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The impact of color of artificial LED lighting on microgreen: a review

Abstract. Microgreen is an emerging agricultural food product that its development can be close type system and rely on the presence of artificial lighting, such as LED. Present study aimed to sum up the artificial LED lighting impact on microgreen production. In general, there were three important variables of light for plant, i.e., light intensity, light duration/photoperiod and light quality. The effect of different LED color on microgreen yield and phytochemical content is also revealed in present review. The red, blue, combination of red and blue, green, white, yellow and UV-A light are numerous choice for optimal microgreen production. However, there is no one-to-all recommendation here, since the LED light suitability is depending upon the plant species and target of market.

Keywords: Artificial lighting · LED color · Microgreen · UV-A light

Dampak warna pencahayaan buatan LED pada microgreen: ulasan

Sari. Microgreen adalah produk pangan pertanian yang sedang marak dikembangkan dan dapat diproduksi dalam sistem tertutup dengan dukungan pencahayaan buatan seperti LED. Penelitian ini bertujuan untuk mereview dampak penggunaan pencahayaan buatan LED terhadap produksi microgreen. Pada umumnya, terdapat 3 peubah penting cahaya untuk tanaman yakni intensitas cahaya, panjang hari/fotoperiodisitas dan kualitas cahaya. Pengaruh dari perbedaan warna LED terhadap hasil panen dan kandungan fitokimia microgreen dijelaskan pada artikel review ini. Lampu merah, biru, kombinasi merah dan biru, hijau, putih, kuning dan UV-A merupakan berbagai pilihan untuk produksi microgreen yang optimal. Namun tidak ada rekomendasi yang bersifat umum, karena kesesuaian LED bergantung pada faktor jenis tanaman dan target pasar.

Kata kunci: Pencahayaan buatan · Warna LED · Microgreen · Lampu UV-A

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Background

Microgreen is a trending food that has begun to be developed and marketed in recent years (Riggio *et al*., 2019a; Kyriacou *et al*., 2017; Stoleru *et al*., 2016; Xiao *et al*., 2012). Microgreen is another step further than sprouts (Wallin, 2013; Verlinden, 2020), forming an immature plant with good taste, interesting color and tender texture that highly suitable to sandwich, salad and others healthy dishes (Renna *et al*., 2017; Xiao *et al*., 2016; Turner *et al*., 2020). Due to its importance, this food product is highly demanded by urban society. In addition, this product can be categorized as a functional food, since its ingredient can prevent certain diseases such as obesity, diabetes and cancer (Choe *et al*., 2018).

Microgreen of red amaranth (*Amaranthus tricolor* L.), China red rose radish (*Raphanus sativus* L.), and peppercress (*Lepidium bonariense* L.) are considered to have good to excellent level of nutritional quality and consumer acceptance aspect (Xiao *et al*., 2015). Additionally, some researchers have reported higher nutrient content in the form of microgreens compared to whole vegetables, such as in red cabbage (*Brassica oleracea* L. var. capitata), coriander (*Coriandrum sativum* L.), spinach garnet (*Amaranthus hypochondriacus* L), and green radish (*Raphanus sativus* L. var. longipinnatus) (Xiao *et al*., 2012), kale (*Brassica oleracea* var. sabellica), broccoli (*Brassica oleracea* var. italica), and cauliflower (*Brassica oleracea* var. botrytis) (Xiao *et al*., 2019), lettuce (*Lactuca sativa*) (Pinto *et al*., 2015), wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) (Niroula *et al*., 2019) as well as 30 plant cultivars from the Brassicaceae family (Xiao *et al*., 2016).

Aside its rich phytonutrient and minerals, microgreen is categorized as low harmful nitrate residue agricultural product so that more safe to consume in order to fulfil healthy diet requirements (Treadwell *et al*., 2010; Rajan *et al*., 2019). Numerous plant species are exploited to be microgreen (Abellan *et al*., 2019; Benincasa *et al*., 2019; Di Gioia *et al*., 2017; Di Gioia *et al*., 2015; Xiao *et al*., 2016; Palmitessa *et al*., 2020), however, most of them are derived from Brassicaceae, Fabaceae and Poaceae famili. In addition, there is still open opportunity to exploit more species in leafy vegetables, fruity vegetables, and herbs as microgreen materials, especially any species locally found in Indonesia and Southeast Asian.

The production of microgreen takes shorter time than conventional vegetables. The formation and fully opening of first true leaf is indicator of harvesting schedule for most of microgreen (Turner *et al*., 2020). The development of microgreen production in overseas is generally carried out in a closed room of a precision farming system, for example in a controlled culture laboratory (Riggio *et al*., 2019b). The production system in a closed space requires the support of artificial light, alike light-emitting diode (LED), due to the limitation of sunlight exposure. There is an urgency to have a brief review that sum up the artificial LED lighting effect on microgreen.

