving the post-harvest quality of leafy vegetables, but the cultivar and species dependency could be strong. Optimizing light quality and pre-harvest light for crops growing in enclosed environments is important to achieve or exceed post-harvest quality. An optimized photosynthetic light recipe enables high production efficiency and produces a tasty and nutritious leafy green with a long shelf life.

We have also demonstrated that some attributes, including nutrient content and appearance, can be significantly improved using a pre-harvest continuous-light strategy. Such a strategy could allow growers to guarantee a specific nutrient content for consumers. Additional investigations would be required, but this strategy might also be able to modify taste and shelf life to bring premium products to market.

LED light can increase the level of vitamin C in tomatoes
Vitamin C is a health-promoting agent found in abundance in plants. Tomatoes offer considerable amounts of vitamin C—from 10 to 20 mg per 100 g of fresh weight.

As Massot et al. have demonstrated, light is a major regulatory factor for vitamin C levels in leaves and fruits.[5] Research performed in conjunction with Wageningen University has shown that LED light can increase the vitamin C levels in tomato fruits still attached to the plant.[6] Irradiating detached tomato fruits with LED lights can also significantly increase their vitamin C content.[7]

Currently, strong nutrition claims for fresh horticultural products can be made based only on their vitamin C content. In general, levels of vitamin C in commercially grown produce are too low to justify strong claims. Special LED lighting can increase levels of vitamin C significantly. In this way, retailers have the possibility of offering tomatoes rich in vitamin C on their shelves.

LED light can reduce nitrate levels in lettuce, spinach, and arugula
Leafy vegetables are known to accumulate excessive amounts of nitrates,[8] which has raised strong health concerns in Europe.[9] Present legislation in Europe limits the nitrates in lettuce and spinach cultivated indoors to 3500 $mg.kg^{-1}$ during the summer; winter limits are higher.

Good agricultural practices can help reduce nitrate accumulation.[10] However, low light conditions and unfavorable climate and irrigation (e.g., excessive rain) can encourage nitrate accumulation in plants just before they are harvested.

Increased photosynthesis plays a role in reducing nitrate accumulation as a result of increased production of photosynthetic products (sugars). Photosynthetically active radiation (PAR) has been shown to be effective for various vegetables in this regard.[11] It seems wise, therefore, to use an optimized light recipe during the growth phase when solar light is absent.
Specific lighting strategies can ensure low nitrate levels in leafy vegetables. Nitrate reductase (NR) can reduce NO^{3}- (nitrate) to NO^{2}- (nitrite) in plants, which in turn reduces amino acids, completing the nitrate reduction process.[12] NR can be influenced by light spectrum, light intensity, and photoperiod.[13]

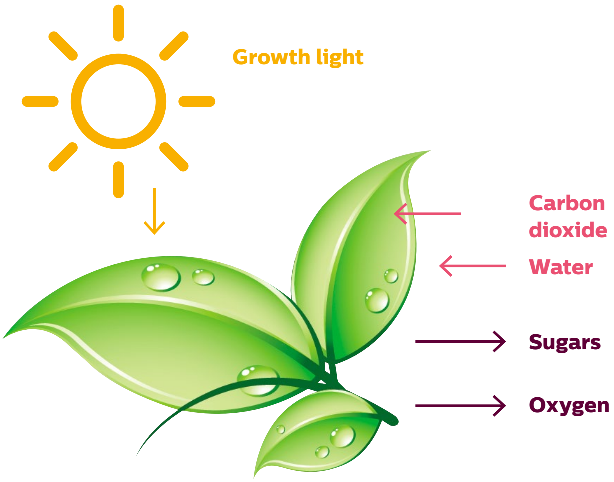
Because nitrate is mainly processed during the day and accumulated during the night, the photoperiod may come into play, especially with short day plants. Our research shows that nitrate levels lower than 1500 mg.kg-1 can be achieved in lettuce, spinach, and arugula by optimizing the light recipe. This has no effect on yield, visual quality, or shelf life.

These results point to opportunities for decreasing nitrate in-store by using the appropriate lighting recipe. Our research shows that the best light recipe is obtained by optimizing the PAR level, while light spectrum plays a secondary role.

Light is an important determinant of final nitrate content in a product. Light applied postharvest may also modify the nitrate content of leafy green vegetables. Research[14] has demonstrated that light exposure during storage successfully prevents accumulation of nitrate, delays loss of chlorophyll, and extends shelf life in minimally processed butterhead lettuce.

The best light for growers

Having completed hundreds of projects, Philips has many years of experience investigating the effects of LED lighting on a range of crops. In every project we are on the lookout for the optimum light recipe. A Philips Horticulture light recipe is an instruction based on knowledge of how to use light to grow a certain crop under certain condition.



