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A Preliminary Study on the Technoeconomic Feasibility of Industrial-scale Microgreens Production

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Prairie View A&M University Research Experience for Undergraduates: A Preliminary Study on the Technoeconomic Feasibility of Industrial-scale Microgreens Production. By: Carol E. Akpan, Kendall R. Lemons, and Lealon L. Martin

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Session XXXX

Research Experience for Undergraduates: A Preliminary Study on the Techno-economic Feasibility of Industrial-scale Microgreens Production

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Abstract

The purpose of this REU project is to design an industrial-scale system to cultivate and harvest microgreens. Microgreens are plants that are edible but only grown to a juvenile stage. As a result, microgreens have short, repeatable cultivation cycles - around seven to ten days per harvest. However, within these short cycles, microgreens can produce compounds (phytochemicals) that offer a plethora of health benefits, at significantly higher levels than their mature counterparts. Illustrative studies have shown that specific classes of microgreens can be enzymatically activated to form special phytochemical-derived compounds with antioxidant, antimicrobial, and anticancer properties. Thus, the unique properties and characteristics of the microgreen life cycle provide strong motivation for a microgreen-driven “medicine-to-table” movement. In this study, we develop a preliminary design to produce microgreens based on mathematical models that describe terrestrial and aquatic cultivation methods. Our analysis assumes the acquisition of a land-based greenhouse facility with dimensions: length = 125 feet; width = 125 feet; and height = 22 feet would be suitable to generate 6 dry tons of microgreen harvests on an annual basis. We determined that the greenhouse structure with the dimensions identified can be acquired for approximately $500,000. Operating costs, which include administrative costs and utilities such as fuel and electricity, are $45.54 per dry ton of microgreens produced. Our studies of aquaponic production methods using the same greenhouse facility indicate that the costs associated with water-based microgreen production is comparable to terrestrial systems of cultivation. It is important to note that the analysis presented here focuses on microgreen cultivation and harvest. The complexities of post-harvest microgreen processing (aside from drying) and transport are not addressed in this study.

Introduction

Because of their high nutritional value, short growth cycle, and diverse sensorial characteristics, microgreens have gained increasing attention as a potential candidate in the fight against food insecurity. According to USDA Economic Research Report No. (ERR-270), an estimated 11.1 percent of U.S. households were food insecure at least some time during the year in 2018, meaning they lacked access to enough nutritious food for an active, healthy life for all household members. As part of the nation-wide effort to combat food insecurity, the Integrated Food Security Research

Center (IFSRC) at Prairie View A&M University encourages and promotes research to better understand and alleviate issues that result in food insecurity among persons and communities in Texas and the surrounding region. As such, this effort falls directly in-line with the stated missions of both the USDA and the IFSRC at PVAMU. It also aligns with a key mission of the USDA – to serve as an advocate for enhanced nutritional opportunities in underserved communities, underrepresented populations, and limited resource clientele.

Additionally, microgreens from the brassicaceae family have been reported to have robust antioxidant content and even inhibit carcinogenesis[9]. Within the class of brassicaceae, Calabrese broccoli microgreens are among the highest producers of nutritionally beneficial phytonutrients[1]. However, the literature is largely silent as to the technical feasibility and the economic viability of large-scale microgreen production operations to meet a potentially growing demand. Thus, it is possible that microgreen production limits have not been established for Calabrese microgreen harvests[8]. It must be noted that phytonutrient levels are elevated in broccoli microgreens compared to other brassicacae species[4]. Therefore cost-effective, high productivity schema for broccoli microgreen cultivation and harvest rates would have direct implications on the wide availability of broccoli microgreen for consumption and derived nutritionally benefits[4].

There are recent studies that provide rudimentary market analysis of microgreens in general without emphasis on the brassicaceae family or broccoli microgreens[2]. These studies underscore the emerging market for microgreen products, the environmental favorability of microgreens, and the positive societal impact of an increase in microgreen availability. Id. In particular, researchers perform analyses of the environments associated with a microgreens market using a PESTLE framework – which identifies the political (P), economic (E), sociocultural (S), technological (T), legal (L), and environmental (E) forces influencing a market. The political environment (P) is favorable towards increased microgreen production. For example, the Farm Bill of 2018 provided the USDA's National Institute of Food and Agriculture with up to $10 million of annual funding toward a competitive grant program supporting the development of urban, indoor, and emerging agriculture practices (USDA)[2]. The economic environment (E) is perceived to be favorable for a microgreens market. Microgreens trade at a premium when compared to other vegetables, with average prices ranging from $25-$45 per pound[7]. The sociocultural environment (S) is favorable for microgreens production when considering those living with higher socioeconomic status. A 2016 Pew Research Center survey estimates that most adults purchase organic food because of perceived health benefits, while the second most common reason to purchase organic is for perceived benefits to the environment[3]. These studies also provide an assessment of the legal and environmental factors (L and E) that may lead to a robust microgreens market.

Surprisingly, this literature does not provide an in-depth technical analysis (T) or a detailed treatment of broccoli microgreen cultivation and harvest strategies that encompasses economic viability (T and E). Fortunately, there is guidance for how to conduct a rigorous albeit preliminary analysis of production methods for commodity crops like microgreens[5]. In their work, industrial agricultural operations are modeled in terms of key design parameters. These key design parameters were then correlated with each other through several cost functions. Using operations, design, and cost models, mathematical programs with objectives of minimizing capital and/or operating costs, maximizing yield, or minimizing environmental impact can be formulated and explored to identify optimal design targets. While Horwich et al. focuses on the cultivation and harvest of Eichhornia crassipes (water hyacinth), a completely different crop type from microgreens, the approach and analysis presented in their work is of significant utility to the instant study. The modeling and analysis techniques presented in the subsequent section as part of our analysis of the technical feasibility and economic viability of broccoli microgreen production is inspired by their work.

