The role of LED in improving nutrient quality of fruits and vegetables stored in household refrigerators

Ghufran Ahmed

Abstract

Light emitting diodes (LED) are semiconductor diodes, which are capable of producing light through electroluminescence. Because of their unique properties, greenhouses use LED for crop production and post-harvest management practise. In addition, studies show that LED have very positive effects on the development of bioactive compounds such as soluble sugars, starch, vitamin C, soluble protein, and polyphenol. Studies show that the vitamin C and polyphenol content increases in vegetables and fruits that are stored in refrigerator compartments equipped with LED. This paper highlights the beneficial effect of LED equipped in the vegetables and fruits compartments of household refrigerators.

Keywords: Light emitting diode, LED, refrigerator, household, agriculture, vitamin C

Die Rolle von LED bei der Verbesserung der Nährstoffqualität von Obst und Gemüse in Haushaltskühlgeräten

Kurzfassung

Licht emittierende Dioden (LED) sind Halbleiterdioden, die Licht durch Elektrolumineszenz erzeugen können. Aufgrund ihrer einzigartigen Eigenschaften werden sie in Gewächshäusern für die Pflanzenproduktion und das Nacherntemanagement verwendet. Außerdem zeigen Studien, dass LED eine sehr positive Wirkung auf die Entwicklung von bioaktiven Verbindungen wie z. B. lösliche Zucker, Stärke, Vitamin C, lösliches Protein und Polyphenol haben können. Der vorliegende Beitrag beschreibt die positive Wirkung von LED speziell in Gemüse- und Obstabteilen von Haushaltskühlgeräten.

Schlüsselwörter: Licht emittierende Diode, LED, Kühlgerät, Haushalt, Landwirtschaft, Vitamin C

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Introduction

Light emitting diodes (LED) are semiconductor diodes, which are capable of producing light by electroluminescence. LED consist of a p–n junction diode that after activation emits light of different wavelength as shown in fig 1. Current enters the semiconductor through the p-side and leaves it through the n-side thus completing a circuit that results in the movement of electrons and holes toward the junction upon a voltage application. Upon applying a desirable voltage, electrons are able to recombine with electron holes within the device, releasing energy as photons. This phenomenon is called electroluminescence. The energy band gap of the semiconductor determines the colour of the light, corresponding to the energy of the photon. LED are typically small (less than 1 mm) and integrated optical components can modify the radiation pattern (Gupta and Jatothu 2013:7).

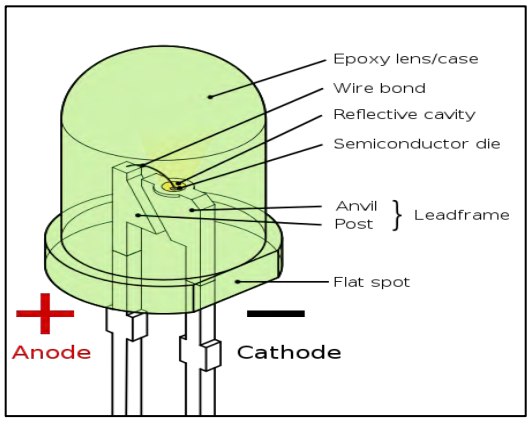

Fig 1: Structural Diagram of LED (modified according to Wikipedia 2018)

Properties of LED

The following are the properties of light-emitting diodes (LED) that make their suitable application in the food and agriculture industry:

- LED emit low radiant heat,
- LED are capable of emitting monochromatic light,
- LED are electrical, luminous, and photon efficient,
- LED are very flexible, available in many varieties and have easy application,
- LED are produced from nontoxic chemicals,
- LED are easily recyclable and thus eco-friendly and
- LED are durable and have long life expectancy.

Application of LED in Food Production

Light source in Green House

Light plays an important role in producing food with support of photosynthesis. It is not easy to summarise the light effect on development of plants. Studies have shown that not the complete light spectrum is useful to plants; plants utilize the visible electromagnetic spectrum in order to produce food, referred as “light”. In addition to photosynthesis, light also controls the time of flowering and morphogenesis. The two major photoreceptors cryptochrome that absorbs blue and ultraviolet light, and phytochrome that absorbs red and far-red-light are responsible for developmental and plant morphological changes (Quail et al. 1995: 268, Deng and Quail 1990: 10).

After the invention of light-emitting diodes (LED), they are growing as a beneficial tool for food preservation and greenhouse crop production (Mitchell et al. 2012: 52). LED possess properties such as emission of radiation with minimal thermal effects, which have narrow bandwidths and have a relatively high photon flux or irradiance. LED are easily to integrate into electronic systems (Branas et al. 2013: 7). Due to these features LED meanwhile play an important role in agronomic application (Hao et al. 2012: 956, Trouwborst et al. 2010: 138).

