PHILIPS

White paper

Fruit & vegetables

Lighting to enhance the healthiness of fruit & vegetables

Today’s consumers want top-quality fruit & vegetables

For supermarkets, the fresh department is key to creating customer loyalty and ensuring that shoppers visit their shop rather than buy online. This is especially true when it comes to the fruit & vegetable department.

According to an in-depth customer survey[1], consumers today are extremely conscious of the positive impact that fruit & vegetables can have on their health. They therefore expect top-quality fresh produce in every store. In addition, these consumers are environmentally conscious; they look for detailed information about where their fresh fruit & vegetables come from, how they were produced, and how fresh they really are. They want to reduce or avoid the use of pesticides, eat fruit & vegetables that fit the season, limit 'food miles', and decrease waste. At the same time, convenience is important to them.

Well-known components of fruit & vegetables that contribute to healthiness and nutritional value are vitamins, minerals, antioxidants, fibers, and carbohydrates. As these components are used to make choices for a healthy diet, one key question arises. How can the healthiness of fruit & vegetables be improved?

Lighting can make an important contribution to improve the healthiness of fruit & vegetables. This white paper explains some broad aspects of this phenomenon. It looks at the impact of lighting, which was studied on both the pre-harvest and the post-harvest phase of fruit & vegetables, and considers how lighting can contribute to the success of both the grower and the retailer, and ultimately lead to more satisfied – and healthier – consumers.

The importance of vitamin C in a healthy diet

Lighting has a particularly important role in the production of vitamin C in fruit & vegetables. Vitamin C, also known as ascorbic acid or L-ascorbate (AsA), is essential for the proper functioning of the human body. It forms proteins which are then used to make skin, tendons, ligaments, and blood vessels. It heals wounds and forms scar tissue, repairs and maintains cartilage, bones, and teeth, and aids in the absorption of iron. It is also an antioxidant that blocks damage caused by free radicals. Studies have also shown the potential of vitamin C for cancer prevention and treatment[2].

However, the human body is not able to make (or store) vitamin C due to the absence of the enzyme that catalyzes the final step in the vitamin's biosynthesis. It is therefore important to include plenty of vitamin C-containing foods in a daily diet. Unfortunately, even in developed societies vitamin C is often not present in the diet in sufficient amounts[3].

Fruit & vegetables are considered the most important source of vitamin C for humans. Consequently, it would be a health benefit if the vitamin C levels of the fresh fruit & vegetables available in supermarkets today could be as high as possible. This is where lighting can play a key role.

How the grower can improve healthiness of fruit & vegetables

In a previous white paper by Signify[4], examples were given of how a grower can use light to improve taste, shelf life, and coloration of leafy green vegetables.

It was explained that optimal use of light during growth can reduce nitrate levels in lettuce, spinach, and arugula, and regulate or increase vitamin C levels[5]. Applying light to any stage in the lifecycle of fruits & vegetables was found to stimulate the synthesis of vitamin C. In this earlier white paper, a case study on tomatoes was presented. Light was applied during growth and after harvest on detached fruits. In both cases a significant increase in vitamin C content was recorded[6].

Emerging technologies in modern agriculture set the scene for developing specialized plant products along the full production chain from growth to storage, to retail markets. Lighting conditions can be easily manipulated by the grower in protected cultivation and storage conditions – for example through the use of LEDs – in order to improve the healthiness and quality of plant products.

Case study: **Arugula**

Arugula is a peppery, distinctive-tasting, green, leafy vegetable grown commercially in various places in the world, such as the Mediterranean region. Also known as rucola or rocket, arugula is a member of the Brassica, or Cruciferous, family. It's well-known for containing high levels of nutrients beneficial for human health, including vitamin C.

Signify Research discovered that the vitamin C content of arugula depends heavily on the environmental conditions during the plant's growth, and in particular the lighting conditions shortly before harvest time.