Process Description and Analysis

A baseline areal space floor plan for microgreen cultivation is shown in Figure 1. Included in this representation is shelving for growing microgreens in vertical space. Shelving (region highlighted in gray) can be used for either soil-based or aquaponic growth strategies. Accommodations are made for spacing for aisles in between each row of shelves. Twenty-five percent of the total space budget is reserved for harvest storage, power generation, and product transport. Floor plans for land-based and hydroponic growing systems can be treated as similar. However, a hydroponic system will require a water filtration system as part of the storage and power generation space budget.

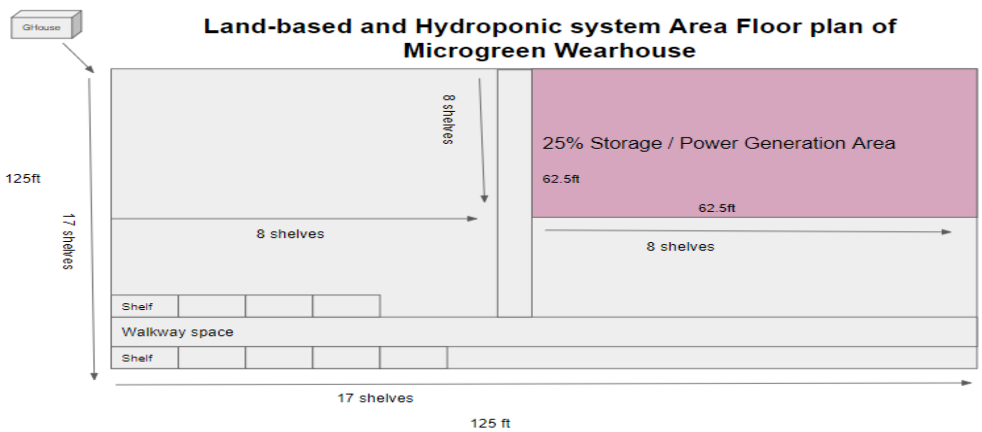

Figure 1: An areal floor plan for both land-based and hydroponic growing systems.

$A_{DH} = A_H t_D$The daily harvest of microgreens, A_{DH}, can be found from the hourly harvest rate and the total hours of harvesting per day:

$M_D = A_{DH} \rho_B$From that calculation, we were able to find the mass of broccoli plants harvested daily, M_D, is found from the daily yield per harvester and the density of broccoli microgreens:

$P_P = \left(18 \frac{hp-hr}{ton}\right) * \left(\frac{M_P(hr)}{907}\right) * (1 - R_{M,press})$Finally, daily yield is used to determine the electricity costs shown in Table 1. Electricity needs are directly related to the amount of energy required for pressing or drying, P_P, for the drying process is modeled as a function of time-power per ton, the mass of microgreens produced per hour, and the rate of microgreen drying (hourly):

$P_{PT} = N_P P_P$To find the total energy used for the press, we accounted for the total power required for pressing and the total number of presses on-site:

Results

After calculating the key operating parameters in our broccoli microgreen land-based and hydroponic systems in the computations above, it was determined that the resulting operating cost will be $45.54 per dry ton biomass as shown in Table 1.

Table 1: Operating costs for indoor production of broccoli microgreens per dry ton.

Operating Cost For 6 Tons ($/dry ton biomass)	
Direct	
Removal credit	$4.00
Operating labor	$15.00
Supervisory and clerical labor	$2.00
Utilities	
Electricity	$14.00
Gasoline	$4.00
Maintenance and repairs	$2.50
Operating supplies	$0.25
Indirect	
Overhead, packaging, storage	$4.05
Local taxes	$1.25
Insurance	$2.50
General expenses	
Administrative costs (25% of overhead)	$1.01
Depreciation	$5.02
Total cost to produce, per dry ton	$45.54

The data presented in Table 1 represent results from a preliminary techno-economic analysis of industrial-scale production of broccoli microgreens using both soil-based and hydroponic systems. In summary, our analysis suggests that a greenhouse facility sized to produce 6 tons of broccoli microgreens will incur operating expenses of only $45.54 per dry ton with a potential sale value of $25-$45 per pound, according to literature estimates. Although a more rigorous economic evaluation is needed, these preliminary results suggest that an economically viable transition from small-scale to large-scale microgreen production appears promising. The bright-side implication is that, from a production perspective, broccoli microgreens can be scaled to address food insecurity and nutritional deficiency concerns facing underserved communities.

Conclusions

Ultimately our research revealed that the possibility of producing 6 tons of broccoli microgreens per year is both ideal and sustainable. Based on analysis, we determined that the greenhouse structure with the dimensions identified can be acquired for approximately $500,000. Operating costs, which include administrative costs and utilities such as fuel and electricity, are $45.54 per dry ton of microgreens produced. In future work, other factors – such as transport, microgreen quality control, and phytonutrient content targeting – must be considered to make a more rigorous assessment of the entire microgreen supply chain.

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