Protect against food spoilage

Food spoilage during post-harvest period for various crops is a big problem to deal with for agricultural scientist. In prospect of protecting crops against various pathogens, LED has been gaining attention as worth full tool in context of sustainable agricultural practices. Single-spectral blue LED can be a useful tool to reduce the postharvest spoilage caused due to *Penicillium* species in citrus fruits, when compared to fruits stored in dark conditions (Liao et al. 2013: 81; D’Souza et al. 2015: 14). Moreover, blue light can directly suppress the sporulation and germination of fungi (Alferez et al. 2012: 63, Liao et al. 2013: 81).

Induce bioactive compound synthesis in crops

The effect of LED on the synthesis of bioactive compounds in different plants review D’Souza et al. 2015: 14 (see tab. 1).

Tab. 1: Bioactive Compound Synthesis in Crops (modified according to D'Souza et al. 2015: 14)

LED Light	Light Intensity ($\mu mol\ m^{-2}\ s^{-1}$)	Crops	Synthesis of bioactive compounds
Red	50	Gossypium hirsutum	Sucrose, starch, soluble sugar
	50	Malus domestica Borkh	Anthocyanin
	128	Pisum sativum	β-Carotene
Blue	100-200	Lactuca sativa	Phenolic content, Vit-C
	50	Brassica campestris L.	Vit. C
	50-80	B. rapa, B. oleracea	Phenolic content, Vit-C
Green	~ 200	Triticum aestivum L	Phenolic content, Vit-C,
Yellow	~ 100	Raphanus sativus	Vit-C ,α-tocopherol

Increase crop yield

LED generate less heat, which makes them suitable to use as interlighting system in greenhouse (Hao et al. 2012: 956). Additionally LED require less power for operation. Therefore, their application saves a noteworthy amount of energy. The use of monochromatic blue or red LED is a significant tool to improve the quality and yield of vegetables and fruits (e.g. cucumber, pepper, and strawberry fruits) when compared to ordinary sunlight or white light (Li et al. 2016: 25).

Animal rearing

As light plays an important role in crop production and yield similarly LED are playing an important role in animal rearing. (Yeh et al. 2014: 32) report that red LED light treatment for 14 h improves reproductive performance of sapphire devils (chrysiptera cyanea). (Kim et al., 2013: 92) study the effect of LED on the growth of broiler chickens and report that yellow LED light causes greatest weight gain per feed intake for 3 week only, compared to white, blue, red, green LED, and normal light control.

Application of LED in refrigerators

The influence of light on vitamin C content in vegetables and fruits during storage is controversial, since both positive and negative effects on shelf life and quality of such products have been observed. But, studies show that it is very effective in enhancing nutrient contents especially vitamin C contents in stored fruits and vegetables, as light plays an important role in photosynthesis thus stimulating plant growth and nutrient quality.

(Young et al. 2007: 14) observe the influence of LED on the cabbage quality and nutritional content in common home refrigerator over period 10 days storage, stored inside the cold 4 °C - compartment. Their studies show that LED are useful in increasing chlorophyll contents, increase the amount of phenolic components and slow down the vitamin C degradation compared to values that are measured in cabbages stored in an identical refrigerator without LED. The vitamin C content doubles in the cabbages that are stored in the LED compartment; also, phenolic content is 14 % more. Additionally the colour of cabbage leaves remains green for a period four times longer than in a conventional refrigerator.

(Lee et al. 2014: 23) study the effect of white, blue, green, and red LED with a wavelength of 436 nm, 524 nm, and 665 nm respectively on the nutrient quality content of cabbages over a period of 18 days. Their studies show that LED treatment has a positive effect on the nutritional quality of the cabbages compared with those that are stored in darkness. Green and white LED are most efficient in stimulating chlorophyll production, followed by red and blue LED. Blue and white LED are generally better at increasing vitamin C, and play an important role in increasing total phenolic contents as shown in fig. 2. However, the irradiances or photon flux received by the cabbages are not specified, although the electrical power of each LED is provided.

