LED Continuous Lighting Reduces Nitrate Content in *Brassicaceae* Microgreens

Alexandra A. Rubaeva, *Elena G.* Sherudilo, and *Tatjana G.* Shibaeva*

Institute of Biology, Karelian Research Center of RAS, 185910 Pushkinskaya, 11, Petrozavodsk, Russia

Abstract. The study was carried out to assess whether continuous lighting (CL) can be used to reduce nitrate content in *Brassicaceae* microgreens. Arugula (*Eruca vesicaria* subsp. *sativa*), broccoli (*Brassica oleracea* var. *italic),* mizuna *(Brassica rapa* var. *nipposinica*) and radish (*Raphanus sativus* var. *radicula*) seedlings were grown in the controlled climate chambers under 16 h or 24 h photoperiod provided by light-emitting diode (LED) or fluorescent (FLU) lamps. At the pre-harvest stage, half of microgreens were treated by CL for 3 days. The results show that nitrogen content was decreased significantly in plants grown under LED CL compared to plants grown under 16 h photoperiod. The highest decrease (by 40 %) was observed in arugula microgreens. In contrast, CL provided by FLU lamps had little effect (decrease by 11 and 6 %) on nitrate content in mizuna and broccoli and no effect in arugula and radish. Pre-harvest treatment by CL resulted in significant decrease of nitrate content in all four plant species. In conclusion, continuous LED lighting applied during microgreen cultivation or at the pre-harvest stage effectively reduces nitrate content in *Brassicaceae* microgreens.

1 Introduction

Microgreens have gained the popularity as a "functional" food and culinary ingredient due to their high nutritional quality, intense flavor, color, and tender texture [1]. Our previous study [2] has shown that *Brassicacea* microgreens can be grown under continuous lighting (CL) without developing leaf light-induced injuries, such as chlorosis and necrosis. Arugula, broccoli, mizuna and radish microgreens treated by CL had higher robust index and yield. Moreover, they had higher nutritional value than plants grown under 16 h photoperiod due to higher accumulation of such antioxidative phytochemicals as proline, carotenoids, flavonoids anthocyanins and higher antioxidant enzyme activity. The differences between photoperiodic treatments (16 and 24 h) were greater in plants grown under light-emitting diodes (LED) than under fluorescent (FLU) lamps. It was concluded that CL-treated plants gained additional nutritional value due to increased antioxidative status. Treatment by Cl before harvest is also suggested as the technique that can allow microgreen growers to increase yield, enhance aesthetic appeal and nutritional quality, and make their market value higher [3]. However, one of the main criteria for "functional

* Corresponding author: shibaeva@krc.karelia.ru

foods" is its safety. Leaf vegetables grown by soilless techniques can accumulate high levels of nitrate [4]. Under conditions of low light and excessive mineral nutrition there can be the situation when the rate of nutrient uptake exceeds the rate of their chemical reduction. This may result in the significant increase of nitrate content [5]. Nitrates ions serve as one of the major sources of nitrogen nutrition for plants and therefore have positive effects on the yield and quality of vegetables. Although nitrates even in high concentrations are not toxic to plants, in the human body their excess is harmful [6]. Therefore, food safety requires the control of nitrate content in edible plants, in particular in microgreens.
It has been shown that concentration of nitrates in plant tissue can be affected by photoperiod, light intensity and its spectral quality [7-9]. The goal of this study was to reveal whether CL provided by LED or FLU lamps may reduce nitrate content in *Brassicaceae* microgreens.

2 Materials and methods

Radish (*Raphanus sativus* var. *radicula* Pers.), broccoli (*Brassica oleracea* var. *italic* Plenck*),* mizuna *(Brassica rapa.* var. *nipposinica* (L.H.Bailey) Hanelt) and arugula (*Eruca vesicaria* subsp. *sativa* (Mill.) Thell.) were grown on coconut coir mats at a temperature of 23°C and relative air humidity of 60%. First three days after sowing growing containers were placed in darkness and seedlings were irrigated with water. Once cotyledons were fully expanded, a half-strength Hoagland nutrient solution (pH 6.2–6.4) was added to each container daily.

In Experiment 1 from the 4th day after sowing four light treatments were set until harvest: (1) 16 h photoperiod provided by FLU lamps (F36W/T8 BRITEGRO, Sylvania, Germany); (2) 16 h photoperiod provided by LEDs (LED GL V300, China); (3) 24 h photoperiod provided by FLU lamps; (4) 24 h photoperiod provided by LEDs. LED light ratio (%) of red:green:blue (RGB) was 50.3:21.1:17.6. The PPFD of 270 μmol m^{-2} s^{-1} was used in all treatments. Plants were harvested on the 11th day. In Experiment 2 plants were grown under 16 h photoperiod with the PPFD of 270 μmol m^{-2} s^{-1} provided by LEDs and on day 8 after sowing (in the end-of-production (EOP) period) half of plants were transferred to 24 h photoperiod with the same PPFD, where were kept for 3 days until harvest.

Nitrate content was measured by using potentiometer (Anion-4100, Infraspak-Analit, Russia) with ion-selective nitrate and silver chloride electrodes. Dry shoot tissue (0.3 g) was dissolved in 15 ml of a 1% potassium aluminium sulphate solution and stirred for 5 min. Then the values of the electromotive force of the solution and pNO3- were recorded. The results are presented in mg/kg fresh weight (FW).

The experiments were carried out twice. The figures show the mean values and standard errors. Differences between the mean values was considered significant at $P < 0.05$.

