SENIOR CAPSTONE/
SENIOR DESIGN EXPERIENCE
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Cultured Meat

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Objective

Develop a profitable business for producing a cell-based meat product:

- Design an industrial scale process to produce 2.6 million kg of product annually
- Create a sustainable, minimal energy plant

Market Analysis

Alternative Proteins

- Cellular Agriculture: $2.8 billion in research in 2022
- Plant-based Protein: > $28 billion globally
- Precision Fermentation: Adapted from pharmaceutical industry

1% US traditional protein market

156 cultivated meat companies globally in 2022 → Largely startups, few FDA approved

Consumers typically < 35 years of age

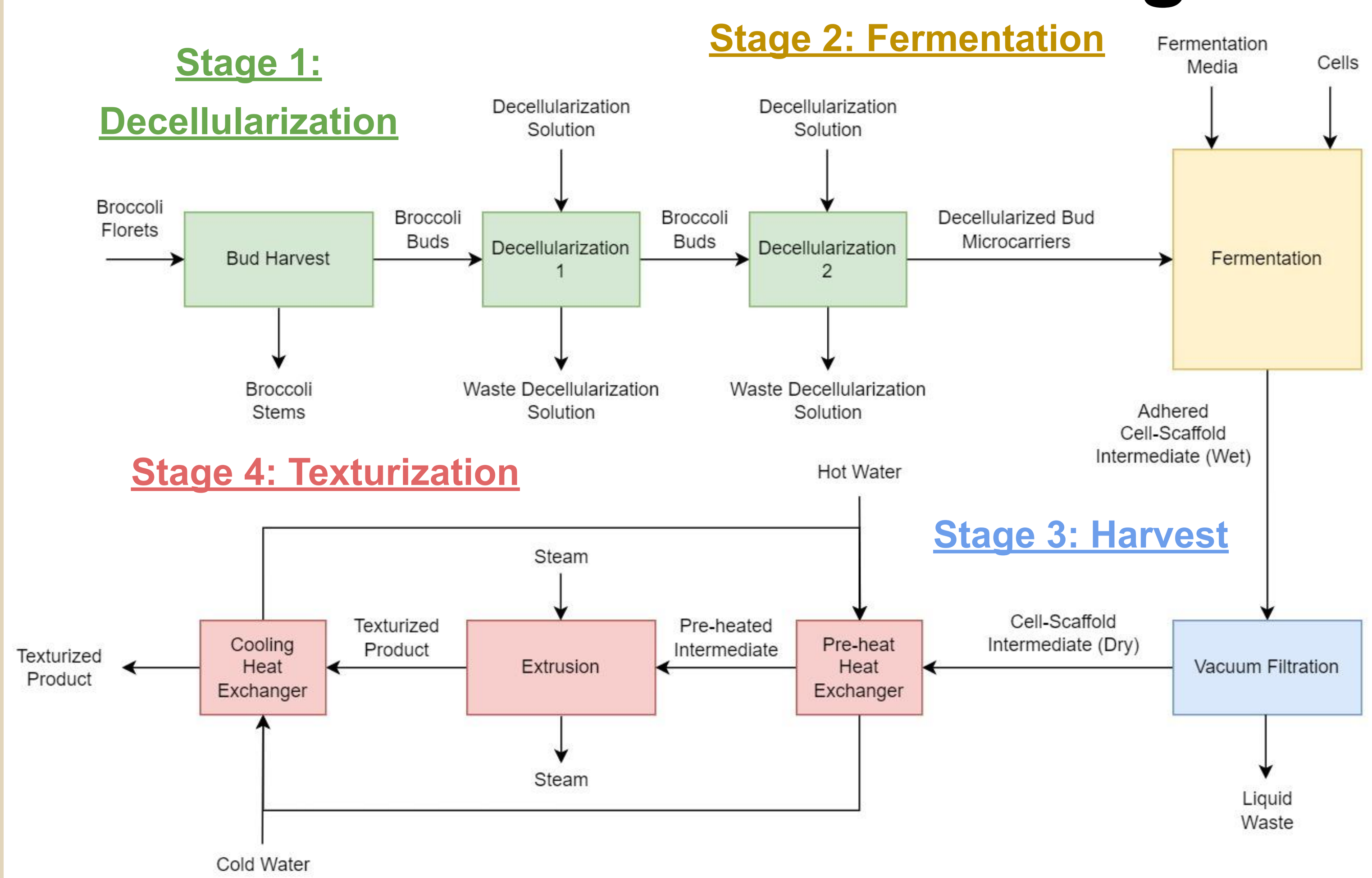
Product Overview

- Cultured meat product consisting of **beef cells** adhered to a decellularized **broccoli bud** scaffold
- After removing the buds' cells, the **cellulose matrix** of the broccoli remains, serving as a **scaffold** for animal cell adhesion and proliferation in a bioreactor
- During **fermentation**, the fibrous scaffold populates with animal cells, which is then texturized and cooked

