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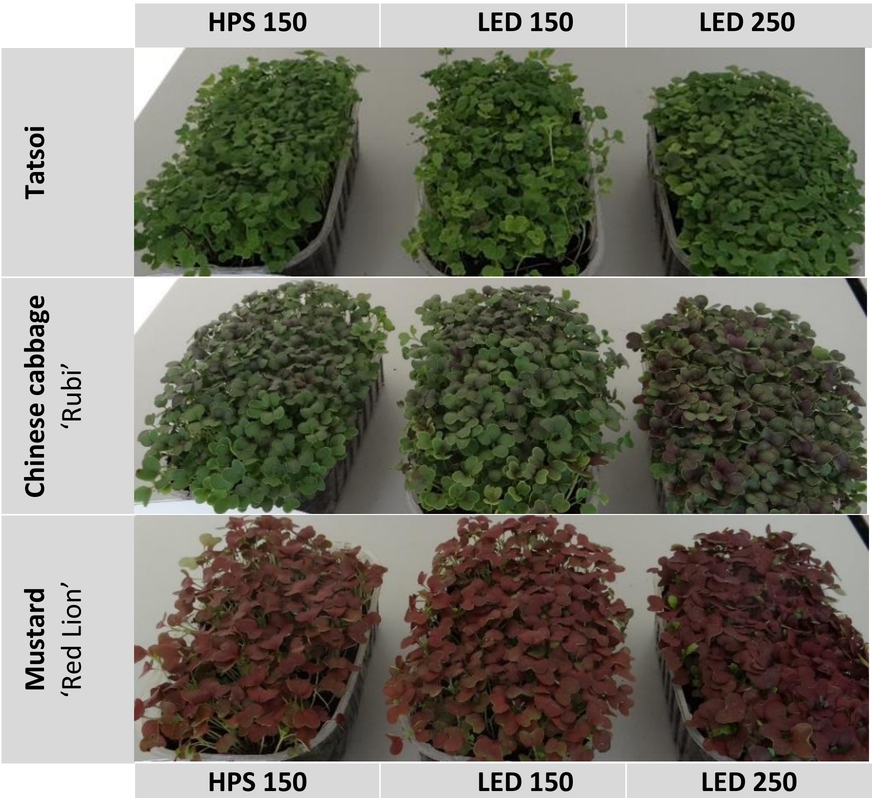
Microgreens –a new, specific type of green vegetables, treated as functional food. These are the young sprouts of different vegetables, consumed as food just after the formation of cotyledons or at the emergence of first true leaf. Cabbages, beetroots, mustards, radishes, basils and other plants of different taste and texture are cultivated as microgreens.

It is stated, that the contents of phytochemical compounds in microgreens are higher, compared to mature plants[1]. However, sensible nature of microgreens decides, that environmental factors, especially suitable lighting, changes their growth parameters and affects synthesis or degradation of phytochemical compounds, thus determining their nutritional value and taste properties. Microgreens are often cultivated in greenhouse in winter period, when natural lighting is not sufficient or in closed growth chambers, in shelves, where the intensity and spectra of artificial lighting are the main critical factors for their internal and externa quality. Moreover, when the distance between plants and light source in limited, LED lighting is the main choice, as they do not emit radiant heat and thus does not heat plants.

HLFC series lighting for microgreen cultivation in growth chambers

Experiments were performed in LRCF Institute of Horticulture, phytotron chambers with HLFC series LED lamps and high pressure sodium (HPS) lighting - the most common in greenhouse horticulture

Fig. 1. Different microgreens, raised under HLFC series LED or HPS lamps, when photosynthetic photon flux density was 150 and 250 μmol m^{-2} s^{-1}



[1] Xiao et al. 2015. Evaluation and correlation of sensory attributes and chemical compositions of emerging fresh produce: Microgreens. Postharvest Biology and Technology 110: 140–148.

