Hydroponic System for Microgreen Growth

TEAM 12

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Overall Objective

Microgreens are an emerging health food due to their high nutrient concentration. Current production systems use large quantities of electricity and water. To improve sustainability, we attempt to design a profitable, resource-efficient system.

Market Analysis

Superfood: cost-effective, easy to grow in 7-14 days, minimal inputs, year-round reliability, convenient, aesthetic.

Micronutrient-dense: up to 40x higher vitamin & antioxidant levels than mature vegetables [1].

Plants over meat: in the coming years, a shift in consumer focus from animal protein to plant-based food will grow to be a 35% to 65% ratio [2].

Hydroponic industry growth: from 2018-2023: hydroponics has a projected compound annual growth rate of 6.5%. When put on a base of $21.2 billion as of 2016, the hydroponics industry grows by $1.4 billion/yr [3].

Target Market: A weekly microgreen salad for the Purdue University-West Lafayette population.

Specifications: 1734 m^2 plant size, Daikon Radish microgreens, 7-day maturation; production rates: hourly: 23.810 kg/hr, daily: 571.44 kg/day, yearly: 208,575.6 kg/yr [4].

Global, Ethical & Societal Considerations

Global indoor farming emergence: by 2025, the global indoor farming technology market will reach $53.1 billion USD, more than double the amount of the same market priced in 2017. Between 2018-2025, the market outlook expects a 9.65 % growth increase [3].

Ethical/societal issues: non-GMO; automated system with minimal human interface; low risk for food poisoning via equipment sterilization and nutrient solution purification to prevent propagation of undesirable bacteria and viruses (esp. compared to sprouts since only microgreen leaf and stem portions are eaten [4].

