a. Research Project Title, Principal and Co-Investigators

From Waste to Worth: Upcycling Fiber-Rich Soybean Byproducts through Extrusion

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b. Research Overview and Objectives

- Research Overview

This project aims to add value to fiber-rich soybean byproducts like soybean meal and okara through extrusion processing. By optimizing extrusion conditions like temperature, pressure, and shear force, the insoluble fiber in these byproducts can be partially converted into more beneficial soluble fiber. Extrusion can also deactivate antinutritional compounds naturally present in soybeans. The resulting products will have enhanced nutritional value and functionality, with potential applications as animal feed, food additives, and fermentation substrates. This research can boost the profitability of soybean farmers and processors by transforming underutilized byproducts into higher-value ingredients and the right conditions to maximize the oil yield. This approach holds the potential to render soybean oil extraction more sustainable and reduce the generation of low-profit by-products.

- Objectives:

The **long-term goal** of this research is to enhance the value of soybean's fiber-rich byproduct, using the extrusion process, to create products such as enriched animal feed, food additives, and fermentation products.

**In the current project, our focus** is on utilizing the extrusion process to transform the fiber-rich byproduct of soybean into products with a higher soluble fiber content. Such products serve as precursors to high-value items. Concurrently, we will assess the extrusion's efficacy in deactivating antinutritional factors. The project encompasses two primary objectives:

Objective 1 Upcycling soybean meal with twin-screw extrusion cooking;

Objective 2 Upcycling okara with twin-screw extrusion cooking.

c. Completed Work: Deliverables and/or Milestones.

The extrusion process has been developed to reduce the insoluble dietary fiber (IDF) in the okara (Figure 1). With the increase in motor rotating speed, the total gross IDF has a decreasing trend. The total IDF tends to decrease with the increasing water supply during extrusion. The current insoluble fiber content decreased from 39.29% to 29.24%

d. Progress of Work and Results to Date

Figure 2 illustrates the IDF content (%) of okara powder and how it changes under different combinations of moisture content (60% and 70%) and screw speeds (200 rpm, 400 rpm, and 800 rpm) during processing.

The results indicate that both increasing moisture and screw speed tend to reduce the IDF content. Okara powder without processing has the highest IDF content (~39.29%), serving as a baseline. At 60% moisture, increasing screw speed from 200 rpm to 800 rpm shows a gradual decrease in IDF content, with 200 rpm maintaining the highest level (~35.87%) and 800 rpm reducing it to 33.71%. The trend is more pronounced at 70% moisture, where 200 rpm shows a

moderate reduction in IDF content (~34.91%), but higher screw speeds (400 rpm and 800 rpm) lead to significant decreases (~31.04% and ~29.24%, respectively).