Controlled experiments[7] were carried out on arugula and the results are displayed in Figure 1. L1, L3 and L5 are different baseline light recipes used during the growing period of arugula plants. During a short period (3 days) in the pre-harvest phase, half of the plants were grown under more intense lighting conditions – L2, L4 and L6. When these plants were harvested, their levels of vitamin C were almost double that of the control batch. Remarkably, the levels of vitamin C of these arugula plants were well above the USDA values for kiwi fruits – for long regarded as a fruit with one of the highest amounts of vitamin C.

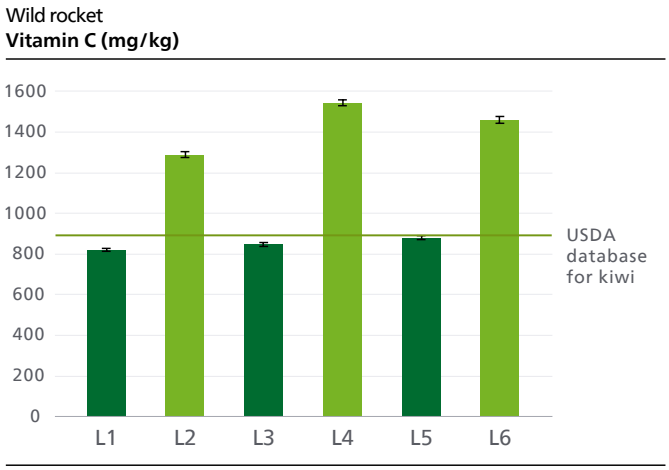


Figure 1. Increased vitamin C content of fresh arugula harvested after increasing the pre-harvest lighting conditions.

Case study: **Lettuce**

Leafy vegetables such as lettuce generally have a short post-harvest life due to mechanical damage and the lack of light during storage and transportation. Post-harvest performance is related to both nutritional quality (measured by the levels of health and flavor related compounds) and sensorial quality (measured by visual quality, texture, and odor).

Important nutritional elements and quality markers include the levels of carbohydrates (sucrose, fructose, glucose, and starch) and vitamin C. Carbohydrates may relate to the sensorial quality of leafy vegetables by providing sweeter or less bitter taste, and delaying crop texture deterioration (shape and crispness) and discoloration.

Signify Research investigated the effect of light treatments applied pre-harvest on the post-harvest performance of lettuce, as a representative crop of leafy vegetables. Most of the previous research on the effects of light intensity on end-product quality has been done by applying different light levels during the entire cultivation period. Different light levels were applied only at the end of production – 6 or 7 days before harvest. The advantage of this approach is that the light treatments will only have limited influence on crop growth, yield and morphology. It also minimizes energy usage.

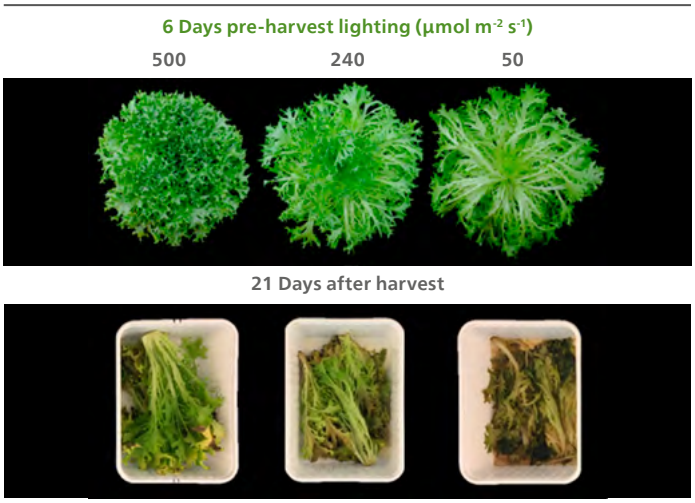


Figure 2. Effect of different pre-harvest lighting regimes on lettuce stored at 10 degrees Celsius.