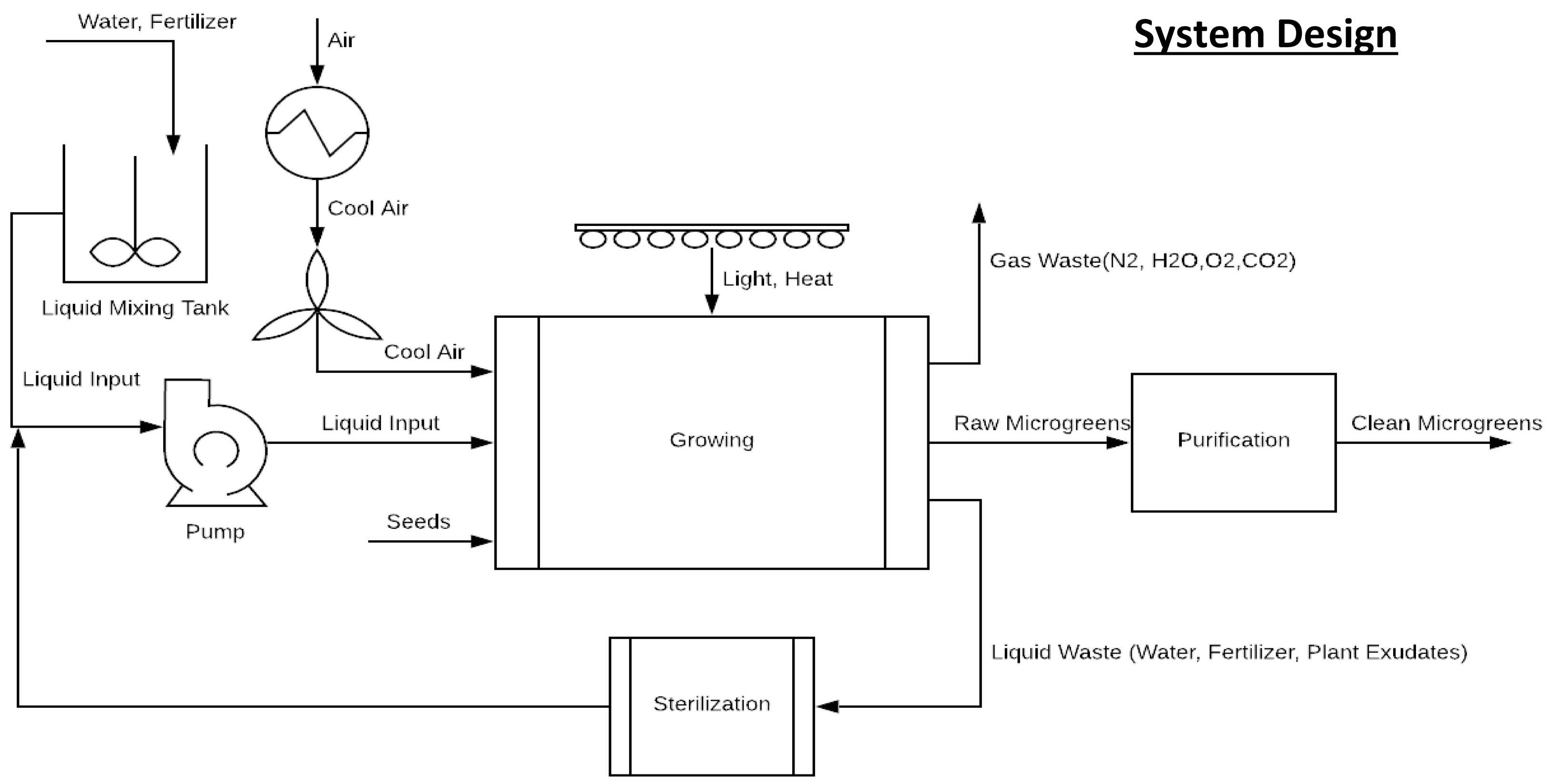
Design Alternatives

Major environmental impacts come from lighting energy and water use from the growth system.

Lighting: Options for indoor lighting have evolved rapidly and LEDs are the alternative of choice due to their energy efficiency, targeted wavelengths, and low heat generation. High Pressure Sodium lamps provide broad spectrum but produces excess heat and fluorescent lighting is not as efficient as LEDs. Specific LED lighting was selected using Phillips recommendations.

Growth System: Alternatives available are soil, media, or solution systems. Soil provides water buffering capacity and additional nutrients, but can harbor disease. Media can provide the benefits of soil with improved cleanability. Solution systems are much easier to sterilize, have better water use efficiency, and increased yields [5].

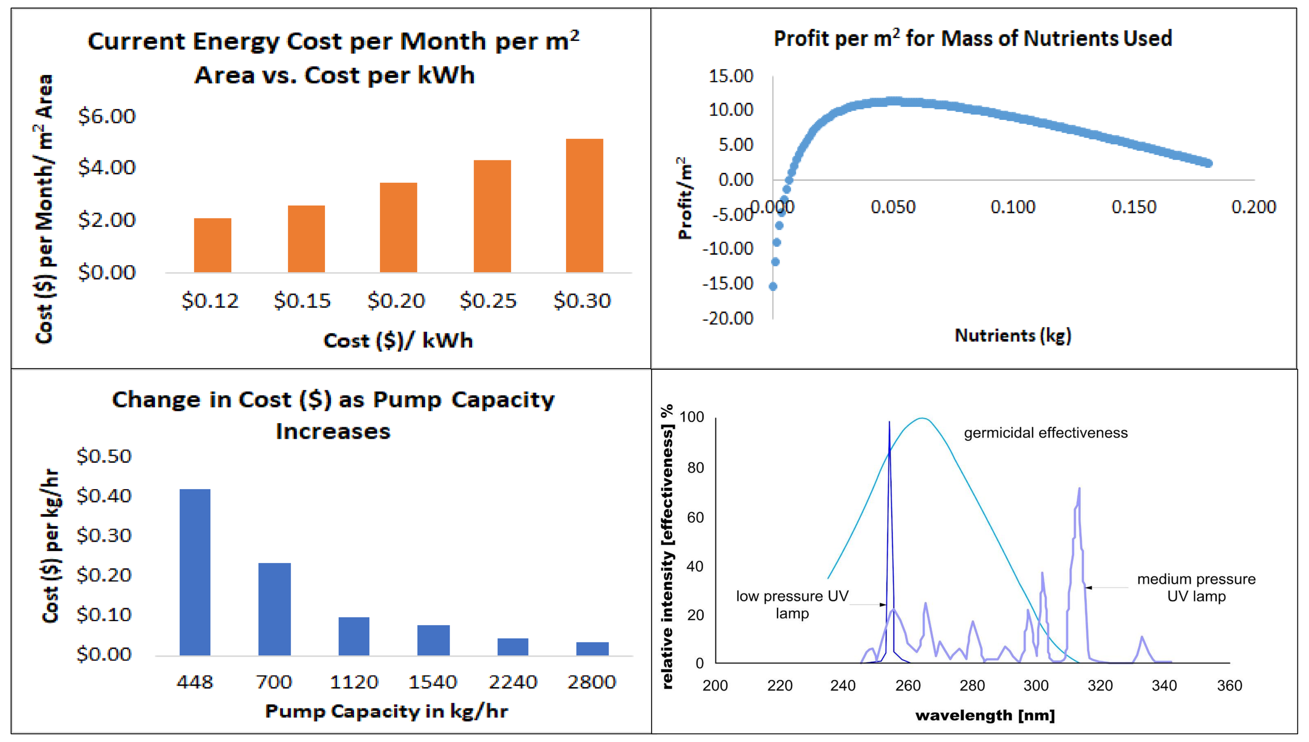
System Design



Overall Mass Balance

Phase	Component	In BioReactor (kg/hr)	Reaction (kg/hr)	Out BioReactor (kg/hr)	Out Filter Biowaste (kg/hr)	Out Filter Recycle (kg/hr)
Liquid						
	Nutrients	5.97	-1.49		0.044	4.435
	Water	4665.27	-212.61		44.53	4408.13
	Biowastes	0	0.023		0.024	0.0002381
Solid						
	Microgreens	0	23.81	23.81		
Vapor						
	CO2	58.85	-5.88	52.97		
	O2	41102.72	4.281	41107		
	N2	154993.5	0	154993.57		
	Water Vapor	2942.91	191.87	3,134.79		
	OVERALL	203,769.32	0	203769.32		

