Technical Prospectus

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As the population continues to grow, the market for meat alternatives has simultaneously increased in recent years with products derived from soy in high demand. There have also been concerns with the environmental impacts of the meat industry, pushing people to try more sustainable diet options (Gerbens-Leenes et al., 2013). Consumer priorities in this industry focus on flavor and texture, so priority will be given to the molecular composition resembling animal tissue (Ignaszewski & Pierce, 2023). Industry projections within this commercial space are optimistic, as the plant-based chicken market alone is projected to grow 18.4% in the next 10 years (Choudhury, 2023). Since the market is heavily soy-based, the proposed alternative protein source can be derived through extraction of sesame seed media (Krosofsky, 2023). Although sesame and soy are now both major food allergens in the US (Califf, 2023) there are limited meat alternatives that are not soy-based, restricting options for people with plant-based diets and a soy allergy. This process has the additional benefit of generating toasted sesame seed oil, a high value product compared to similar oils such as soybean oil.

The process can be split into four main blocks: seed oil extraction, seed cake fermentation and lactic acid separation, yeast extract processing, and mixing to create the end protein product (Figure 1). This vertical integration of processes allows for development of a unique fermentation media and maximization of production value. The primary source of profit in this case will most likely stem from the oil extraction process, but innovation of the fermentation of the oil byproduct will result in a protein source that can be used to generate a protein dense food to meet market demands sustainably.

To begin the solvent based extraction of oil from sesame seeds, the seeds must first be toasted. This pretreatment not only improves the oil yield and shelf life but also enhances the flavor and aroma of the oil. The seeds are ground to release the oil before mechanical pressing and solvent based extraction (ABC Machinery, n.d.). The majority of experimentation suggests n-hexane as the ideal solvent for oil extraction as it produces the highest yield (Osman et al., 2019). Choosing hexane prevents byproduct formation and simplifies purification. However, the high cost and toxicity of hexane will require a solvent recovery mechanism, most likely through evaporative processes. Both regression models and neural networks exist for prediction of extraction rates, and a method will be chosen that aligns with the precision required for determining average yield. Common yield levels are roughly half of the dried mass of the seeds (Mujtaba et al., 2020).

The leftover seed cake will be used in the protein product, but must undergo additional processing to improve flavor and digestibility. Experiments have shown that *Lactobacillus plantarum,* a fermentable bacterium typically found in milk and other fermented food products, can be cultured in seed cake at reasonable timeframes (12-24hrs) (Khalfallah et al., 2022). The results of said fermentation greatly reduce fiber and sugar content, while only resulting in small protein losses in the medium. This is a means of concentrating flavor and nutritional value to produce a higher value added product.

Following the fermentation, downstream processing is needed to reduce the lactic acid produced, and further improve the consumer experience. A study in consumer reactions to chicken preservation techniques found that the upper limit of consumer preference of lactic acid concentration in chicken products is 1 g/L. (Van der Marel et al., 1989). The expected lactic acid output from fermentation is roughly 6 g/L so an extraction will be needed to reduce this value (Khalfallah et al., 2022). A summary of lactic acid retrieval methods recommended an extraction as the most scalable option (Li et al., 2021). Optimization of this procedure involves low pH which will coagulate most of the protein (80%) and a centrifuge operation before extraction with butanol (Kumar et al., 2020). Lactic acid is a feedstock for PLA production, and so the extracted lactic acid could be sold as a side product. The polar components of the supernatant are likely to be disposed of as a waste stream due to butanol contamination.

To enhance the flavor of the protein product, yeast extract will be added to the fermented sesame product to enhance the savory or "umami" flavor more similar to traditional meats (Tomé, 2021). To create yeast extract, brewer's yeast or *Saccharomyces cerevisiae,* a byproduct of beer fermentation, is used as the initial source of yeast. This yeast is subjected to a fermentation process with added sugars to increase the number of yeast cells. Once the culture has reached its desired biomass, the yeast cells are centrifuged to remove the liquid medium. Subsequently, they undergo disruption and separation to eliminate their cell walls and then the resulting solution is toasted and concentrated through evaporation (Tao et al., 2023). In this particular method, sugar cane molasses serves as the carbon source for the yeast, while urea is introduced as the nitrogen source to promote yeast growth (Polyorach et al., 2013).

