

ASSESSING THE EFFECTS OF LED IRRADIATION ON THE VOLATILE COMPOUNDS OF SWEET BASIL (*Ocimum basilicum*)

By

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Abstract

Sweet basil (*Ocimum basilicum* L.) is a commonly grown herb valued for its strong aroma and health benefits, which come mainly from its phenolic and volatile compounds. This study examined how supplemental LED lighting affects the volatile compounds in basil. Fresh leaves were analysed immediately after harvest using SPME combined with GC-MS. Seven volatile compounds were identified, including monoterpenoids, sesquiterpenoids, and phenylpropanoids. The use of LED light clearly changed both the type and amount of these compounds compared to sunlight. Phenylpropanoids, especially methyl chavicol and methyl eugenol, were significantly higher under red LED light, with methyl chavicol being the most dominant. Sesquiterpenoids like α -bergamotene and τ -cadinol increased under red and white LEDs, while α -humulene was higher under red light. Monoterpenoids showed mixed responses, with camphor increasing under white LED and γ -selinene under red LED. These results indicate that LED lighting can enhance the quality and economic value of basil for food, pharmaceutical, and fragrance uses.

Keywords: Sweet basil, Volatile compounds, Light-emitting diode (LED)

Introduction

Plants that contain high levels of secondary metabolites are very important because they help prevent diseases and improve human health. One of such plants is sweet basil (*Ocimum basilicum*), which belongs to the Lamiaceae family. Basil leaves are rich in important compounds such as monoterpenes, flavonoids (kaempferol and rutin), and phenolic acids (rosmarinic acid and caffeic acid). These compounds are responsible for its antioxidant, antiviral, and anti-inflammatory properties (Jokic et al., 2025; Sale et al., 2023). Sweet basil is also a major source of essential oils, including eugenol, thymol, methyl chavicol, and linalool. These compounds give basil its strong aroma and are widely used in the food industry for flavouring (Solouki et al., 2023). In addition, basil is commonly used in cooking, especially in dishes such

as soups, stir-fries, and curries (Changsawake et al., 2015). Due to these benefits, there is increasing interest in improving the phytochemical quality and shelf life of basil leaves.

Light plays an important role in plant growth, yield, and the production of secondary metabolites (Ouzounis et al., 2015). Plants use light within the photosynthetically active radiation (PAR) range of 400–700 nm, which includes red, blue, and white light (Jokic et al., 2025). Light-emitting diodes (LEDs) are widely used in plant production because they consume less energy, produce less heat, and can provide specific light wavelengths that influence plant responses (Liu, 2012). For example, blue light can increase the production of phenolic compounds by inducing mild stress in plants (Iwai et al., 2010). The use of supplemental LED lighting can also extend the light period, improve plant growth, and increase yield (Rahman et al., 2021). Previous studies have shown that combining different light spectra can improve antioxidant levels and nutritional quality in crops such as lettuce and basil (Da Young et al., 2025; Hooks et al., 2022; Solbach et al., 2021). For instance, red and blue LED lighting has been reported to increase phenolic compounds and antioxidant activity more effectively than shorter light durations (Kaur et al., 2022). However, limited studies have focused on how preharvest LED lighting affects postharvest quality, especially the essential oil composition of basil. Therefore, this study aims to evaluate the effect of preharvest LED lighting on the postharvest quality of essential oils in sweet basil.

Materials and Methods

Plant Material and Growing Conditions

Sweet basil (*Ocimum basilicum* L.) seeds were grown in a greenhouse from July to September 2022. After one month, the seedlings were transplanted into bags (20 × 24 cm) containing soil (pH 7.3; EC 642.7 $\mu\text{S cm}^{-1}$) and 0.5 g of NPK (16:16:16) fertilizer. Two weeks after transplanting, the plants were exposed to different light treatments: sunlight, white LED, red LED (660 nm), blue LED (455 nm), and red + blue LED at an intensity of 100 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Light intensity was adjusted using a quantum meter, while spectral properties were measured with a spectroradiometer. Plants received 12 h of sunlight and 6 h of supplemental LED light daily (18:00–24:00). Watering was done every morning, and the average greenhouse temperature was 32.5 °C.