Optimization



System Equipment Sizing and Costs

Unit Operation	Operating Requirement	Energy Consumption	Equipment Model	# Equipment	Total Cost
Heating	4665 kg/hr	215,022 kJ/hr	Sussman Q-83 Flanged Immersion Heater	1	$1079.99
Mixing	4671 kg/hr	2700 kJ/hr	Satake Mixer: 360 RPM	1	$879
Storage Tank	4671 kg	N/A	1500 Gallon Roto-Mold Storage Tank	1	$809.99
Pumping	4671 kg/hr	331 kJ/hr	Hydrofarm Active Water Pump: 1000 GPH	1	$78.19
Air Flow	196,194 kg air/hr	10,800 kJ/hr	Strongway Open Motor Direct-Drive Drum Fans	10	$2199.99
Lighting	2.5 lights/m2	447,022 kJ/hr	Philips GreenPower LED Production Module	4435 lights	$490,067.25
UV Nutrient Solution Sterilization	4671 kg/hr	65 kJ/hr	Mighty-Pure UV Water Purifier	1	$825
Equipment Sterilization - Pump Spray	909 kg/hr	4500 kJ/hr	NorthStar NSQ Series 12V On-Demand Sprayer Diaphragm Pump - 4 GPM	8	$799.92
Equipment Sterilization - Storage Tank	8.5 gallon tank	N/A	NorthStar Horizontal Sprayer Tank — 10-Gallon Capacity	8	$279.92
Filtration	4671 kg/hr	86,400 kJ/hr	Culligan Top-Mount Series	1	$4486
Growth System	1733.9 m2	N/A	FarmTek NFT Hydroponic System	1	$70,506.72

Experimental Results

Date planted: 2/22/19	
Date harvested: 3/2/19	
Trial 1	Yield [g]
Tote 1	125.8
Tote 2	102
Tote 3	79.3

Date planted: 3/19/19		
Date harvested: 3/26/19		
Trial 3	Final Height [mm]	Yield [g]
Tote 1	84	62.7
Tote 2	89	105.8
Tote 3	39.6	41.5

Trial 1 and 3 Operating Conditions:
Fans on setting 2, run 24/7
Lighting on 12 hours/day after 2 day germination period

Date planted: 3/26/19		
Date harvested: 4/4/19		
Trial 4	Final Height [mm]	Yield [g]
Tote 1	29.8	36.5
Tote 2	5	0
Tote 3	5	0

Date planted: 4/4/19		
Date harvested: 4/11/19		
Trial 5	Final Height [mm]	Yield [g]
Tote 1	25.2	3.3
Tote 2	29.8	42.7
Tote 3	20.8	5.8

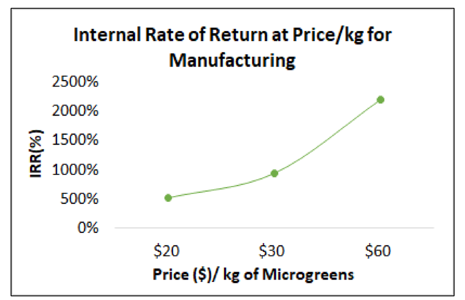
Trial 4 Operating Conditions:
Fans on setting 2, run 24/7
Variations:
- **Tote 1:** 24 hours lights on
- **Tote 2:** 12 hours lights on
- **Tote 3:** 8 hours lights on

Trial 5 Operating Conditions:
Fans on setting 2, run 24/7
Lighting on 8 hours/day after 2 day germination period

Experimental results are inconclusive due to some equipment failures, variability between each setup, lighting, fan functionality, and nonconformity to lab procedure affecting quality and quantity of data collected.

Economic Analysis

Annual production: 208,576 kg/yr
Total equipment cost: $572,012
TCI: $1,623,038/yr or $7.78/kg
TPC: $1,367,794/yr or $6.56/kg
Sales revenue range: $4,171,512 - $12,514,596/yr for $20 - $60/kg
Shipping, storage, and waste are additional major costs.



Conclusion/Future Work

Water recycling can greatly improve sustainability of microgreen production in an economic fashion. Humidity and lighting have a strong effect on microgreen growth, but current data is not sufficient to develop a model. Microgreens can be manufactured at a low expense, but transportation, storage, and waste are major costs that must be estimated to determine potential for business success.

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