Light in General

Light is one of plant daily needs for their growth and development. The absence of light is only favourable in a short germination step, while at further stage it can bring detrimental effect of growth performances and yield. There are three variables of light that frequently reported to influence the plant growth and development, i.e., light intensity, quality, and duration/photoperiod.

Light intensity is frequently indicated by photosynthetic photon flux density (PPFD) variable and expressed in the unit of μmol m^{-2} s^{-1}. Microgreen growth was optimally achieved in light intensity of 300 μmol m^{-2} s^{-1} (Jones-Baumgardt *et al*., 2019) or 330–440 μmol m^{-2} s^{-1} specifically for Brassica species (Samuoliene *et al*., 2013). Lower light intensity, in range of 110 to 220 μmol m^{-2} s^{-1} was used to gain the α tocopherol and ascorbic acid content of microgreen (Samuoliene *et al*., 2013). For arugula (*Eruca vesicaria* ssp sativa), kale (*Brassica oleracea* var. sabellica), cabbage (*Brassica oleracea* var. capitata), (Kong *et al*., 2019), calibrachoa (*Calibrachoa parviflora*), marigold (*Tagetes erecta* Linn), geranium (*Geranium* sp.) and petunia (*Petunia* sp.) (Kong *et al*., 2018). The light intensity of 50-100 μmol m^{-2} s^{-1} is reported to have growth promotion effect.

Another important light variable is light duration, also known as photoperiod, that is defined as the number of day to dark time. In tropical condition, the land is commonly exposed to 12 hours of day and 12 hours of dark. The combination of lower light intensity and longer lighting time resulted in a good yield as indicated by a larger leaf area, while the higher light intensity followed by shorter lighting time tended to produce good quality of spinach as indicated by its nutritious and tasteful characters (Zou *et al*., 2020).

Another variable is the light quality that could be indicated by the ratio between red and blue light. Light quality was reported to affect the growth, morphology, color, flavor, and nutrition of plant (Kyriacou *et al*., 2016). The effect of three mentioned light variables was through the alteration on morphogenesis, metabolic and photosynthetic apparatus functionality (Wang *et al*., 2017). In spinach, earlier study reported the order from the most to the least influential light factor as photoperiod, light intensity and light quality (Zou *et al*., 2020). However, previous study by Bian *et al*., (2015) reported opposite result than light quality was more complex effects than light duration and intensity.

There is an absence of sunlight in close room agriculture system, therefore there is a need to set the artificial lighting for plant over there. The advantage of artificial light usage was the opportunity to make light customization by using specific spectral composition to meet plant need, leading to the gain of yield in both quantity and quality (Morrow, 2008). Light management was required to (i) achieve energy efficiency (Bian *et al*., 2015), and (ii) avoid the photo-negative effect such as high-light condition that could impede plant growth and eventually yield (Kopsell *et al*., 2012; Walters, 2005). The choice of artificial light is important step to prepare good and nutritious microgreen. Earlier reports had been underlined the different content of phytochemicals in response to different LEDs supplementation (Samuoliene *et al*., 2011; Loedolff *et al*., 2017; Brazaityte *et al*., 2015a; Rahmani *et al*., 2021).

Red light

Artificial red light in form of red LED is successfully proved to have positive effect on microgreen production and quality, i.e., growth stimulative and phytochemical accumulative effect, that seemed to be vary in differs genotype (species-dependent). The red light improved photosynthesis (Alrifai *et al*., 2019), leaf macro nutrient status (Brazaityte *et al*., 2018), hypocotyl length (Brazaityte *et al*., 2021) and the accumulation of certain phytochemical such as carotenoid in pea (*Pisum sativum*) (Wu *et al*., 2007), red pak choi (*Brassica rapa*) and taksoi (*Brassica rapa* subsp. narinosa) (Choi *et al*., 2015); soluble solids and vitamin C in buckwheat (*Fagopyrum esculentum*) (Choi *et al*., 2015), mineral accumulation in lettuce (*Lactuca sativa*) (Amoozgar *et al*., 2017), basil (*Ocimum basilicum*) (Pennisi *et al*., 2019) and marigold (*Tagetes erecta*) (Sams *et al*., 2016). In addition, the lighting by using red LED, commonly with a wavelength of 638 nm, was reported to elevate ascorbic acid and anthocyanin level in microgreen of purple mint (*Perilla frutescens* var. cripsa) (Brazaityte *et al*., 2013). Interestingly, this kind of light could be used to decrease the nitrate content on leaf, due to the amplification of nitrate reductase activity (Ohashi-Kaneko *et al*., 2007).