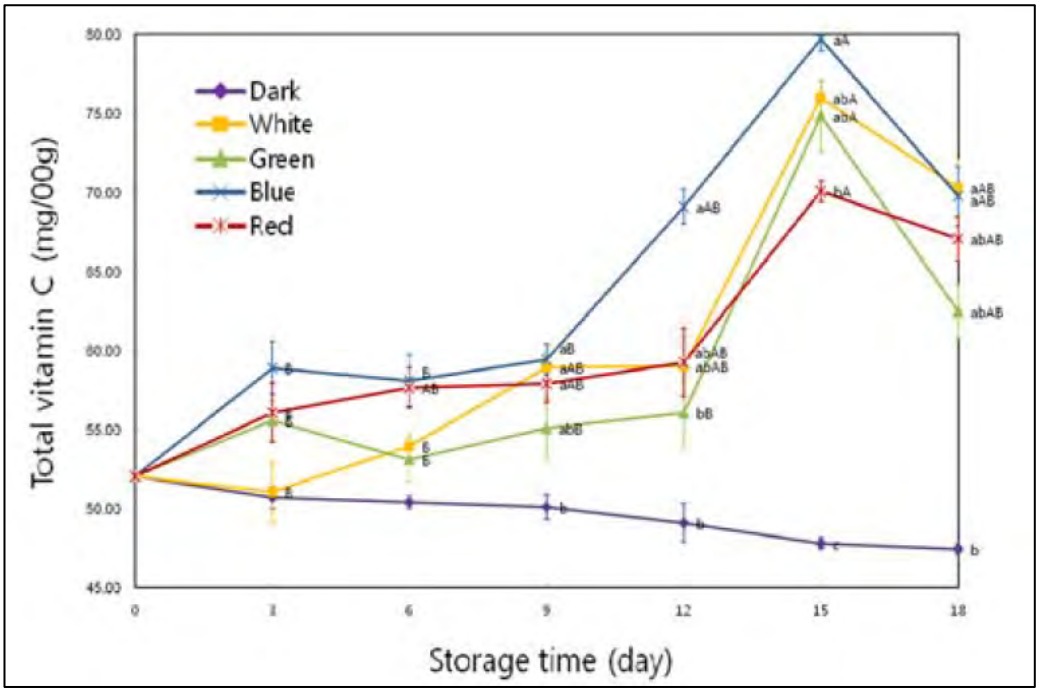

Fig. 2: Vitamin C contents (mg / 100 g) (modified according to Lee et al. 2014: 23)

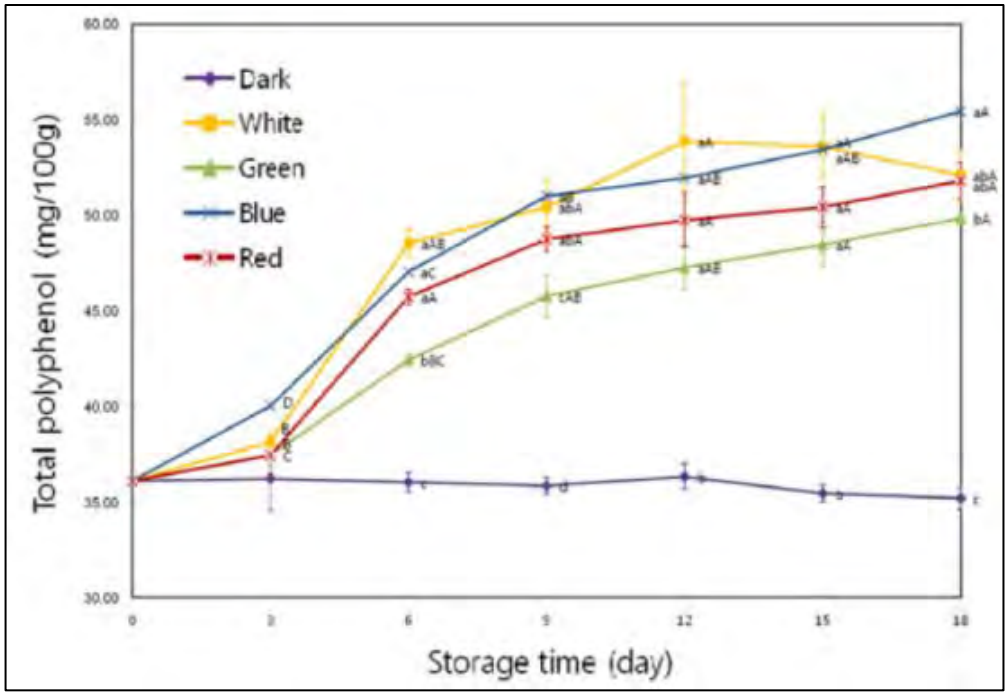

Fig. 3: Total Polyphenol contents (mg / 100 g) (modified according to Lee et al. 2014: 23)

The input of utilized electrical power ranges from 1.0 to 1.5 W for each LED system, which makes it a suitable efficient low-power source system of lighting for a refrigeration system.

This phenomena is successfully integrated by Beko and Blomberg who have introduced “blue light” light-emitting diodes (LED) lighting to the salad drawer of some of their refrigerators (Beko 2016 as shown in Fig 4). This “blue light” technology allows fruits and vegetables to continue to photosynthesize thus prolonging storage life and even increasing vitamin C content.

Fig. 4: Blue light vegetable compartment (modified according to Beko 2018)

LED lighting shows an antibacterial effect, which can help in hindering bacterial destruction of vitamin C (D'Souza et al. 2015: 14).

Conclusion

As LED possess unique properties such as low heat radiant source, emitting monochromatic light, being cheap, and requiring low voltage, refrigerator systems can apply LED for improving nutrient contents of stored vegetables. Additionally, greenhouses use LED successfully for improving crop production and quality. Monochromatic lights can improve the vitamin C and other nutritional content of fruits and vegetables even in refrigerator compartments. Blue LED-light is most effective in improving vitamin C and phenolic content in green vegetables. Beko integrates this technology successfully in refrigerators. However, more research is need to established LED role in improving the vitamin C and other nutritional content of fruits and vegetables in refrigerator compartments. Additionally, the antibacterial effect of LED in preventing spoilage of food and in preserving nutrient quality of food should be studied.

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