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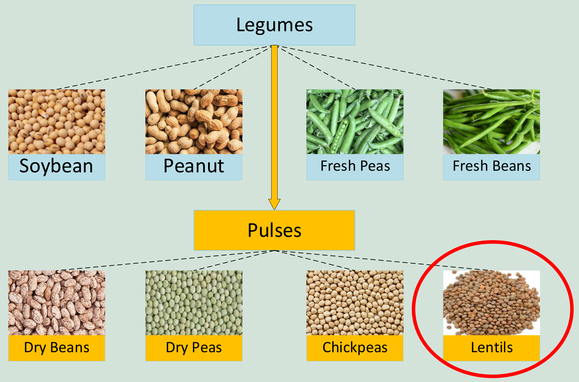
Pulse Protein Powder Production

Introduction

High quality plant-based protein supplements are a growing market in North America [1]. Pulse Protein Powder Production is a project concerning the design of a facility capable of producing a protein supplement from agricultural pulses. Various engineering concepts were applied to design the unit operations employed in the production of a protein powder product.



Design Process

Air-Classification:

I. Determined particle size filtering requirements for lentil flour protein [6]
II. Determined initial air velocity calculations for particle separation [7]
III. Constructed a COMSOL simulation and used particle tracing to test the use of air classification for protein separation

Leaching:

I. Determined stage requirements by applying solid-liquid equilibrium data [1] and application of Seader leaching method [4]
II. Determined operating regime by calculating particle settling time within vessel

Ultrafiltration:

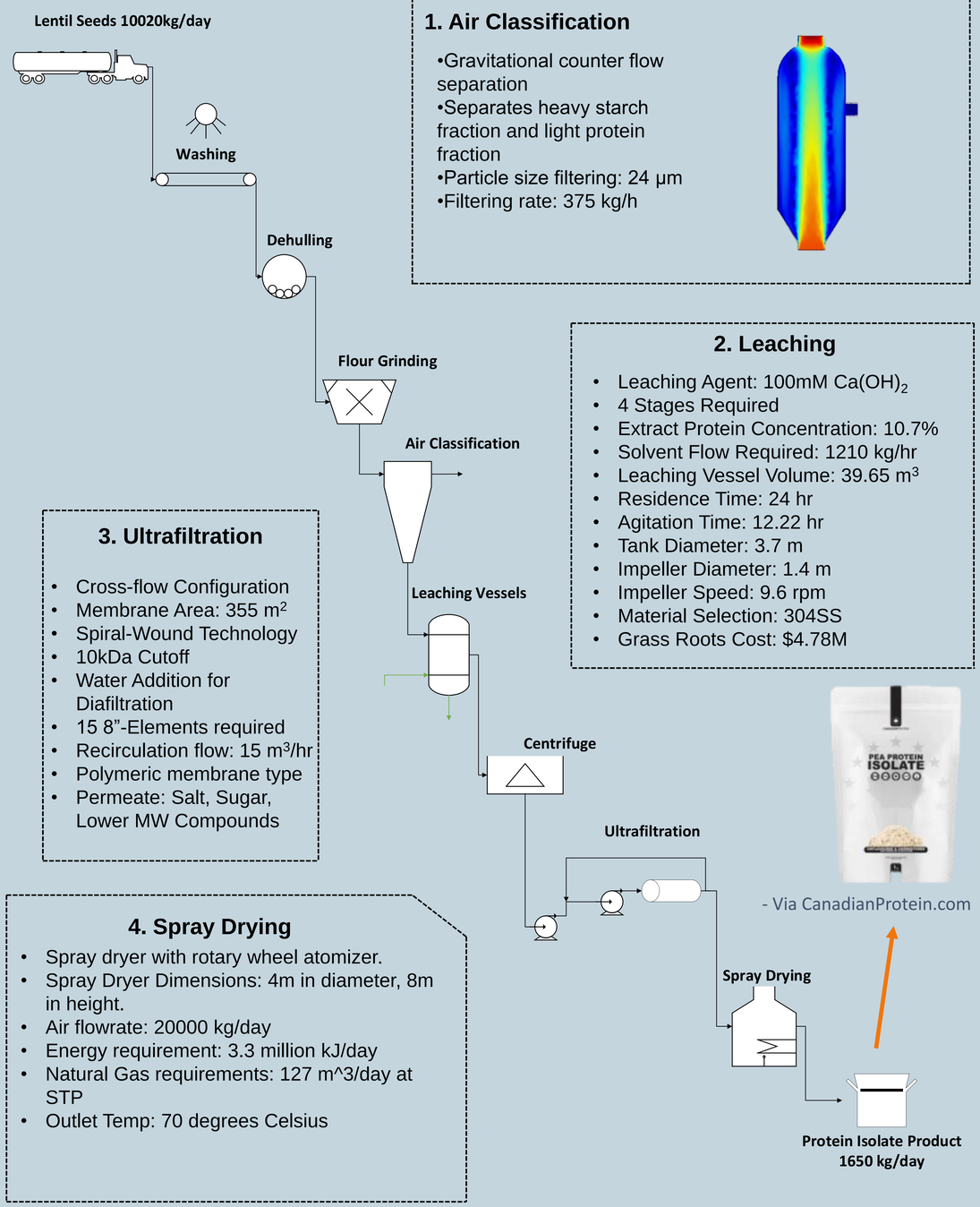
I. Determine membrane area requirements from literature review [5]
II. Select membrane technology based on manufacturer specifications