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It was determined, that LED lighting helps to raise qualitative microgreens, characterized by compact morphology (Fig. 1, table 1). Even if seeds are sown in high density, microgreen hypocotyls are not too elongated, does not fall down, because HLFC LED lighting eliminates the concurrence of young sprouts for lighting. High nutritional value is also determined by high concentrations of ascorbic acid, phenolic compounds, and pigment, responsible for cotyledon coloration, contents (Fig. 1, 2). Microgreens raised under LED illumination distinguishes by more intense leaf color and richer taste properties.

Fig. 2. Biochemical parameters of microgreens, cultivated under HPS and HLFC series LED lamps. Photosynthetic photon flux density – 150 ir 250 µmol m^{-2} s^{-1}. Results are presented in green microgreen matter.

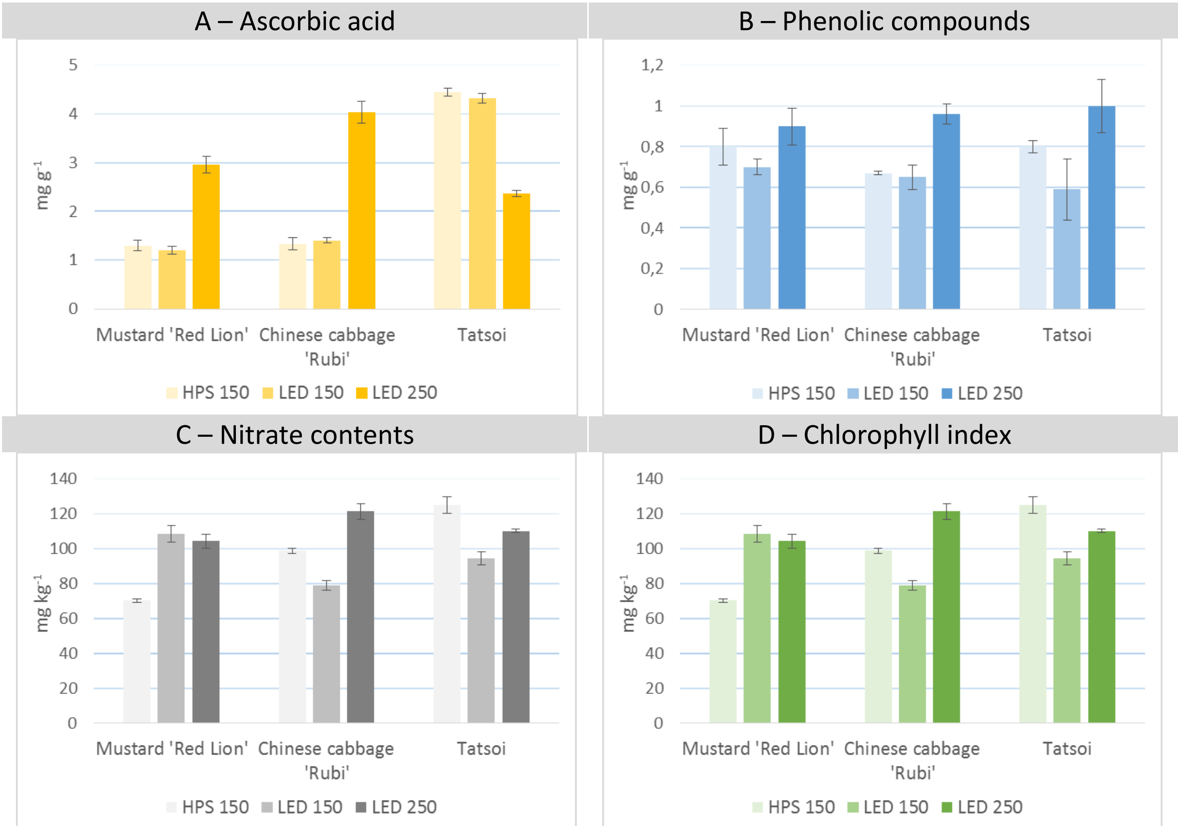

Table 1. Biometric parameters of microgreens, raised under HPS or HLFC series LED lighting at photosynthetic photon flux density of 150 and 250 µmol m^{-2} s^{-1}.

