Plant Protein Substitute from Sesame Seed Waste

Regulatory Issues Within the Flavoring Industry

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By
Brett Hogan

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Isabelle Sowers, Avery Baker, Tayler Newton

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Prof. Pedro Augusto P. Francisco, Department of Engineering and Society

Prof. Eric Anderson, Department of Chemical Engineering

Introduction

Food, as an essential component for life, is central to all cultures and a vital aspect of the human experience. The American food system has undergone rapid changes through industrialization and centralization. As a result, while nutritional access has increased from the past, it has done so through inherently unsustainable practices of high resource usage. Of particular concern environmentally is the large emphasis on meat consumption. Meat consumption represents a low metabolic conversion and high time to slaughter as the major factors that draw additional resources. Microbial systems are scalable, have high turnover, and do not face the same ethical concerns that conventional meat has. New products based on microbial production could reduce the impact of our current practices, and involve technologies only recently available.

In recognition of the cultural entrenchment and high demand for meat consumption, several alternative products have been created to imitate this experience while reducing the ecological footprint. The majority of these products use soy as feedstocks, due to the high rate of subsidies with soy production. We seek to use sesame seed cake as the substrate and physical basis for the protein substitute. As a post processed material, it represents both environmental considerations of reuse and the economic considerations of high volume value added products. The microbial processing also represents the usage of natural methods rather than chemical flavorants which is another system to ensure the environmental efficacy of the product. The plant microbe blend of the final product also results in a much lower resource cost of production, and through eventual scaling and optimization, a more cost effective product than meat as well.

The success or failure of a food product depends largely on its public acceptance. While simple factors of cost and user experience can fine tune market share for common items, novel foodstuffs can face additional difficulties. These include both alterations of the ingredients themselves, and their means of production. Advances in biotechnology have brought a shift to the production of many whole foods and additives. While these changes have caused consumer backlash for whole foods, recombinant additives have been positively received in most cases. The question then arises why have these similar technologies inspired such different public reactions.

The question of food acceptance is integral to the success of new products. Therefore, understanding public reactions to alternative methods of production can avoid business failures that could have long lasting environmental consequences. Artificial meat products contain high degrees of processing, and frequently contain many additives to ensure their similarity with the food they are emulating. Integrating the public as a stakeholder for these large biological processes can improve safety, health, and foster trust between manufacturers and consumers. By combining the technical and sociological aspects of highly processed food production, we can gain a better understanding of the business decisions facing some of the world's largest companies.

Plant Protein Substitute From Sesame Seed Waste

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.