3 Results

Microgreen plant treated by LED CL during 8 days had significantly lower nitrate content than plants exposed to 16 h photoperiod (figure 1a). Nitrate content was decreased by 40, 36, 10 and 16% in arugula, mizuna, radish and broccoli, correspondingly. In contrast, the effect of FLU CL treatment on nitrate content was less pronounced. Thus, nitrate content was reduced by 11 and 6% in FLU CL-treated mizuna and broccoli, but not affected in arugula and radish (figure 1b).

Pre-harvest treatment of plants by CL significantly (by 19-24%) reduced nitrate content in all four microgreens (figure 2).

4 Discussion

The present study was undertaken with the aim to reveal if CL (LED or FLU) can reduce nitrate accumulation in several *Brassicaceae* microgreens. Our results show that LED CL strongly affects the nitrate content both when applied during production period and at preharvest stage. This result corresponds to that obtained by Bian et al. [10] who found that nitrate accumulation in lettuce can be decreased by growing plants under continuous red and blue LED lighting at preharvest stage. In the other study [11], nitrate content was reduced by 56 and 20% in red and green lettuce, respectively, by treating plants with red LED for 3 days in the end of the production period. It was also reported spectral composition may affect nitrate accumulation. Thus, effects of white LED were less pronounced than RB and RGB LEDs [10]. Nitrate content in leaf lettuce grown under Treatment of lettuce plants by white FLU light has resulted in much greater nitrate content than compared to red or blue FLU light [12]. In our study FLU lams were also less effective in reducing nitrate accumulation than RGB LED lamps.

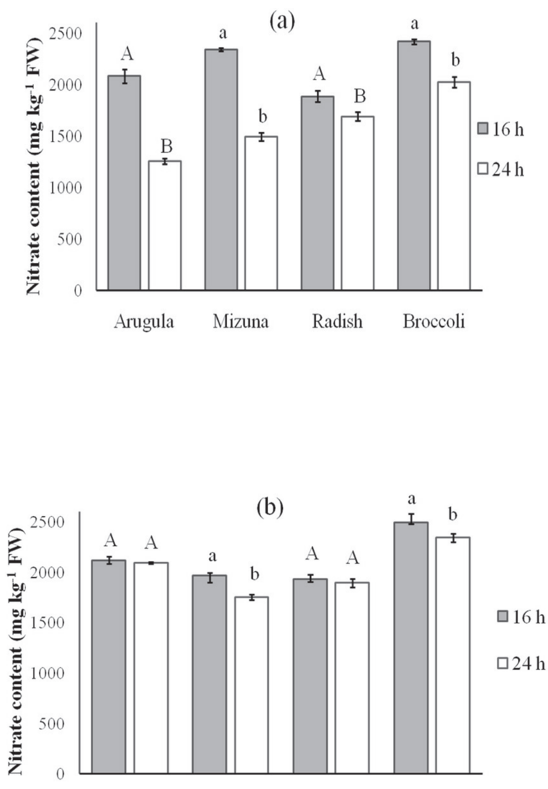

Fig. 1. Nitrate content of arugula, mizuna, radish and broccoli microgreens exposed to 16 h or 24 h photoperiod provided by (a) LED or (b) fluorescent lamps.

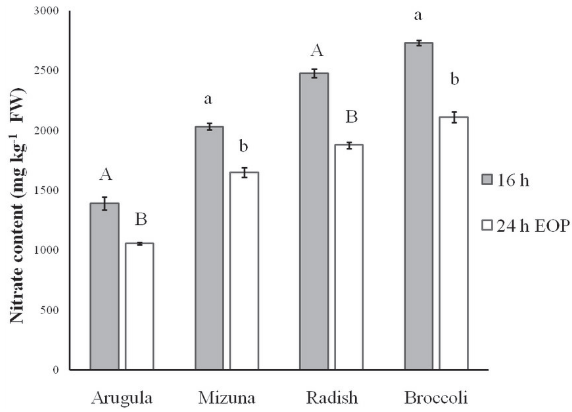

Fig. 2. Nitrate content of arugula, mizuna, radish and broccoli microgreens exposed to 16 h photoperiod during the whole production period or treated in the end-of-production by 24 h photoperiod (24 h EOP).

One of the possible explanations of the decreased nitrate content in CL-treated plants can be related to increased carbohydrate synthesis under CL conditions. It may lead to increased supply of ferredoxin and NADPH, that are used for nitrate reduction in leaves [9]. Another reason is that CL may increase the activity of nitrate reductase and, consequently, the reduction of nitrate [4]. The question of how different light spectra cause changes in nitrate content remains open.

5 Conclusion

This research was carried to investigate the effects of CL (LED and FLU) to four *Brassicacea* microgreen species. CL provided by LEDs significantly decreased nitrate content in arugula, broccoli, mizuna and radish microgreens. CL provided by FLU lamps had much weaker or no effect on nitrate content depending on the plant species. LED CL applied only 3 days before harvest has also significantly reduced nitrate content in all four microgreens. Results of this study show that LED CL can be used to decrease nitrate concentration in microgreens. Microgreens that are used as functional foods may gain additional value due to reduction of harmful for human health substances. This study also confirms that nitrate metabolism is affected by light spectra.

The reported research was funded by Russian Science Foundation, project number 23-16-00160. The Core Facility of the Karelian Research Centre of RAS was used. We are particularly grateful for the assistance given by Kseniya M. Nikerova.

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