Spray Drying:

I. Determine Spray dryer dimensions. Then select spray dryer based on manufacturer specifications.
II. Determine volumetric flowrate of air needed to evaporate water from protein isolate solution
III. Determine energy requirements and fuel consumption
IV. Model system in Excel to determine outlet air temperature

Details of Design

- Production of plant protein isolate powder can be broken into four distinct unit operations: grinding and air-classification, solid-liquid extraction (leaching), ultrafiltration, and spray drying.



1. Air Classification

- Gravitational counter flow separation
- Separates heavy starch fraction and light protein fraction
- Particle size filtering: 24 µm
- Filtering rate: 375 kg/h

2. Leaching

- Leaching Agent: 100mM $Ca(OH)_2$
- 4 Stages Required
- Extract Protein Concentration: 10.7%
- Solvent Flow Required: 1210 kg/hr
- Leaching Vessel Volume: 39.65 m^3
- Residence Time: 24 hr
- Agitation Time: 12.22 hr
- Tank Diameter: 3.7 m
- Impeller Diameter: 1.4 m
- Impeller Speed: 9.6 rpm
- Material Selection: 304SS
- Grass Roots Cost: $4.78M

3. Ultrafiltration

- Cross-flow Configuration
- Membrane Area: 355 m^2
- Spiral-Wound Technology
- 10kDa Cutoff
- Water Addition for Diafiltration
- 15 8”-Elements required
- Recirculation flow: 15 m^3/hr
- Polymeric membrane type
- Permeate: Salt, Sugar, Lower MW Compounds

4. Spray Drying

- Spray dryer with rotary wheel atomizer.
- Spray Dryer Dimensions: 4m in diameter, 8m in height.
- Air flowrate: 20000 kg/day
- Energy requirement: 3.3 million kJ/day
- Natural Gas requirements: 127 m^3/day at STP
- Outlet Temp: 70 degrees Celsius

- Via CanadianProtein.com

Conclusion

- Current facility design estimates a production of 1650kg per day of a protein isolate product having a purity of 88% protein by weight, produced from 10020kg per day of lentils.
- Facility annual revenues are currently estimated at $12.72M, with an annual operating cost of $5.02M.
- Facility CAPEX expenditure is currently estimated at $7.3M, with a payback period of approximately 1 year.
- All financial estimates are dependent on the sensitivity of lentil bulk sale price, which has varied significantly in the past.

Recommendations

- Starch byproduct produced from air classification has significant value-added product potential.
- Perform sensitivity study to gauge economic viability of facility with change in lentil price.
- Perform mass-transfer calculation to determine stage-efficiency of leaching section
- Consider feasibility of heat-recovery system in spray-drying section

References

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