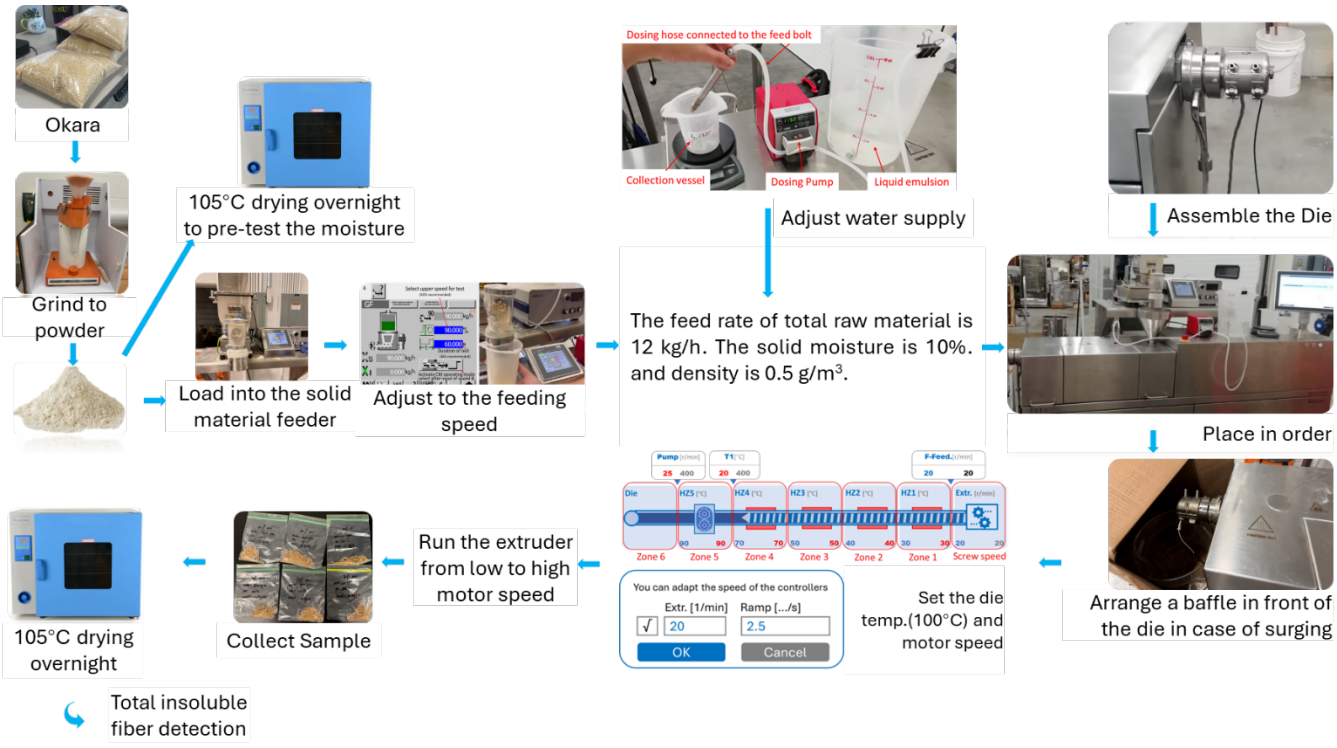


Figure 1 The flow chart of extrusion process

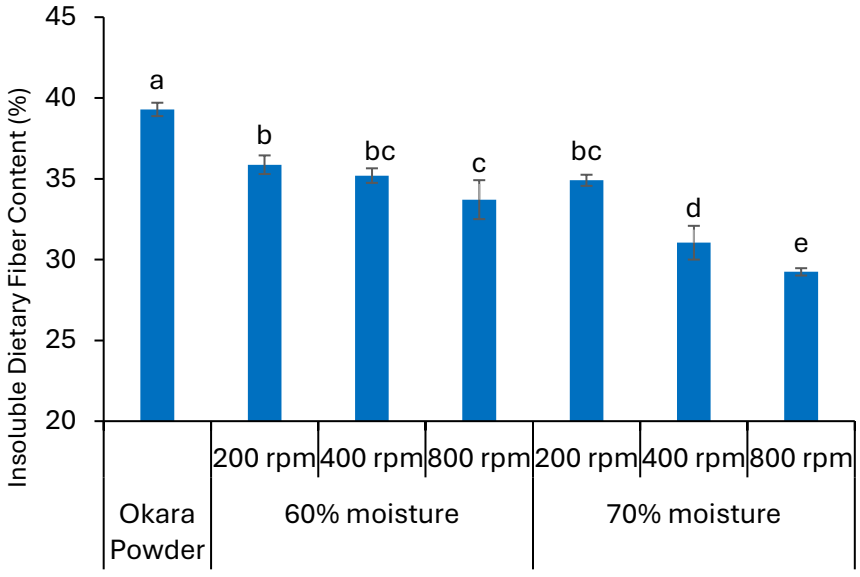


Figure 2 Effect of moisture and screw speed on the IDF conversion

These results suggest that higher moisture levels and screw speeds lead to more extensive mechanical and thermal stresses during processing, which likely break down the fiber matrix,

reducing the insoluble fraction. High moisture might soften the structure, making it more susceptible to disintegration, while high screw speeds increase shear forces and frictional heat, exacerbating fiber degradation. The synergistic effect of both parameters is evident as the IDF content is lower under higher moisture (70%) compared to 60%, even at the same screw speeds.

e. Work to be Completed.

Keep improving the method to upcycle okara with a twin-screw extruder.

Upcycling soybean meal with twin-screw extrusion cooking.

f. Other relevant information: potential barriers to achieving objectives, risk mitigation strategies, or breakthroughs.

Our target is to reduce the insoluble fiber into <10% from the twin screw extrusion process. We will try to buy the high pressure die if our current die can not reach this goal.

g. Summary

The findings from this study demonstrate that the extrusion process effectively modifies the IDF content in okara powder, offering valuable insights into optimizing processing parameters. Increasing moisture and screw speed during extrusion significantly reduces the IDF content due to enhanced mechanical and thermal stresses, which degrade the fiber structure. This reduction in IDF highlights the potential to convert insoluble fibers into more functional soluble fibers, thereby enhancing the nutritional and functional value of soybean byproducts like okara. The research underscores the importance of carefully balancing extrusion parameters to achieve desired product properties while maintaining efficiency in upcycling efforts. Future work will focus on refining the extrusion method to achieve targeted fiber composition and extending these findings to soybean meal, ensuring economic and environmental benefits for soybean processors and farmers.