What retailers can do with light

How can retailers use light to maintain quality and optimize presentation once products are on the store shelves? We ran experiments on lettuce, basil, and potatoes on the shelves to find out what light is best for preserving the quality of produce. We also compared different lighting scenes to determine which lighting options shoppers prefer.

Maintaining quality with light: When green is good for business

In darkness, there is no photosynthesis, and as a consequence the level of carbohydrates in plants rapidly declines. Researchers have suggested that this decline is the main cause of dark-induced senescence.[15] Consequently, light may be a possible factor in delaying senescence during postharvest storage.[16]

Some researchers have reported positive effects of postharvest lighting at relatively low intensities.[17] Professor E. Woltering from Wageningen University has described the effects of preharvest light intensity on subsequent shelf life of intact leaves and fresh-cut butterhead and iceberg lettuce.[18]

As Woltering's research shows, exposing lettuce to light preserves its visual quality longer at a level that customers find acceptable.

We performed a series of experiments to determine the influence of different wavelengths (colors) of light on the overall visual quality of butterhead lettuce. We used lettuces that were harvested in the greenhouse the morning that the experiment started. Each head of lettuce was handled with gloves and sterile knives and stored in a container with humidity-controlled packaging to allow oxygen exchange.

Different samples of the lettuce were exposed to different colors of light. We also stored a sample in the dark, for comparison. Over time, we looked for browning of veins, bleaching of leaves, greening of leaves, the appearance of more visible veins in leaves, weak leaves, shrinking of leaves, and dark spots.

So which light worked best? At 92 days, the lettuce stored in the dark becomes pale, while leaves stored under light stayed greener longer. Different areas of the spectrum produced very different effects. Some areas of the spectrum preserved the green color longest, while other areas made the lettuce leaves deteriorate more quickly or become weak.

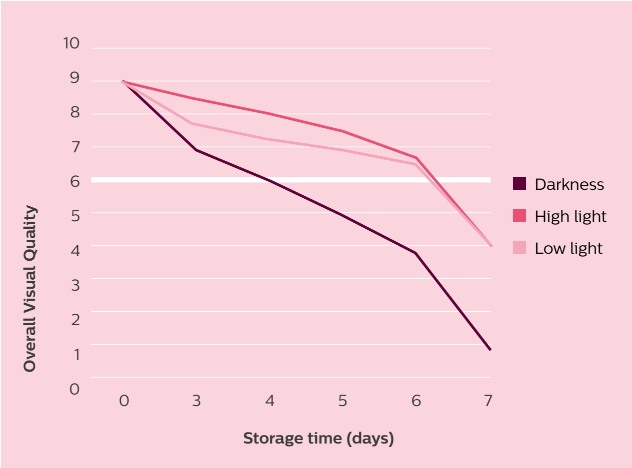


Figure 3: Overall visual quality (OVQ) of fresh-cut product stored in darkness and under continuous low and high light intensity. OVQ=6 represents the limit of consumer acceptance.

Figure 4: On the left: Appearance of lettuce under light from the optimal area of the spectrum after 92 days. On the right: Appearance of lettuce left in the dark for 92 days.

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Storage and transportation of harvested fresh vegetables usually takes place in darkness. Under such conditions, carbohydrate reserves such as starch and sugars rapidly decline and this may lead to energy starvation and subsequent deterioration of the product. By using increased growth light intensities in the days just before harvest we were able to significantly increase the carbohydrate levels of harvested lettuce. The higher carbohydrate levels greatly improved the shelf life of both the intact heads and the fresh-cut product. This showed that application of alternative growth lighting recipes just before harvest can improve the products nutritional quality and prolong the shelf life."

Professor E. Woltering - Wageningen University

Maintaining quality with light: When green isn't so good

When potatoes are exposed to light, they can form a greenish pigmentation on their skins. This process is known as "greening." Unfortunately, greening is not just unsightly, but it also a warning sign that toxic species can be formed. Greening in potatoes is caused by the formation of chlorophyll, but solanine can also be formed at the same time. Chlorophyll is harmless, but solanine is poisonous. For supermarkets, therefore, potato greening means waste and loss of revenue.

Your best bet for avoiding potato greening is to store them in the dark. But when you have to shine light on them, make sure it's the right light.

We conducted several experiments to monitor the greening of potatoes due to exposure to light of different wavelengths (colors). The results accord with the absorption properties of the photoreceptors present in potatoes. When we tested different white spectra, we discovered that our Champagne recipe causes less greening. Under a cool white spectrum, the potatoes greened about a day earlier.

