Advantages of Microgreen Carotenoid Composition for Space Travel

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Abstract: Microgreens are attractive space crop candidates for their ease of maintenance and nutrient density. These tender greens are particularly rich phytochemicals like carotenoids. To determine the effect of space conditions on carotenoid synthesis, this NASA funded research used Gilroy's Life Sciences TOAST database to compare transcriptomic data of *Arabidopsis thaliana* grown on previous spaceflight missions. Of the eight genes studied that involve carotenoid biosynthesis, it was determined that most were upregulated.

Introduction

As space exploration delves deeper into the solar system, astronauts require a regenerative food supply to sustain long-range missions. Ready-to-eat, nutrient dense plants like microgreens are an attractive potential space crop. Their short life cycle and ease of maintenance provide plentiful nutritional benefits without demanding much crew time. Beyond baseline nutrition, microgreen phytochemicals can help mitigate space-induced health effects. Particularly, the abundance of carotenoids in certain microgreens can stimulate optimal health and wellbeing and reduce the risk of SANS (Spaceflight Associated Neuro-Ocular Syndrome), a common condition among returning astronauts affecting near eyesight. Considering the health benefits of carotenoids, it is important to understand how their synthesis is impacted in microgravity. With this understanding, conditions can be altered, and hardware can be built to counteract changes in expression.

Microgreen Nutrient Composition

Though it varies greatly by species, microgreens of the *Brassicaceae* family display strong antioxidant activity and high amounts of glucosinolates and carotenoids. They can be an integral tool in reaching 100% daily recommended allowances for many vitamins and nutrients that are lacking in the spaceflight diet or breakdown over time.

Table 1. Mean vitamin and nutrient concentrations in select microgreens compared to their mature counterparts. Mean concentrations in microgreens adapted from Xiao et al., (2012) and Xiao et al., (2016). Data for mature counterparts from USDA National Nutrient Database and Massa, et al., (2015)

	Vitamin K (µg/100 g FW)	Mature (µg/100 g FW)	Vitamin C (mg/100 g FW)	Mature (mg/100 g FW)	Zeaxanthin + Lutein (mg/100 g FW)	Mature (mg/100 g FW)	ß-Carotene (mg/100 g FW)	Mature (mg/100 g FW)	K (mg/100 g FW)	Mature (mg/100 g FW)
Arugula	160 ± 10	108.6	45.8 ± 3.0	15	5.4 ± 0.1	0.3555	7.5 ± 0.4	1.424	343 ± 13	369
China Rose Radish	180 ± 10	1.3	95.8 ± 10.3	14.8	4.9 ± 0.4	0.01	5.6 ± 0.5	0.004	270 ± 7	233
Mizuna	200 ± 0	2320	42.9 ± 1.6	14.1	5.2 ± 0.3	387	7.6 ± 0.4	n.d.	354 ± 7	n.d.
Peppercress	240 ± 20	541.9	57.2 ± 1.6	69	7.7 ± 0.4	12.5	11.1 ± 0.6	4.15	320 ± 26	606
Purple Kohlrabi	230 ± 10	0.1	62.8 ± 7.3	62	4.0 ± 0.1	0	5.7 ± 0.2	0.022	342 ± 7	305
Red Cabbage	280 ± 10	38.2	147.0 ± 3.6	57	8.6 ± 1.0	0.329	11.5 ± 1.2	0.67	240 ± 2	243
Red Mustard	190 ± 10	257.5	62.2 ± 2.6	70	4.9 ± 0.3	3.73	6.5 ± 0.4	1.79	289 ± 5	384
Wasabi	190 ± 10	257.5	44.8 ± 1.9	70	6.6 ± 0.3	3.73	8.5 ± 0.2	1.79	387 ± 9	384

Arabidopsis thaliana Carotenoid Synthesis in Microgravity

Carotenoids are warm-colored pigments synthesized by all photosynthetic organisms. When consumed by humans, carotenoids have vital functions in promoting the vision process and protecting against excess light damage. They can also act as antioxidants to prevent disease and mitigate radiation effects.

Table 2. Select differentially expressed genes involved in carotenoid biosynthesis of *Arabidopsis thaliana* seedlings grown in light during the GLDS-7 mission on the ISS.

Gene	Description	+/-	Log10 FC	P-value
CHY1	Converts beta-carotene to zeaxanthin via cryptoxanthin	+	0.42	0.0396
CHY2	Converts beta-carotene to zeaxanthin via cryptoxanthin	+	1.02	0.00208
CRTISO	Encodes carotenoid isomerase	+	0.45	0.0183
LUT 2	Encodes lycopene epsilon cyclase	+	0.57	0.00683
PDS3	Encodes phytoene desaturase	+	0.49	0.00969
ZEP	Encodes zeaxanthin epoxidase	+	0.41	0.047