LIGHTING PROTOCOLS TO CO-OPTIMIZE DUCKWEED YIELD, NUTRITONAL QUALITY, AND ENERGY-USE EFFICIENCY FOR CREW DIET SUPPLEMENTATION

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University of Colorado at Boulder (CU) and Space Lab Technologies, LLC are investigating duckweed plants (family Lemnaceae) as an attractive candidate crop to enhance crew diets. This tiny, fast-growing plant (also known as water meal or water lentil) produces O_2, sequesters CO_2, and has high nutritional value. Duckweed protein, unlike that of most edible plants, contains all essential amino acids needed by humans. Duckweed is also rich in essential micronutrients like omega-3 fatty acids and antioxidants that fight chronic inflammation and immune system dysfunction – conditions exacerbated when humans spend extended time in space. This research aims to identify growth conditions that produce high nutrient content, volumetric yield, and CO_2 sequestration with minimal energy input. The research goal is thus to environmentally (rather than genetically) modify duckweed plants for superior yield, nutritional density, and energy-use efficiency (biomass/antioxidants produced per energy input), at spacecraft-relevant CO_2 levels (up to 1%).

In year one of the project, we found a remarkable plasticity in the plant's ability to maintain high growth rates across a broad range of light intensities and Earth ambient CO_2 levels. Duckweed was able to fuel rapid growth under low light intensity by strongly upregulating light-harvesting capacity (i.e., chlorophyll content). Modest energy input (modest growth light intensity) was thus sufficient to saturate plant productivity. In addition, duckweed's plasticity included the ability to thrive under extremely high light intensities with potentially dangerous excitation pressure. Duckweed's tolerance of high light was due to an accumulation of antioxidants that detoxify excess excitation energy under intense radiation. One such antioxidant was the carotenoid zeaxanthin – an essential micronutrient that prevents radiation damage in human eyes and skin as well as protecting against chronic inflammation in other organs.

The next step in our work will be to further manipulate growth light environment to co-optimize duckweed growth and zeaxanthin content. We will combine a moderate growth light intensity sufficient to saturate plant growth, O_2 evolution, and CO_2 sequestration with a few short high-intensity light periods each day to trigger production of zeaxanthin, which is also expected to enhance accumulation of other antioxidants like phenolics and vitamin E. We have already shown proof-of-concept for the success of this approach with the model plant species *Arabidopsis thaliana*. This technique will be demonstrated at Earth ambient and elevated, space-relevant CO_2 levels. Finally, the research will conclude with an investigation of spectral quality effects on energy-use efficiency (biomass and zeaxanthin/antioxidant content per power consumed) informing Equivalent System Mass (ESM) optimization of lighting protocols for space crop production.

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