SENIOR CAPSTONE/ SENIOR DESIGN EXPERIENCE 2025

Objective

industrial system for Design an melanin production and extraction using recombinant E. coli that utilize MelC1 and MelC2.

Markets and Trends

- Melanin, a biostable compound naturally produced by most organisms which impacts markets such as:
- Cosmetics
- Superconductors
- Wide-spectrum UV absorption
- Metal ion affinity for bioremediation
- Biomedicine
- Valued at \$9.5 billion in 2023, the market is projected to exceed **\$18 billion** by 2031 due to rising demand and limited production pathways.

Design Considerations

- Environmental Impact
- Biocompatibility & Safety
- High-Purity, Market-Ready Pigment

Sustainability and Ethics

Low-Carbon Process

• Offset energy use by purchasing carbon credits and incorporating solar power.

- Waste Valorization
 - Repurpose *E. coli* biomass as biofertilizer or biofeed, reducing biowaste.
- Green Inputs
- Use renewable feedstocks and recyclable buffers to minimize environmental impact.
- Ethical Biomanufacturing
- Ensure transparency, safety, and scalability for broader global access.



Melanin Production Using Recombinant E. coli

¹Biological Engineering: Cellular and Biomolecular Engineering



Figure 3: Resulting experimental growth curve. Figure 1: Plasmid Constructed to express MelC1 and Measurements were taken at **OD600** and converted to **MelC2** for melanin biosynthesis. This plasmid also colony forming units per mL. includes **ampicillin resistance** for transfection screening.

Process Development



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Experimentation



Figure 2: Before (left) and after (right) fermentation of *E. coli* for **24** hours while being agitated at 250 **rpm** at **37°C**.



Figure 4: Designed industrial process for a pure melanin product using heat exchange/transfection, fermentation, centrifugation, and drying.

The process takes an *E. coli* culture and mixes it with the genetic material to be transfected. It is put into a **heat shock** for the plasmid to uptake and then put into a batch reactor with ampicillin to **ferment** to melanin. The raw melanin goes through a series of washes and **centrifugation**. It is then **dried** into the pure melanin.

Centrifugation

Alternatives: Tangential Flow **Optimization:** 7,000 RPM

Drying





Figure 5: The cumulative cash flow of the factory compared to the time in months that the factory is fully operational, with the break-even point highlighted in green at **0.27 years**.

Total Ca Raw/Ba Labor/E Utilities Price/B **Batch S** Breakev

Research

- Melanin extraction verification Future Products • Cosmetics, biomedicine and superconductors Future System Improvements Secretion gene from Streptomyces Streptomyces Research Optimizing natural melanin production



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Agricultural and Biological Engineering

apital Investment	\$14,580,000
atch	\$14 <i>,</i> 654.48
Batch	\$9,163.48
s/Batch	\$2.89
atch	\$23 <i>,</i> 820.85
ize	1.04 kg
ven Capacity	29.2 batches

Future Work

Figure 6: Pure powdered melanin ready for future applications.