Analysis of Volatile Compounds

Fresh basil leaves were analyzed immediately after harvest before storage using a modified method of Sale et al. (2023). Volatile compounds were determined using gas chromatography-mass spectrometry (GC-MS) combined with headspace solid-phase microextraction (SPME). About 0.1 g of sample was placed in a 20 mL vial, and volatiles were extracted using an SPME fibre for 20 minutes with the help of an autosampler. The absorbed compounds were then released into the GC injection port at 240 °C for 5 minutes in splitless mode. Separation was carried out using a DB-5ms capillary column, with helium as the carrier

gas at a flow rate of 0.5 mL/min. The oven temperature started at 50 °C, increased gradually to 210 °C, and was held for 2 minutes. Data were analyzed using ChemStation software, and compounds were identified by comparing their mass spectra with Wiley and NIST libraries, using a minimum match of 90%.

Result and Discussion

Effect of supplemental LEDs on volatile compounds

The volatile compound composition of sweet basil was analyzed under different light sources, and the findings are presented in Table 1. A total of 7 compounds were detected, comprising 2 monoterpenoids, 3 sesquiterpenoids and 2 phenylpropanoids. Our findings indicate that the use of LED treatments enhanced the accumulation of volatile compounds while inhibiting the synthesis of specific compounds (Carvalho et al., 2016). A comparison between basil grown under LEDs and sunlight demonstrated a significant rise ($p < 0.05$) in the levels of phenylpropanoids and sesquiterpenoids classes in basil subjected to LED light. Photoreceptor families like phototropins and cryptochromes are responsible for perceiving blue light and mediating a range of plant responses, including the regulation of stomatal opening, phototropism, movement of chloroplast, and gene expression (Davis and Burns, 2016). Red light, on the other hand, is sensed by phytochromes and influences photobiological responses like germination and leaf expansion. Activation of cryptochromes and phytochromes can lead to the upregulation of the shikimate and mevalonate (MVA) pathways (Ahmadi et al., 2021), which in turn affects the production of sesquiterpenoids derived from isopentenyl pyrophosphate and dimethylallyl pyrophosphate. LED light stimulates photosynthesis, resulting in increased glucose production and influencing the synthesis of phenylalanine, a primary amino acid precursor for phenylpropanoid metabolism and the synthesis of isopentenyl pyrophosphate and dimethylallyl pyrophosphate (Pech et al., 2022; Vavitsas et al., 2018). Methyl chavicol and methyl eugenol, both belonging to the phenylpropanoids group, exhibited significantly higher levels in basil plants cultivated under red LEDs in comparison to those raised under sunlight. Among all the detected compounds, methyl chavicol showed the highest concentration. Specifically, the red LED treatment significantly elevated the concentrations of methyl chavicol compared to sunlight. Methyl chavicol, also known as estragole, is a naturally occurring organic compound ($C_{10}H_{12}O$) renowned for its pleasant, anise-like fragrance. It is commonly utilized as a flavoring agent in the food and beverage industry, and it has also been studied for its potential antioxidant activity and its role in disease management. Methyl chavicol can be found in various plants, including sweet basil (Lewinsohn et al., 2000). Similar findings were reported by Aldarkazali et al. (2019), demonstrating that red LEDs can enhance the production of linalool, eugenol, and E-cinnamate in sweet basil.

The effect of LED light on sesquiterpenoids also exhibited variations. α -Bergamotene levels was increased with red and blue LED light, while α -humulene was enhanced with red LED light. White LED and red LED lights, however, favored the production of τ -cadinol, which