Biometric parameters	HPS 150	LED 150	LED 250
Mustard 'Red Lion'			
Height, cm	5,6±0,5	5,6±0,2	5,1±0,4
Leaf area, cm^2	2,4±0,6	2,5±0,6	2,7±0,8
Green weight, g	0,75±0,07	0,78±0,09	0,80±0,20
Dry weight, g	0,04±0,01	0,04±0,01	0,04±0,01
Chinese cabbage 'Rubi'			
Height, cm	6,2±0,3	5,9±0,7	6,2±0,5
Leaf area, cm^2	1,5±0,3	2,6±0,6	2,4±0,6
Green weight, g	0,82±0,13	0,86±0,16	0,97±0,09
Dry weight, g	0,05±0,01	0,04±0,01	**0,07**±0,01[a]

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Tatsoi			
Height, cm	5,3±0,4	5,6±0,5	4,9±0,2
Leaf area, cm^2	1,9±0,4	1,7±0,5	1,6±0,3
Green weight, g	0,63±0,06	0,48±0,12	0,50±0,15
Dry weight, g	0,04±0,01	0,03±0,01	0,04±0,01

a – significantly higher, b – significantly lower than HPS 150; when p≤0,05.

Microgreens usually do not accumulate nitrates, thus reduction or increase in nitrate contents under different lighting conditions is not significant for human nutrition (Fig. 2 C). However, lighting effects are very specific for different microgreen varieties, thus seeking for exceptional microgreen quality it is important to select suitable LED lighting spectra, intensity and photoperiod.

HLFC series LED lighting in greenhouse

Usually microgreens in greenhouse are less sensitive for lighting spectra, than in growth chambers, due to natural light background. However, in autumn-winter period, when natural lighting is low, young and tender microgreens require for the suitable light source, because it determined their growth, internal and external quality.

Qualitative microgreens have compact morphology, not too elongated, possessing pronounced taste properties, excellent external quality and shelf life. Suitably selected LED lighting ensures these parameters, as well as higher contents of biologically active compounds and mineral elements. It was approved by experimental results, obtained in industrial greenhouses of LRCAF Institute of Horticulture with HLFC series LED and High pressure sodium lamps.

Table 2. Biometric parameters of microgreens cultivated under HLFC series LED or HPS lighting in greenhouse. Photosynthetic photon flux density was 150 and 250 µmol m^{-2} s^{-1}.

Biometric parameters	HPS 150	LED 150	LED 250
Mustard 'Red Lion'			
Height, cm	4,7±0,2	**3,8±0,2**[b]	**3,5±0,1**[b]
Leaf area, cm^2	0,9±0,1	0,8±0,1	0,9±0,1
Chinese cabbage 'Rubi'			
Height, cm	4,9±0,5	**4,0±0,3**[b]	**4,0±0,3**[b]
Leaf area, cm^2	0,9±0,1	0,9±0,1	1,00±0,10
Tatsoi			
Height, cm	5,6±0,4	**3,5±0,3**[b]	**3,9±0,3**[b]
Leaf area, cm^2	0,7±0,2	0,6±0,1	0,57±0,07

a – significantly higher, b – significantly lower than HPS 150; when p≤0,05.

Microgreens, cultivated under LED illumination, possess more compact morphology (Table 2) – their hypocotyl is less elongates even when sown very densely; as well as higher concentrations of antioxidants, like ascorbic acid, phenolic compounds (Fig. 3 A, B) and free radical scavenging activity (Fig. 3, C), what determined their high nutritional value.

LED lighting also results in higher uptake of mineral elements (table 3) (Ca, K, Mg, Na, P, Fe, Zn), especially iron and zinc, as compared to microgreens cultivated under high pressure sodium lighting. Higher photosynthetic flux of LED light (250 μmol $m^{-2}s^{-1}$) strengthens this effect.