Signify's research results have been published together with a team of researchers from Wageningen University that specializes in production and control of crop quality[8]. Figure 2 clearly shows the effect on lettuce quality of different light intensities applied for a few days before harvesting the product. Figure 3 shows the impact of these lighting regimes on vitamin C levels.

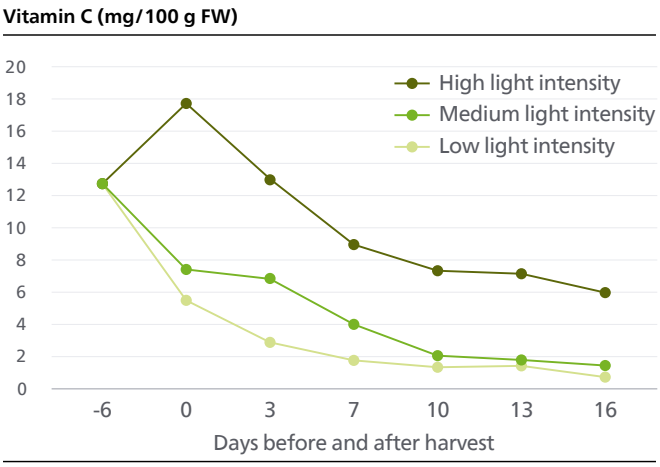


Figure 3. Effect of different pre-harvest lighting regimes on vitamin C content of lettuce.

In other words, both the shelf life and the nutritional status of lettuce were improved by increasing the pre-harvest light intensity. Furthermore, light can also increase other essential metabolites important for health and taste.

Case study: **Basil**

In plants and plant products of subtropical and tropical origin, chilling injury may occur following exposure to temperatures below 10-12°C. Basil, for example, when exposed to chilling temperatures, suffers from a loss of glossy appearance and premature wilting, followed by brown leaf spots and black necrotic lesions. During prolonged storage under chilling temperatures basil may develop soft rot from fungal and bacterial attack.

Often fresh basil is transported together with other herbs and leafy vegetables, which greatly benefit from temperatures down to 0°C. Such transport and storage conditions, however, are unfavorable for basil and can lead to severe losses.
An increase in antioxidants would be beneficial for the plant to minimize the damaging effect of chilling stress. One way to increase the antioxidant content is to increase the light intensity during growth. Experiments were conducted[9] and the results are displayed in Figure 4. It can be clearly seen that the higher the light intensity, the more vitamin C was produced in the basil, and the more resistant the plants should be to chilling injuries and stresses.

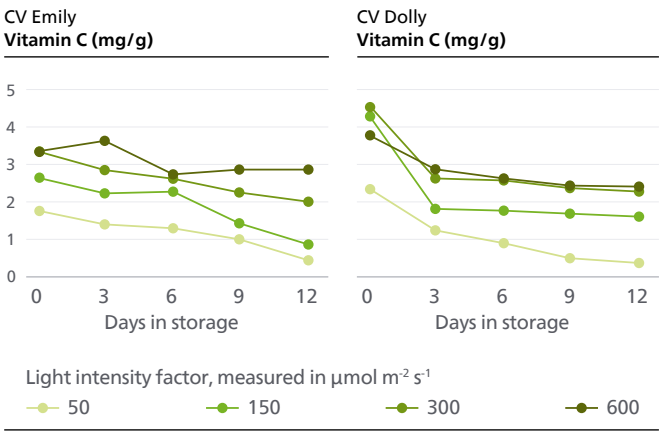


Figure 4. Effect of different lighting regimes on two varieties of basil.

How the retailer can improve healthiness of fruit & vegetables

The retailer also has a key role to play in making sure consumers purchase and eat the most healthy fruit & vegetables. While the grower can increase the healthiness of fresh produce during the growing phase, the retailer can take actions to maintain this healthiness in the fresh food department for as long as possible.