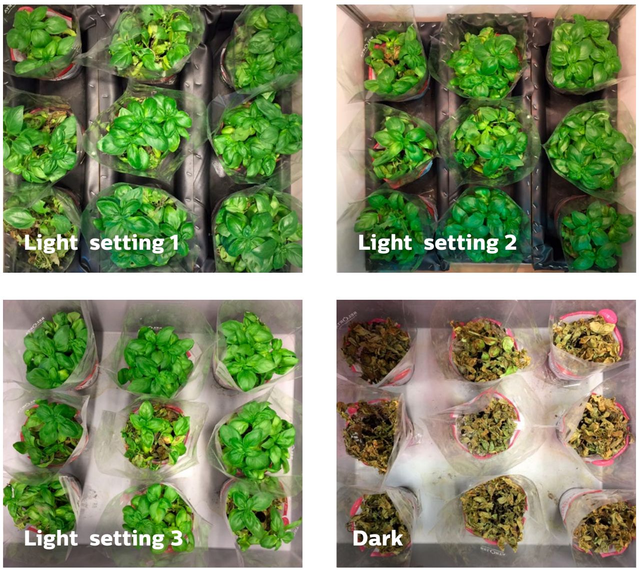

Figure 5: Pictures show result of exposing basil to different light settings or dark after three weeks.

Maintaining quality with light: What about herbs?

"Of all the herbs, Jasmine thought, basil was her soul mate. She rubbed her fingers over a leaf and sniffed deeply at the pungent, almost licorice scent. Basil was sensuous, liking to stretch out green and silky under a hot sun with its feet covered in cool soil." So writes Nina Kilham in her 2005 novel, *How to Cook a Tart*. She might also have mentioned that basil is fragile, prone to bruising, and easily spoiled if not treated carefully.

To discover what kinds of light treat gentle basil best, we conducted a series of tests that exposed basil plants at room temperature to light with three different spectra. We also kept one sample in the dark. The plants were exposed to light for 14 hours per day, at a level of intensity that compares to light levels in a typical supermarket.

We performed two overlapping trials. In both trials, we evaluated nine samples per test per light treatment for visual appeal, yield, plant height, metabolites, conductivity, and other quality parameters. Generally, plants from trial 1 maintained better quality than plants from trial 2, which reflects a difference in quality of the greenhouse-grown plants in each batch.

We concluded that basil plants last longer in light than in darkness, regardless of spectrum. We found only small differences among plants stored under different light treatments. Therefore, retailers can select light colors that enhance shopper perception and preference when displaying basil, rather than focusing solely on the influence of light on the plants.

Optimizing presentation

We commissioned a study with the University of Leuven which investigated, how customer preferences and color memory play a role in their perception of fresh foods. The study demonstrated that the saturation of color is of key importance. Interestingly, people remember the colors of fresh foods as being more saturated than they are in real life, 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 we conducted with the Independent Retail Institute in Cologne, Germany, which found that lighting can have a positive impact on sales in a supermarket's fresh produce department.

Recently, we ran a series of tests to investigate how the use of our Fresh food PremiumColor LED recipe affects the presentation of fruit, vegetables, and flowers in supermarkets. We compared PremiumColor LED recipes with our Champagne LED recipe and standard 930 LEDs.

Twenty-three participants-eleven women and twelve men-examined three comparisons for each of ten objects. They viewed paired comparisons and were asked to identify which presentation in each comparison was more attractive. To minimize bias, we randomized the object and comparison orders, as well as which light was on the left and which was on the right.

The results of the tests offer some specific recommendations for supermarket retailers who want their fruit, vegetables, and flowers to look their best. For all objects, PremiumColor scored the best—by a lot. The standard 930 scores were better than the Champagne scores, which were the lowest for all objects.

There were some variations in the results. For yellow, white, yellow and purple, and mixed-color flowers, the standard 930 and PremiumColor scores were roughly the same. But PremiumColor was strongly preferred for red and orange objects.

Based on the results from the lettuce and potato experiments, we expect no issues using PremiumColor for green vegetables, but recommend not using PremiumColor for potatoes, because of the possibility of more greening.

Objects

Figure 6: Objects used for the study to investigate how customer preference and memory color play a role in their perception of fresh foods.

What retailers should do

Based on the studies we've done, the research we've collected, and our experience helping retailers light fresh food in the best way possible, we offer the following pieces of advice:

- In general, it's best to light your fresh food fruit and vegetables with our Fresh food PremiumColor LED recipe, with the exception of potatoes
- Potatoes should be stored as much as possible in the dark, but when illuminated for display we recommend using our Fresh food Champagne LED recipe
- Herbs and lettuces benefit from optimized lighting

Visit **www.philips.com/freshfood** for more information about our Fresh food lighting recipes for fruit and vegetables, meat, and cheese.


Spezialitäten aller Länder
Glutenfrei
Backmischungen

Notes

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