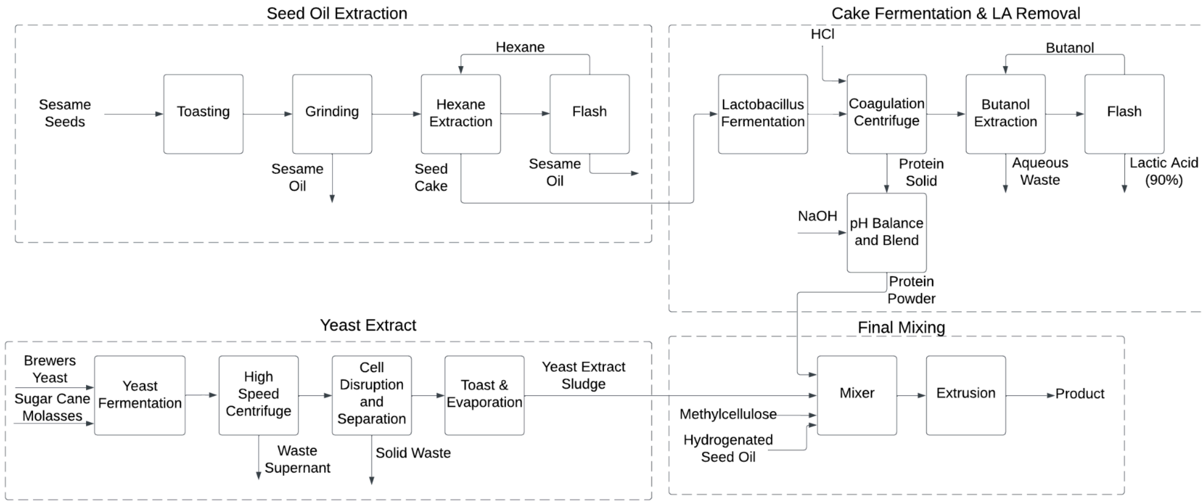

Figure 1. Overview of Production Process

Regulatory Issues Within the Flavoring Industry

Improvements in computing technology allowed for the ability to identify gene sequences to produce valuable products. Further advancements with gene insertion systems made the possibility for these products to be upregulated, greatly reducing the cost of certain molecules. This has resulted in a quiet implementation of these transgenic processes in many additives. While other uses of genetic engineering in the food industry were met with severe pushback, no major effort has existed for these additives. This is because the highly processed food environment greatly favors manufacturer secrecy and the labelling systems resulted in these GMO options being advertised as a better health alternative compared to their chemical synthetic predecessors (Carocho, 2015). This allowed manufacturers to stabilize the status quo before health scares or organized opposition occurred.

Investigation within this subject will contrast the motivations and actions of consumers, manufacturers, and government systems to understand how the interplay results in the current implementation of nearly uncontested GMO microbial systems. Information about each actor will be obtained from different sources. Consumer opinions will be obtained from surveys and psychological risk studies. The manufacturing perspective will be determined from historical lobbying efforts and current advertising methods. Lastly, the government reactions will be gauged with the current text of the GRAS legislation and FDA congressional interactions. Another important aspect to recognize is the difficulty in food regulation compared to medicines. Food is a higher volume good, with a lower barrier to entry, and less public priority in regulation. FDA resources must be spread to where they are most valuable, and it cannot be used to conduct long term toxicity studies on trace chemicals within some foods (Solet, 2001). This testing burden lies with the producer, who is heavily incentivized to either not conduct testing or display positive results (Zwanenburg, et al., 2014).

Another adjacent topic that is vital to the understanding of this scenario. While the bulk of the thesis will focus on American food policy, European attitudes, especially that of the United Kingdom are useful to show that even with a united public, information scarcity still wins. English issues with industrial food processes such as bovine spongiform encephalopathy have resulted in a widespread distrust of both biotechnology and food regulatory agencies throughout the region (Devaney, 2016). While this political front has been able to change labelling systems for ingredient lists, the system that replaces it has more levels of abstraction and a steeper learning curve for consumers (Al Harthy, 2017).

The opacity of processed food contents, both accidental and intentional, have rendered it difficult for the government and impossible for individual consumers to accurately assess the risk from consuming certain products. Recombinant culturing procedures have allowed manufacturers to sidestep public fear, but have turned it into a branding opportunity with statements of no artificial flavors. The continued use of these chemicals under a new manufacturing name represents an unknown risk undertaken by the public.

Conclusion

New food production techniques are vital to maintaining a healthy populace and reducing the environmental strain of food production. Plant protein substitutes have the possibility for nutritionally dense foods which mimic the flavors of meat without intensive feedlot agricultural systems. While soy presents itself as the current leader of the system, other plant wastes such as sesame seeds have the potential to be converted into consumer grade goods. Vital to its success is consumer acceptance, which is heavily dependent on perceived safety. Safety occurs when demanded by voters and then through regulatory systems. The current environment of flavorant regulation is heavily manufacturer centric, and represents an unknown risk and possible trust barrier. By understanding the tactics used by manufacturers when implementing recombinant flavoring agents to assay public fears and prevent increased regulation, the likelihood of a product becoming culturally entrenched increases, to the benefit of both the consumer and environment.

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