Of course, the retailer faces numerous challenges, such as the large variety of fruits & vegetables, the varying quality of produce delivered to the store, demanding customers, and the trend to reduce (plastic) packaging materials. At the same time, the retailer must also take care that the shop looks attractive and that all products, and especially the fresh products, are well presented.

So, what can the retailer do? He or she can influence parameters such as temperature and humidity through controlling the setup of the HVAC system, and by implementing dedicated solutions for fruit & vegetables such as dry misting. Another important parameter a retailer can control is the light. In particular, the spectrum, intensity, and schedules (on/off, dimming) of lighting systems can contribute to maintaining the quality of fresh produce, while at the same time creating a pleasant and attractive shopping environment.

As explained earlier, often customers use visible clues and 'general knowledge' for making their choices for what they perceive as healthy fresh food. However, not all elements of nutritional value are visible and as we saw with the arugula case study, actual vitamin content can be different from what is expected. This is exemplified by the case study on broccoli.

Case study: **Broccoli**

Broccoli is a popular, widely available vegetable that is generally perceived as a healthy addition to the diet. Signify Research investigated what a retailer can do to maintain the vitamin C content of broccoli. A series of experiments was conducted on light parameters such as spectrum and intensity, as well as on the effect of temperature. Moreover, the effect of these parameters on the color of broccoli was studied.

Basically, when broccoli is stored, vitamin C levels inevitably fall. However, this drop in vitamin C levels was found to be significantly less when the broccoli was stored in light rather than in dark conditions.

Regarding storage temperature, the reduction in vitamin C levels was less at 4°C than at room temperature, while for spectrum it was found that certain parts of the visible spectrum, such as royal blue, induced much more vitamin C loss than others such as deep red. The largest effects were again found at room temperature (Figure 5).

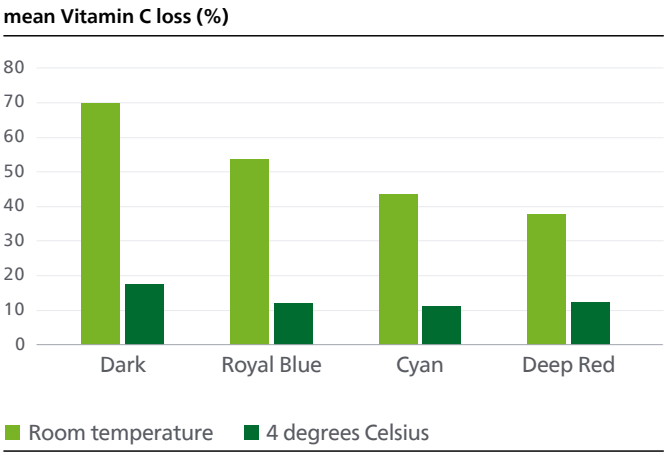


Figure 5. Vitamin C reduction of broccoli under light/dark storage conditions and different temperature settings.

Regarding light intensity, no significant effect on vitamin C loss was found. Similar losses were noted for light levels that are commonly used in stores and for levels that were three times higher.

As regards the color of the broccoli, it was clear that storage in light has a beneficial effect. The color loss of the broccoli stored in the dark was far greater over time than for broccoli stored in light (Figure 6). No clear effects on broccoli color were observed for different spectra or intensities.

Figure 6. Broccoli stored after one week in the light (left) and in the dark (right).

However, at the same time it's important to realize that certain food products such as chicory need to be stored and presented in the dark, to prevent spoilage by light. This can be accomplished by special light-tight lids[10] that fit on vegetable crates.

Conclusions and recommendations

Based on its findings, Signify Research can make several recommendations for the retailer to maintain the quality and nutritional value of fresh produce in their store.

Avoid darkness when storing (most) fruit & vegetables: Light has a positive impact in reducing vitamin C loss and reducing undesirable color changes of that produce. Avoid too much blue in spectra, so choose lighting with a lower CCT or a dedicated LED recipe.

