

# String Hopper Maker for SME Integrating Mixing and Extrusion

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## I. INTRODUCTION

String hoppers are a staple food in Sri Lanka, characterized by consistently high demand in restaurants and canteens. However, supply often falls short due to the labor-intensive and time-consuming nature of traditional preparation methods. The current market primarily offers separate machines for mixing and extrusion processes, which can lead to hygiene issues and inconsistencies in product quality. This paper presents an integrated string hopper maker that automates the process of dough mixing and extrusion for SME. The objectives include identifying critical parameters like water-flour ratio and water temperature, designing an integrated system to eliminate the manual dough handling, and developing a working prototype. The resulting machine is expected to enhance and ensure consistent quality and hygiene, and help food centers to meet market demand effectively, thereby increasing their sales and competitiveness in the market.

## II. LITERATURE REVIEW

Mixing plays a major role in achieving the correct dough texture and is typically performed using planetary or spiral mixers, though these are not specialized for string hopper dough. For extrusion, various manual and automated systems are available, including rack and pinion [1], pneumatic [2], hydraulic [3], and screw type extruders. However, these are standalone units that require manual dough transfer from the mixer which can create a bottleneck, compromising hygiene, and affecting consistency. A comprehensive review of these technologies reveals a gap in research to develop a string hopper maker integrating mixing and extrusion for SME.

## III. METHODOLOGY

### A. Design of Experiment

An experimental setup was designed to determine the optimal parameters of string hopper extrusion process. The experiment aimed to identify and analyze the effects of extrusion pressure, sieve hole diameter, and water-flour ratio on the quality and extrusion speed of the prepared dough. A dedicated extrusion workbench was arranged, featuring an air compressor for pressure application, a pressure regulator and sensor for precise control and measurement of applied pressure, interchangeable sieve plates with varying hole diameters, and a flow control valve. The procedure tested three different dough water-to-flour ratios (200:210, 200:220, 200:230) under three distinct pressures (0.4, 0.45, 0.5MPa) through each of three sieve sizes (1,1.5,2mm), with data

collected on the required extrusion pressure and the visual quality of the resulting string hoppers.

### B. Decision Matrix

To determine the optimal design parameters for the integrated machine, a decision matrix was used. Input parameters were extrusion pressure, and water-flour ratio. Output parameters were extrusion speed and the quality of the string hopper. The relationship between input parameters and output parameters was evaluated. The decision matrix provided a structured scoring system, weighing each output based on its importance to the machine performance and enabling the data to select the most effective parameter combination.

### C. Design Considerations

The design of the machine focuses on hygiene to ensure food safety and quality [4]. The choice of materials for every part of the machine is a crucial factor. The aim of low surface roughness is to prevent microbial adhesion and facilitate cleaning [5]. The design maintains clear of interior ledges, sharp edges, and crevices where residue might collect. Further, fabrication of the machine adheres to relevant international standards, including ISO 14159:2002 for hygienic machinery design and ISO 22000:2018 for food safety management systems, to minimize the risk of contamination and ensure operational safety.

### D. Concept Generation

Several mechanism concepts were developed. Each was evaluated through 3D modeling based on criteria such as manufacturability, cost, adaptability, and ease of cleaning. using decision matrix, one concept was selected.

## IV. DESIGN AND PROTOTYPING

An integrated machine was designed to automate the mixing and extrusion processes. Power requirements and sizing of the critical components were done using machine design fundamentals [6]. For the fabrication of the prototype food grade stainless steel (304 SS) was used. Fig. 1 and Fig. 2 show the 3D model and prototype of the machine.



Fig. 1. SolidWorks design



Fig. 2. Developed prototype

## V. RESULTS

### A. Results of Design of Experiments (DOE)

Experimental results from the Design of Experiment (DOE) analysis identified the Flour-to-Water (F/W) ratio as the most statistically significant factor ( $p < 0.05$ ) affecting product quality, with a lower ratio (20:23) yielding superior results. The main effects plot for quality is presented in Fig. 3. For extrusion speed, both the F/W ratio and the sieve hole diameter were significant, with larger diameters and lower F/W ratios increasing throughput, as shown in Fig. 4. Interaction plots further revealed a strong interdependence between the hole diameter and the F/W ratio, indicating that these parameters must be optimized together. Fig. 5 and Fig. 6 show the interaction plot for extrusion speed and quality. Extrusion pressure had a less significant impact within the tested range.