had the highest concentration among the sesquiterpenoids. τ -Cadinol is widely valued in the food and cosmetics industries for its unique and fragrant odor, and it also shows potential clinical applications for treating gastric spasms and vasospasm diseases (Sun et al., 2022). The observed response pattern to the LED spectrum is consistent with the results reported by Sale et al. (2023), who found that blue light enhanced the total essential oil content, whereas red light diminished it in basil plant. Several studies have demonstrated that different LEDs induce the biosynthesis of various sesquiterpenoids in plants. For instance, an increase in sesquiterpenoids was reported under red + blue LED treatment in thyme and lemon balm (Tohidi et al., 2019; Ahmadi et al., 2021; Sale et al., 2023), and under blue LED treatment in perovskia (Ghaffari et al., 2019). Red and blue LEDs are light spectra that are highly assimilated by photosynthetic pigments, stimulating the production of phytochemicals and the subsequent accumulation of primary and secondary metabolites (Thoma et al., 2020). Consistent with our own findings, Wang et al. (2015) also highlighted the crucial roles of red and blue wavelengths in promoting plant growth and development through photosynthesis. According to Ahmadi et al. (2021), LED lighting promoted the levels of sesquiterpenes including β -caryophyllene, α -humulene, germacrene-D, β -ionone, and β -cubebene, while inhibiting the biosynthesis of caryophyllene epoxide, calamenene, and α -muurolene.

Monoterpenes exhibit different responses to various light sources. In the case of camphor, their levels were increased when basil was exposed to white LED light where as γ -Selinene by red light. Monoterpenes such as, γ -Selinene and linalool play a significant role in treating various conditions like depression, inflammation, convulsion, viral and bacterial infections (Salakhutdinov et al., 2017). The composition of volatile compounds in vegetables is affected by various factors, such as environmental conditions (Fernandes et al., 2013), light duration, intensity (Shafiee-Hajjabad et al., 2016), and spectrum (Li and Kubota, 2009). Most plant species possess acclimation mechanisms to adapt to different light conditions which can include altering their volatile constituents. This could be considered as a potential mechanism through which sweet basil reacts to sunlight (Zhang et al., 2003; Sale et al., 2023).

Table 1 Volatile compounds identified in basil leaves grown under sunlight and different supplemental light-emitting diode (LED) treatments

Kovats index (RI)	Compounds	Overall peak area ($\times 10^7$)			
		Sunlight	White LED	Red LED	Blue LED
<i>Monoterpenoids</i>					
1031	Camphor	1.86 \pm 0.19 ^{ab}	2.47 \pm 0.54 ^a	1.82 \pm 0.25 ^{ab}	1.20 \pm 0.16 ^b
1410	γ -Selinene	4.04 \pm 0.14 ^{ab}	5.05 \pm 1.03 ^{ab}	6.38 \pm 1.37 ^a	3.39 \pm 1.42 ^b

<i>Sesquiterpenoids</i>					
1404	α -Bergamotene	8.98±0.10 ^b	12.35±2.40 ^{ab}	10.87±0.56 ^{ab}	10.38±0.78 ^{ab}
1407	α -Humulene	4.26±1.08 ^c	4.85±0.11 ^b	5.19±1.62 ^a	4.57±0.71 ^b
1506	τ -Cadinol	10.08±0.43 ^c	16.83±0.33 ^a	17.90±1.36 ^b	11.23±1.04 ^c
<i>Phenylpropanoids</i>					
1201	Methyl chavicol	54.55±5.03 ^c	62.80±4.21 ^b	67.61±7.83 ^a	54.79±7.07 ^c
1401	Methyl eugenol	15.06±1.65 ^c	23.27±1.50 ^{ab}	28.91±2.69 ^{bc}	25.75±3.22 ^a

Data represent the means of triplicate analysis for each sample \pm standard errors. Values with the same letters (a, b, c,) within rows are not significantly different at $p \geq 0.05$ confidence level following Duncan's Multiple Range Test.

Conclusion

This study shows that using LED light can improve the quality of sweet basil by increasing important aroma compounds. Red LED worked best, especially in increasing methyl chavicol, which was the highest compound found. White and red LEDs also helped to increase other useful compounds like τ -cadinol and α -bergamotene. In general, basil grown under LED performed better than the one grown under normal sunlight. This means that using the right type of LED light, especially red light, can help farmers and researchers produce better quality basil with stronger aroma and higher value for food, medicine, and other uses.

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