Design Considerations

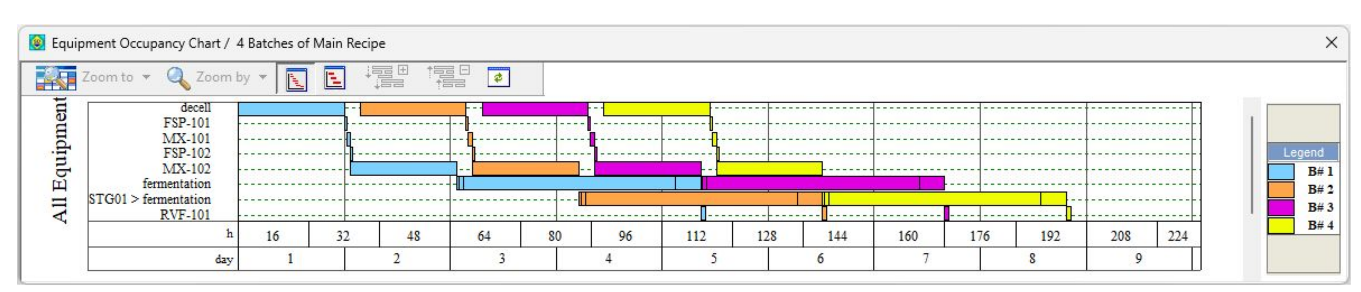
Ethical	Global	Societal
• Show respect for animals • Decrease antibiotic use	• Address sustainability • Feed growing population	• Develop nomenclature • Gain consumer acceptance

Product & Process Design



Design Analysis

- SuperPro system analysis identified areas where less input ingredients could be used to achieve the same output flow
- Scheduling was implemented to achieve a semi-continuous process using a two-batch fermentation system



Analysis of Alternatives

Process Stage	Selected Technology	Benefits
Decellularization	Vertical agitator	• Minimize shear stress • Minimize power consumption
Fermentation	Airlift bioreactor	• Minimize cost • Low mechanical stress on cells • Control over fermentation parameters
Harvest	Vacuum filtration	• Minimize cost • High degree of temperature control
Texturization	Single-screw high-moisture extrusion	• Simple design • Texturization of final product • Minimize cost

Experimentation

Stage 1: Decellularization

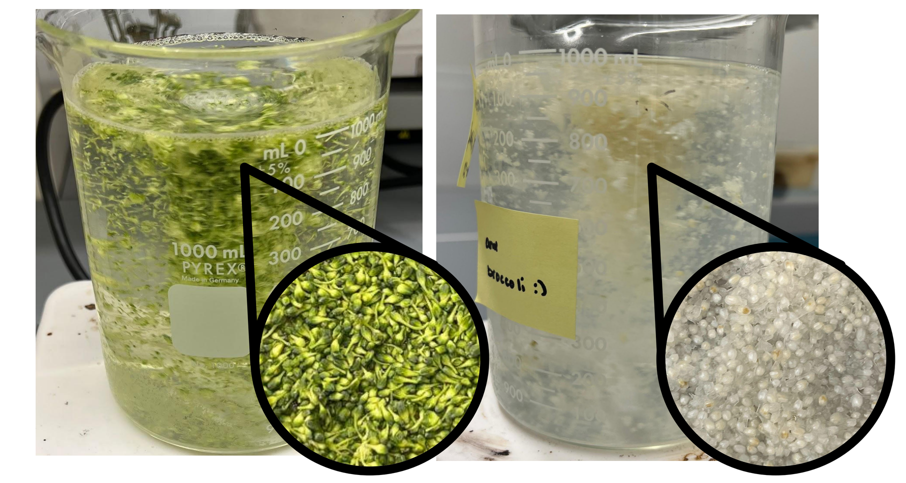


Figure 1: Decellularizing broccoli buds allows them to serve as an empty, fibrous scaffold for cell adhesion.

Stage 2: Fermentation

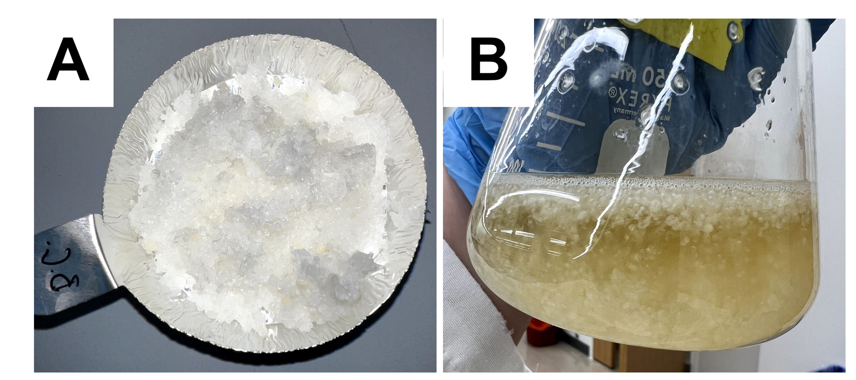


Figure 2: Fermentation step in which cell growth, adherence, and attachment to the scaffolding occurs. (A) Empty scaffolding prior to growth. (B) Populated scaffolding in media suspension.