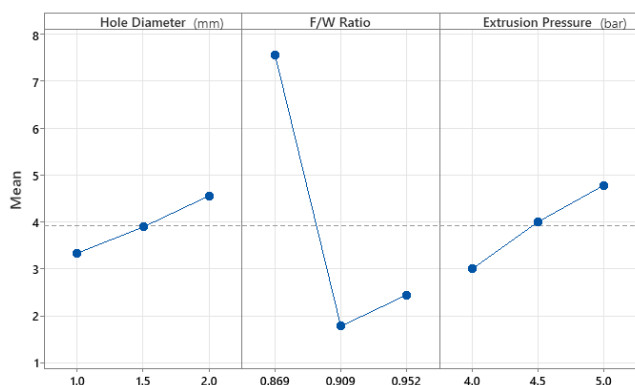


Fig. 3. Main effects plot for quality

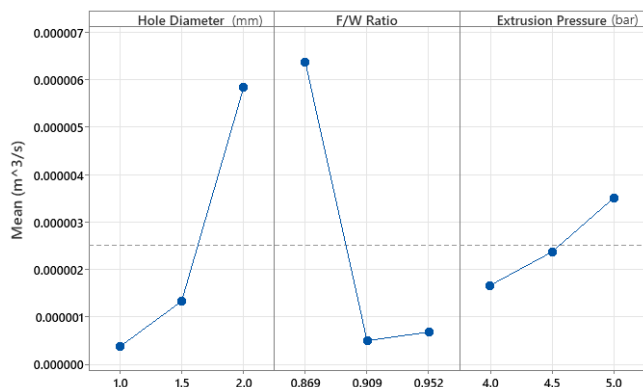


Fig. 4. Main effects plot for extrusion speed

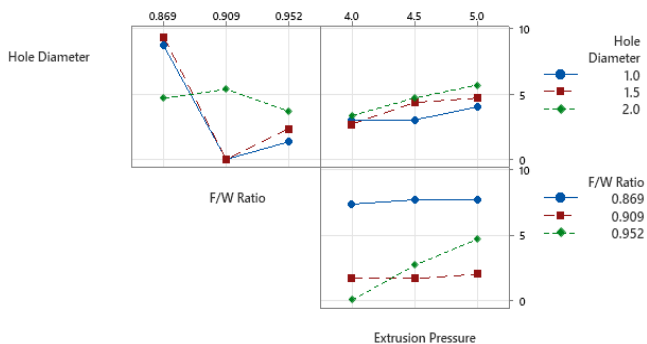


Fig. 5. Interaction plot for quality

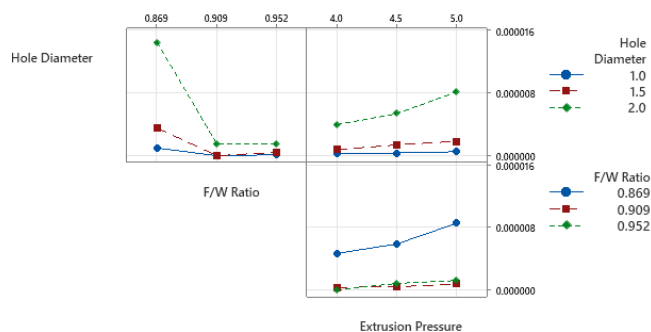


Fig. 6. Interaction plot for extrusion speed

### B. Result of Prototype Testing

The operational success of the manufactured prototype was confirmed by testing. Compared to conventional methods, the integrated machine produced almost 500 string hoppers per hour, resulting in a significant reduction in production time and manual effort. The machine produced string hoppers with a constant size, shape, and texture that was on par with those made by hand. The prototype's compact size, safety, and ease of use confirmed that it could be used in small- to medium-sized food manufacturing plants.

## VI. CONCLUSION

The research gap was successfully achieved by developing a functional, integrated string hopper maker. A comprehensive review of existing methods was conducted. An efficient hygienic design was developed and selected. An integrated machine was designed targeting SME, and a prototype was fabricated. It was then tested to confirm its ability to produce uniform string hoppers with reduced labor compared to traditional methods. Further investigation into integrating a continuous line steaming unit is also recommended to create fully continuous production.

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