Zinc biofortification of hydroponic mustard microgreens grown under different red and blue LED lighting ratios

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Introduction

- Zinc (Zn) is a microelement that plays a vital role in several organisms, being essential for human and plant growth.
- It is involved in the formation and activation of enzymes that impact plants growth, development, and production.
- Zn is a wide-distribution trace element in the human body, necessary for the activity of more than 200 enzymes involved in the maintenance of important metabolic pathways of the organism.
- Approximately one-third of the human population suffers from an inadequate intake of Zn and is significantly higher and widespread in developing countries primarily affecting young children and women.

Biofortification

- agronomic biofortification, which consists of increasing the accumulation of target nutrients in edible plant tissues through fertilization or other eliciting factors has been increasingly proposed in recent years;
- the application of LED lighting could be a promising tool for biofortifying various mineral nutrients including Zn, in plants;
- however, there is a lack of information on the effect of LED light spectrum on alteration in Zn content in leafy greens.

The aim of this study -

to evaluate the effect of Zn doses applied to the hydroponic solution and to increase the concentration of this element in the edible tissues of mustard microgreen depending on the different blue–red light ratios in light-emitting diode lighting

Materials and Methods

- **Mustard** (*Brassica juncea* L. 'Red Lace') microgreens (CN Seeds, Cambridgeshire, UK);
- **Lighting:** blue (B, peak = 447 nm) and red (R, peak = 660 nm) light-emitting diodes (LEDs) at different PFD ratios: 10%B:90%R, 75%B:25%R (treatments code B10R90, B75R25). TPFD 220 μmol m^{-2} s^{-1};
- **Zinc (Zn)** disodium ethylenediaminetetraacetate (Zn EDTA, $C_{10}H_{12}ZnN_2Na_2O_8 \cdot 2H_2O$)) was used to maintain different Zn concentrations:

  1 (Zn1),

  5 (Zn5),

  10 (Zn10) mg L^{-1}.
- **Hydroponic solution (mg L^{-1}):** N, 120; P, 20; K, 128; Ca, 72; Mg, 40; S, 53; Fe, 4; Mn, 0.08; Cu, 0.08; B, 0.16. pH - 5.5–6.5, EC - 1.3–1.7 mS cm^{-1}.
- **Growth** in closed, controlled environment, walk-in growth chamber: photoperiod 18 h, day/night temperatures 21/17 ± 2 °C, relative air humidity 60% ± 5%.

Results

Table 1. Effect of different blue-red light ratios in LED lighting and zinc doses on zinc content (Zn), bioconcentration (BCF_{Zn}), and translocation (TF_{Zn}) factors in mustard microgreens.

Variables	Treatment						Source of Variance		
	B10R90			B75R25			L	Zn	L×Zn
	Zn1	Zn5	Zn10	Zn1	Zn5	Zn10			
Zn, mg g^{-1} dry weight	0,118 f	0,312 d	0,514 b	0,160 e	0,418 c	0,621 a	*	*	*
BCF_{Zn}	46,5 d	58,1 b	38,8 f	90,5 a	53,2 c	44,4 e	*	*	*
TF_{Zn}	2,53 a	1,07 e	1,33 d	1,76 b	1,57 c	1,40 d	*	*	*

B10R90, B75R25 – a percentage of blue (B) and red (R) light. Zn1, Zn5, Zn10 – zinc doses 1, 5, 10 mg L^{-1} respectively. L – blue and red light. All values in the table are expressed as mean ± standard error (n = 9). Means with different letters are significantly different at the $p < 0.05$ level by Tukey's honestly significant difference test. * significant at $p < 0.05$

Results

Table 2. Effect of different blue-red light ratios in LED lighting and zinc doses on the chlorophyll (CHL), flavonols (FLA), anthocyanin reflectance (ARI1), and carotenoid-to-chlorophyll ratio (CRI2) indexes of mustard microgreens.

Variables	Treatment						Source of Variance		
	B10R90			B75R25			L	Zn	L×Zn
	Zn1	Zn5	Zn10	Zn1	Zn5	Zn10			
CHL	20,33 bc	20,13 bc	17,97 c	20,09 bc	21,67 ab	23,47 a	*	*	
FLA	0,85 a	0,81 a	0,80 a	0,71 a	0,73 a	0,78 a		*	
ARI1	0,074 a	0,083 a	0,050 b	0,050 b	0,046 b	0,048 b	*	*	*
CRI2	0,074 a	0,080 a	0,057 b	0,059 b	0,054 b	0,056 b	*	*	*

B10R90, B75R25 – a percentage of blue (B) and red (R) light. Zn1, Zn5, Zn10 – zinc doses 1, 5, 10 mg L^{-1} respectively. L – blue and red light. All values in the table are expressed as mean ± standard error (n = 3). Means with different letters are significantly different at the $p < 0.05$ level by Tukey's honestly significant difference test. * significant at $p < 0.05$.

Results

Table 3. Effect of different blue-red light ratios in LED lighting and zinc doses on the growth parameters of mustard microgreens.

Variables	Treatment						Source of Variance		
	B10R90			B75R25			L	Zn	L×Zn
	Zn1	Zn5	Zn10	Zn1	Zn5	Zn10			
HL	2,18 bc	2,63 ab	3,16 a	2,28 bc	2,09 bc	1,78 c	*	*	
LA	2,25 abc	2,40 ab	2,52 a	2,13 bcd	1,91 cd	1,89 d	*	*	
SFW	60,45 ab	63,75 a	61,43 ab	52,04 ab	48,45 b	53,34 ab		*	
SDW	3,84 a	4,01 a	3,96 a	3,15 a	2,91 a	3,53 a		*	

B10R90, B75R25 – a percentage of blue (B) and red (R) light. Zn1, Zn5, Zn10 – zinc doses 1, 5, 10 mg L^{-1} respectively. L – blue and red light. HL – hypocotyl length, cm; LA – leaf area, cm^2; SFW – shoot fresh weight, mg; SDW – shoot dry weight, mg. All values in the table are expressed as mean ± standard error (n = 3). Means with different letters are significantly different at the $p < 0.05$ level by Tukey's honestly significant difference test. * significant at $p < 0.05$.

Conclusions

In this study, the amount of Zn in mustard microgreens increased with the increasing concentration of Zn in the hydroponic solution. The higher proportion of blue light (B75R25) in the applied LED lighting enhanced this effect. However, this lighting regime has reduced the growth parameters and bioactive compounds of mustard microgreens. The results suggest that Zn biofortification could be a technique in which the inherent Zn status of the edible parts of microgreens could be improved through a proper dose application in the hydroponic solution and adapted LED lighting.

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