Fermented sesame cake and yeast extract from the process will be combined with methylcellulose and hydrogenated oil produced elsewhere to form a final plant-based meat product, a chicken simulacrum (Figure 1). Side products from this process include lactic acid and toasted sesame oil that can be sold to increase profits.

This project will be completed as part of a two-course capstone project, CHE 4474 and CHE 4476, in a group of 4. The majority of the design work will be completed in CHE 4476. Process modeling and calculations will be completed using AspenPlus, Excel, and Matlab.

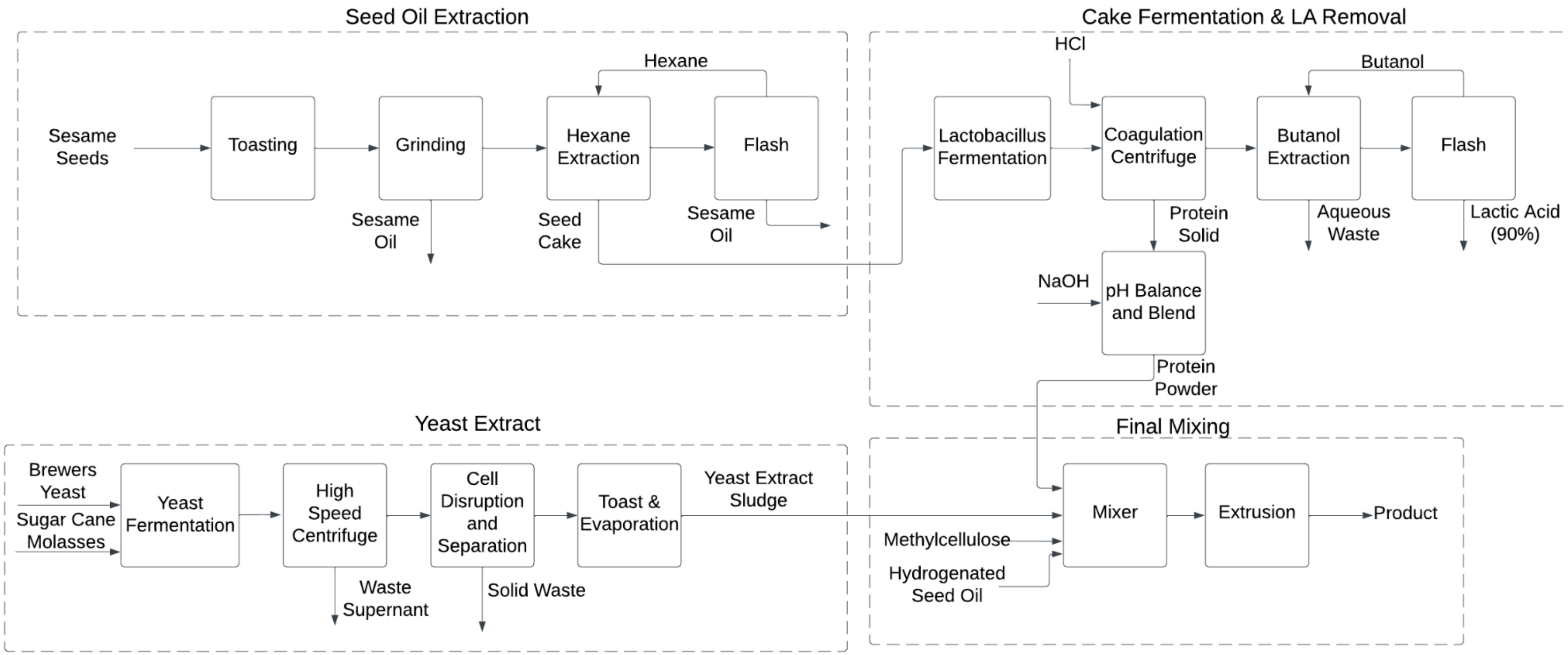

Figure 1. Overview of Production Process

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