More pronounced positive effect was obtained when illuminating plants, more resistant for environmental effects (like mustard), however HLFC series LED lighting is also suitable for tatsoi, which is very sensitive for environment.

Fig. 3. Biochemical parameters of microgreens, raised under HOS and HLFC series lighting in greenhouse. Photosynthetic photon flux ratio 150 and 250 μmol m^{-2} s^{-1}. Results are presented in green plant weight.

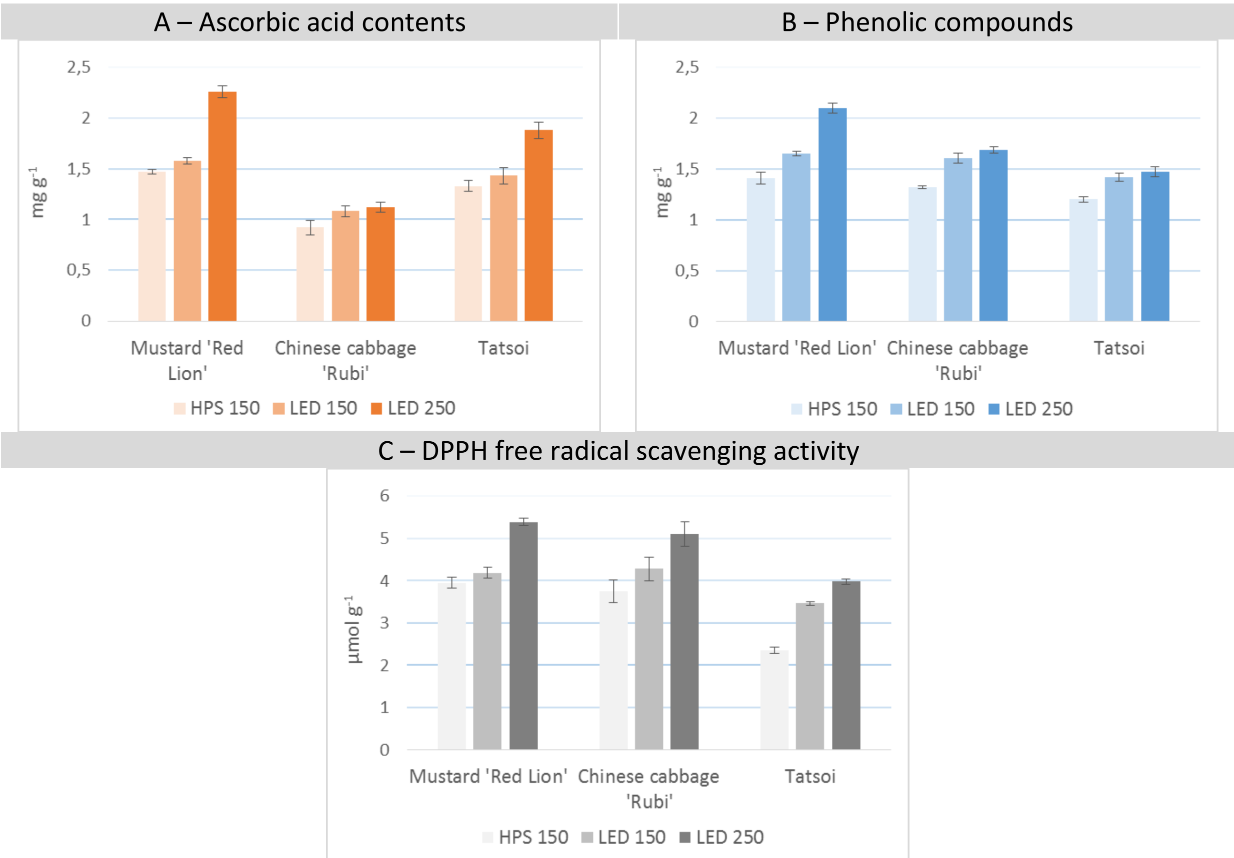

Table 3. Mineral element contents in fresh weight of microgreens, cultivated under HPS and HLFC series LED lighting.