Stage 3: Harvest

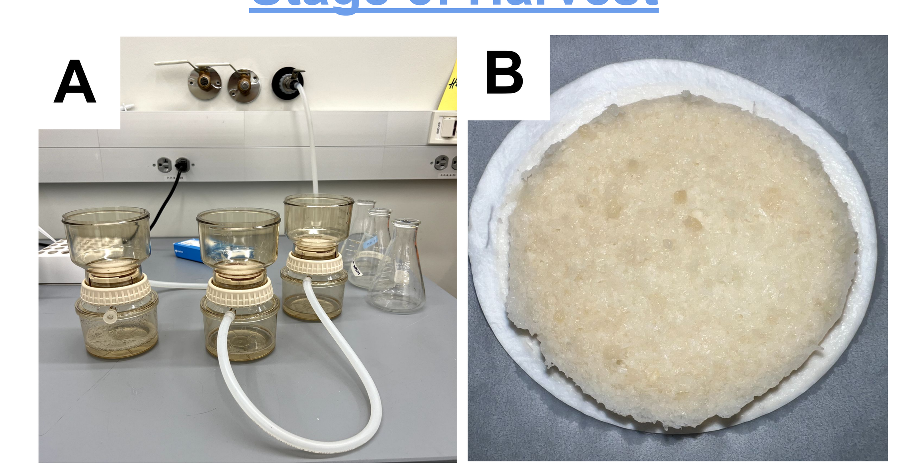


Figure 3: (A) Vacuum filtration removes excess fermentation media from the scaffolding. (B) Cell growth evidenced by change in color and increase in size.

Stage 4: Texturization

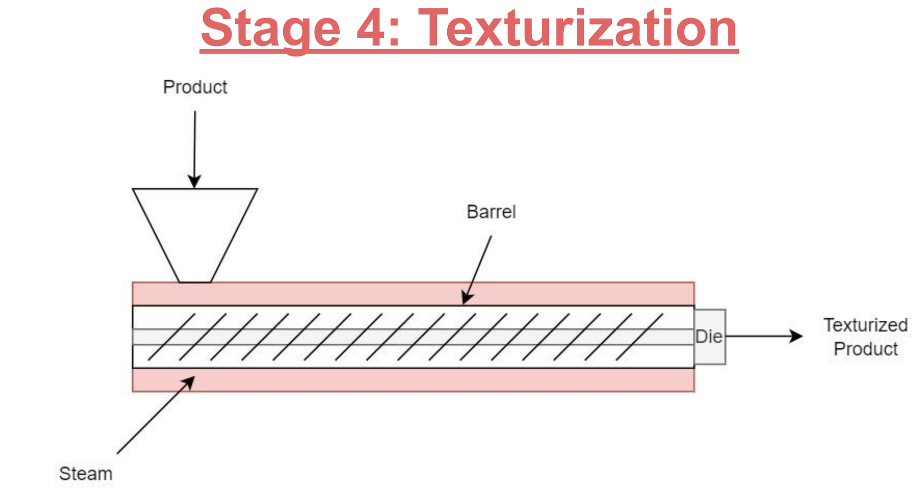


Figure 4: Diagram of food extrusion system showing flow of product through barrel and external heating elements.

Optimization

Stage 1: Decellularization

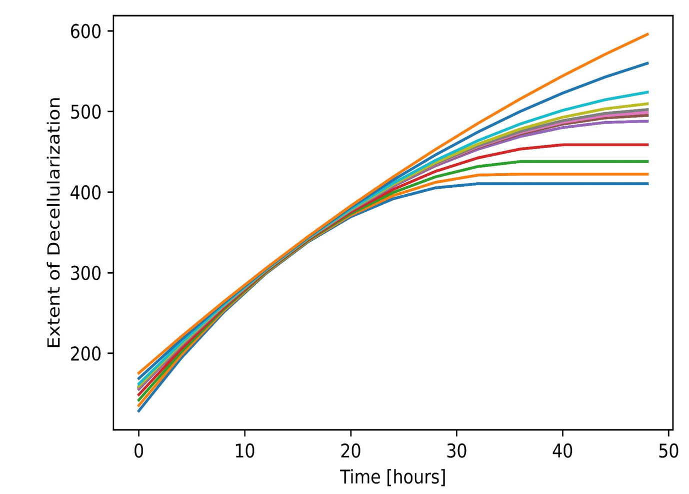


Figure 5: Optimal [Tween-20] = 3% v/v.