Signify recommends accent lighting luminaires with the Philips fresh food LED lighting recipe PremiumColor for the fruit & vegetable department. This specifically developed recipe for accent lighting enhances the presentation of fruit and vegetables. In addition, its low CCT is beneficial for preservation.

Specifically, PremiumColor technology enhances the contrast between colors and whites, and achieves new depths of color for a more saturated, vibrant retail experience that also has a positive effect on energy efficiency. For fruit & vegetables it enhances their crisp, colorful and healthy look which is important for the sales area.

For the fruit & vegetable department, the right amount of light is needed to create a pleasant atmosphere in the area and to attract the attention of customers. Therefore it is recommended to create an average light level (Eave) of around 1000 to 1500 lx. To create additional highlights on the center islands, this should be increased to around 3000 to 4000 lx. It is important to create evenly distributed light without harsh peak illuminances. It is also recommended to select either an oval or wide beam to create a uniform lighting effect. A further point to emphasize when it comes to lighting design is that light distribution is just as important as shopper eye comfort.

Signify's solutions

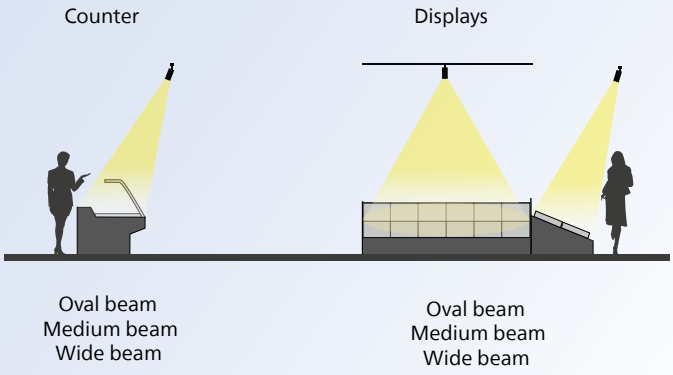
Unlike one-size-fits-all solutions, luminaire families featuring the Philips PerfectAccent reflector range, such as StyliD Evo or LuxSpace Accent, can highlight specific products and create different ambiances with superior eye comfort. The variety of beam shapes, lumen packages and recipes like PremiumColor that are available within the key spotlight ranges makes it easy to define the right level of intensity.

StyliD Evo

LuxSpace Accent

Further advantages can be gained by combining Philips LED lighting recipes with Interact scene management software for the fruit & vegetable department. Interact scene management software works with a connected LED lighting infrastructure to remotely monitor, zone, schedule, and control the lighting of your stores or a selection of stores.

Retail areas



References

1 The Fruit Logistika Trends Report 2019

2 Fitzpatrick et al (2012). Vitamin Deficiencies in Humans: Can Plant Science Help? The Plant Cell

3 Schleicher et al (2009). Serum vitamin C and the prevalence of vitamin C deficiency in the United States, The American Journal of Clinical Nutrition

4 The Best Light for Fruits and Vegetables (2019)

5 Massot et al (2012). Light affects ascorbate content and ascorbate-related gene expression in tomato leaves more than in fruit. Planta.

6 Verkerke et al (2015). The effect of light intensity and duration on vitamin C concentration in tomato fruits. Acta Hortic.

7 Nicole et al (2019). Effects of LED lighting recipes on postharvest quality of leafy vegetables grown in a vertical farm. Acta Hortic.

8 Min Qianxixi et al (2021). High Light Intensity Applied Shortly Before Harvest Improves Lettuce Nutritional Quality and Extends the Shelf Life. Frontiers in Plant Science

9 Larsen et al (2020). Response of Basil Growth and Morphology to Light Intensity and Spectrum in a Vertical Farm. Frontiers in Plant Science.

10 https://en.with-lof.com/

www.lighting.philips.com