Blue light

In general, the blue light solely was also positively promote the plant growth through photosynthesis booster effect, leading to faster harvesting schedule (Yoshida *et al*., 2016). Moreover, the blue LED lighting was proved to be able to increase both the area and fresh weight of microgreen cotyledon, as well as the content of functional phytochemicals, such as anthocyanin, chlorophyll, phenolic content, and free radical scavenging activity (Lobiuc *et al*., 2017), carotenoids (Samuoliene *et al*., 2017), glucosinolates, mineral elements (Kopsell and Sams, 2013; Kopsell *et al*., 2015), shoot tissue pigment (Kopsell *et al*., 2015), vitamin C and total soluble solids (Choi *et al*., 2015). Interestingly, Kopsell *et al*. (2014) reported the nutrient dense character in microgreen cultured under blue light. This nutrient rich condition was associated with the amplification of membrane transport activity and stomatal opening (Wu *et al*., 2007; Kopsell *et al*., 2014). To overcome nitrate residue issue in several case of leafy vegetable, the use of blue lighting treatment was strongly recommended to apply at 3 days prior harvesting schedule is reported to reduce nitrate content (Simanavicius and Virsile, 2018).

Combination of red and blue light

Not only red and blue light solely, but also the combination of both lights was effective to reduce nitrate residue in vegetable plant (Ohashi-Kaneko *et al*., 2007). The combination of blue and red LED in one lighting board was popular practice in horticulture industry, including microgreens (Ying *et al*., 2020; Jones-

Baumgardt *et al*., 2019; Massa *et al*., 2008). Earlier study showed the success of blue-red combination to enhance growth, yield, and pigment content in terms of chlorophyll and carotenoid (Madar *et al*., 2022). Previous study revealed red to blue light ratio of 95 : 5 and 85 : 15 as the best option to have optimal cotyledon area and hypocotyl length in mustard (*Brassica nigra*) and kale (*Brassica oleracea* var. sabellica) microgreen (Ying *et al*., 2020). The red : blue light ratio of 85 : 15 was also reported to be success for increasing the fresh weight of Brasiccaceae microgreen (Jones-Baumgardt *et al*., 2019). Interestingly, the elevation of chlorophyll content in cucumber (*Cucumis sativus*) leaf was also reported to be the effect of blue light proportion improvement to 50% in the red : blue light combination treatment (Hogewoning *et al*., 2010). Different proportion of blue to red light in the lighting equipment also caused different phytonutrient content on basil (*Ocimum basilicum*), pakchoi (*Brassica rapa* subsp. chinesis) and tatsoi (*Brassica rapa* subsp. narinosa) microgreens (Vastakaite *et al*., 2015). In more specific, the content of carotenoid on beet (*Beta vulgaris* subsp. vulgaris) microgreen could be increased by the blue light proportion improvement up to 33% in the combination of blue : red lighting (Samuoliene *et al*., 2017).

Other lights

Aside red, blue and combinations of both light, there were several studies reported the use of green, white, yellow and UV-A light. Green light with a wavelength of 520 nm was reported to gain the phytonutrient such as b-carotene in mustard (*Brassica nigra*) microgreens, (Choi *et al*., 2015). Greenlight was also control the production of anthocyanin content in red and green leaf color of microgreen (Carvalho and Folta, 2016). White LED with a PPFD for about 400–600 μmol m^{-2} s^{-1} was successfully increase the leaf crown biomass of lettuce (*Lactuca sativa*) (Lin *et al*., 2013). Aside plant biomass, white LED also alter the phytochemical composition, by increasing zeaxanthin content in mustard (*Brassica nigra*) microgreens (Kopsell *et al*., 2012) and soluble solids and vitamin C content in buckwheat (*Fagopyrum esculentum*) microgreen rather than dark/control treatment (Choi *et al*., 2015). However, in certain case, the used of white LED solely is less effective strategy to improve yield and quality. The use of white and yellow were reported to less effective in reducing nitrate concentration rather than red, blue and combination of both lights (Ohashi-Kaneko *et al*., 2007). Far red supplemented in white light resulted the significant gain on harvested weight of lettuce (*Lactuca sativa*) than only white light treatment (Li and Kubota, 2009).

Another supplemental light ever reported on microgreen production is the Ultraviolet-A (UV-A) light. The UV-A is a range of light with a wavelength of 315 to 400 nm that could displays both inducer of inhibitor effect for plant growth and development (Verdaguer *et al*., 2016). The application of UV-A at 366 and 390 nm was reported to increase the activity of antioxidant (Brazaityte *et al*., 2015b) and the content of ascorbic acid, anthocyanins and phenol of several microgreens (Brazaityte *et al*., 2015a). Similar finding by Vastakaite *et al*. (2015), also reported the antioxidant improvement as the impact of supplemental UV-A LED lighting on 7-14 days prior to harvest.

Conclusion

Microgreen production under closed type system requires suitable artificial LED setting. The present study review several important variables of light for plant and the effect of different LED colors on microgreen yield and phytochemical content. The red, blue, combination of red and blue, green, white, yellow and UV-A light are numerous choice for optimal microgreen production. Determination of suitable LED color should be made by considering the species and targeted phytochemicals on cultivated microgreen.

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