Mineral elements mg g^{-1}	**Ca**	**K**	**Mg**	**Na**	**P**	**Fe**	**Zn**
				Mustard 'Red Lion'			
HPS 150	0,4±0,0	0,9±0,0	0,1±0,0	0,3±0,0	0,2±0,0	3,4±0,1	1,5±0,1
LED 150	**1,6**±0,0[a]	**3,6**±0,0[a]	**0,5**±0,0[a]	**0,9**±0,0[a]	**1,0**±0,0[a]	**24,0**±0,2[a]	**13,8**±0,1[a]
LED 250	**1,4**±0,0[a]	**2,6**±0,0[a]	**0,4**±0,0[a]	**0,7**±0,0[a]	**0,8**±0,0[a]	**30,6**±0,3[a]	**10,1**±0,1[a]

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				Chinese cabbage ‘Rubi’			
HPS 150	1,3±0,2	2,8±0,0	0,4±0,0	0,6±0,0	0,6±0,0	14,5±0,1	13,2±0,1
LED 150	1,3±0,0	3,8±0,0[a]	0,4±0,0	**1,2**±0,0[a]	0,8±0,1[a]	17,7±0,3[a]	15,3±0,1[a]
LED 250	**3,7**±0,0[a]	**7,9**±0,0[a]	**1,1**±0,0[a]	**1,8**±0,0[a]	**1,8**±0,0[a]	**59,9**±0,2[a]	**36,7**±0,1[a]
				Tatsoi			
HPS 150	1,2±0,0	2,7±0,0	0,3±0,0	0,6±0,0	0,6±0,0	13,3±0,1	13,6±0,3
LED 150	1,2±0,0	3,1±0,0[a]	0,4±0,0[a]	**0,8**±0,0[a]	0,7±0,0[a]	**21,6**±0,2[a]	**17,6**±0,2[a]
LED 250	1,5±0,0[a]	3,0±0,0[a]	0,4±0,0[a]	0,8±0,0[a]	0,7±0,0[a]	16,8±0,1[a]	15,2±0,1[a]

a – significantly higher, b – significantly lower than HPS 150; when $p \leq 0{,}05$.

Conclusions

- At the same photosynthetic photon flux density (150 µmol $m^{-2}s^{-1}$), microgreens raised under HLFC series LED lamps, were of equal or higher internal and external quality, as compared to HPS lamps: they were less elongated, accumulated more of ascorbic acid and pehenolic compounds, possessed higher antioxidant properties.
- When photosynthetic photon flux density was increased to 250 µmol m^{-2} s^{-1}, excess hypocotyl elongation was reduced even more, antioxidant ascorbic acid and phenolic compounds improve their nutritional value and anthocyans affects brighter coloration of leaves.
- HLFC series lighting affected 2-3 times higher uptake of mineral elements, especially of iron and zinc.
- Seeking for optimal effect, the spectra and intensity of solid state lighting must be selected according properties of specific varieties.

Methods

Mustard ‘Red Lion’, chinesse cabbage ‘Rubi’ and Tatsoi were cultivated in plastic V-type greenhouse of closed phytotoron growth chambers in winter season. In plastic trays, neutralized peat substrate PG mix, 11 days from sowing. Day/Night temperature 21/17 °C. Sprayed with tap water when needed,

Supplemental lighting was provided by HLFC series LED lamps, photosynthetic photon flux density of 150 or 250 µmol m^{-2} s^{-1}. High pressure sodium lamps were used for reference at photosynthetic photon flux density of 150 µmol m^{-2} s^{-1}.

10 occasionally selected plants, suitable to represent the treatment were used for biometric analysis. For biochemical analysis, the conjugated biological sample from representative plants was prepared. Ascorbic acid, DPPH free radical scavenging activity were determined by spectrophotometric method. Nitrate contents – by potentiometric method, using nitrate selective electrode. Chlorophyll index using Dualex meter (Force-A). Mineral element contents were determined by ICP-OES spectrometer. Results are presented as the average ±standard deviation.

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