Stage 2: Fermentation

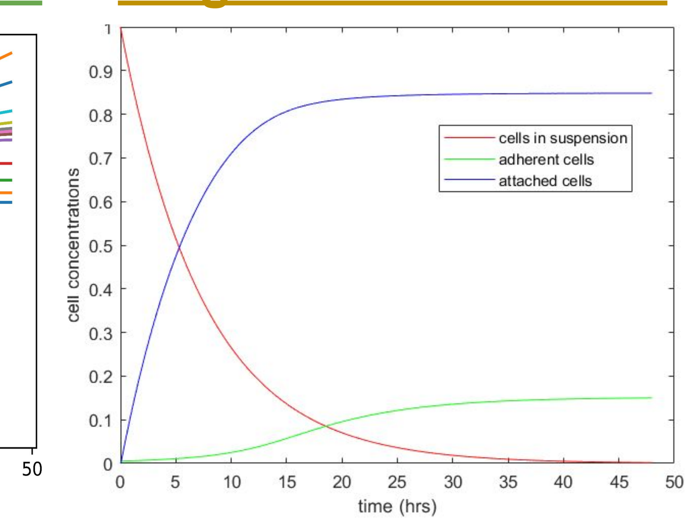


Figure 6: Optimized 85% attachment.

Stage 3: Harvest

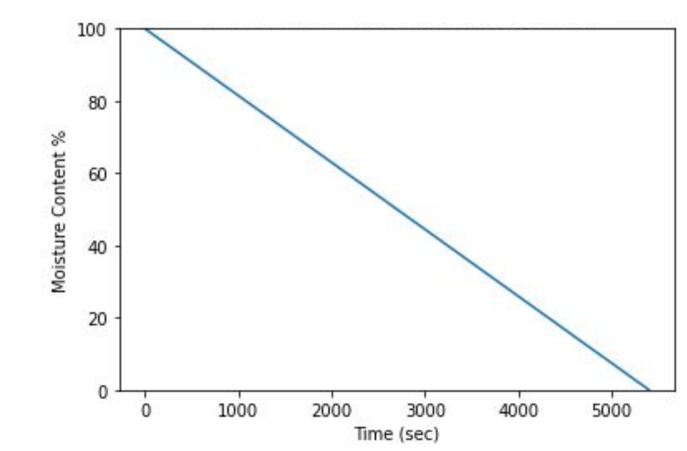


Figure 7: Optimized 25% moisture content, 4131 seconds of filtration.

Stage 4: Texturization

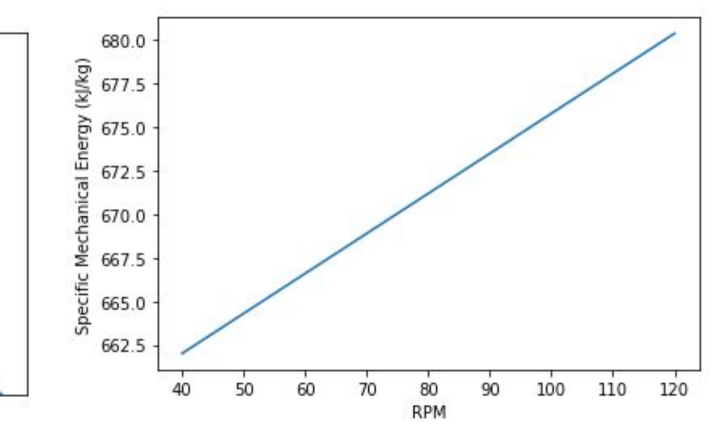


Figure 8: Effect of extrusion RPM on mechanical product texturization. Optimal extruder has 5.8 cm barrel diameter and operates at 60.5 RPM and 197°C.

Business Plan

	Original	Optimized
Total Capital Investment	$1,728,423	$1,728,423
Annual Production Cost	$1,986,062,000	$1,619,016,978
Total Annual Production	2,600,000 kg	2,600,000 kg
Cost per kg	$900	$775

Conclusions & Future Work

Lowering Consumer Cost	Collaborate with other industries to sell waste products Utilize cost-effective alternative ingredients Minimize use of chemical inputs
Optimizing Texture	Conduct consumer research to determine ideal texture to optimize extrusion
Safety	Evaluate washing to ensure trace chemicals do not remain in the final product

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Original Decellularization Report: Thyden, R., et al. (2022). An Edible, Decellularized Plant Derived Cell Carrier for Lab Grown Meat. *Applied Sciences, 12*(10), 5155–5155. DOI: 10.3390