DEVELOPMENT OF A PORTABLE COLD EXTRUDER FOR VALUE-ADDED PRODUCTS

Submitted by

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2024

DECLARATION

We hereby declare that this project report entitled **“Development of a portable cold extruder for value-added products”** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Place: Tavanur
Date: 11/06/2024

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CERTIFICATE

Certified that this project report entitled **"Development of a portable cold extruder for value-added products"** is a record of project work done jointly under our guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CHAPTER 1
INTRODUCTION

Extrusion technique is a process in food processing technology which combines several unit operations including mixing, cooking, kneading, shearing, shaping and forming. It is a process by which a set of mixed ingredients are forced through an opening in a perforated plate or die with a design specific to the food, and is then cut to a specified size by blades. The machine which forces the mix through the die is an extruder, and the mix is known as the extrudate. The extruder consists of a large, rotating screw tightly fitting within a stationary barrel, at the end of which is the die. Based on the method of operation, extrusion can be classified into hot and cold extrusion. Also based on the type of construction single or twin-screw extruders are available (Mishra and Rao, 2012).

Single screw extruders contain a single rotating screw in a metal barrel. The most commonly used single screws have a constant pitch and come in varying patterns. The raw materials are fed from the hopper located in the feed section and the rotating screw conveys the material to the transition section. In the transition section, the screw channel becomes shallower and the material is compacted results in a rise in temperature of the material. Starch becomes gelatinized, and the material becomes more cohesive. It is transported further by the metering section and pushed through the die opening (Rao and Thejaswini, 2015)

In cold extrusion, food temperature is constant (around 100ºC) which is used for shaping and mixing of food including meat products and pasta. Temperature less than 100ºC is also used for low pressure extrusion, as in pet foods. Chilling, baking or drying methods are used for the preservation of cold extruded products. (Shelar *et al*., 2019)

The extruded products market in East Asia and South Asia is anticipated to grow at 4.7% in the forthcoming years, owing to growing number of working population as well as urbanization. High demand of processed products as well as increasing preference for snackification, especially in India and China, further makes Asia-Pacific region a lucrative market for extruded products. The demand for extruded baked products is estimated at US$ 39.3 billion for 2023 and is expected to grow at 3.9% value CAGR (compound annual growth rate) in the impending years. The high demand for bakery products due to a greater variety and novelty of items available on the market is expected to have positive impact on market. Based on extrusion process, the market is segmented into hot extrusion and cold extrusion.

The valuation for cold extrusion is marked at US$ 144.2 billion for 2023 and holds a value share of above 60% in the global extruded products space.

In South Asian countries, rice holds a central and culturally significant role in daily diets. The consumption of rice varies across the region, reflecting diverse culinary traditions. In countries like India, Bangladesh, and Sri Lanka, rice is a staple food and often serves as the primary source of energy. In southern parts of Asia, an important culinary dish made of rice flour is called Idiyappam (Zibaee, 2013).

Idiyappam is a delicately crafted dish, composed primarily of rice flour, water, and a pinch of salt; the preparation of idiyappam involves the artful extrusion of pliable rice flour dough through a special press, resulting in fine, thread-like noodles. These strands are then steamed to perfection, creating a bed of soft, white idiyappam with a subtle chewiness. Idiyappam stands as a testament to the rich culinary heritage of South India (Suresh, 2021).

The objective of developing a portable cold extruder for small-scale uses is to offer easily accessible, affordable, and flexible production capabilities. These small machines enable customized items or components to be produced by startups, small firms, and individuals without the need for specialist equipment or a large infrastructure. Because of their portability, affordability, and convenience of use, portable cold extruders enable individuals and small-scale producers to compete in a variety of industries, innovate, and explore new avenues for growth.

CHAPTER 2
REVIEW OF LITERATURE

Rossen *et al*. (1973) evaluated a foundational examination of food extrusion technology, detailing its principles, applications, and technical aspects. Their work explored the mechanics of single-screw and twin-screw extruders, emphasizing the role of temperature, pressure, and shear in shaping food products. They highlighted the versatility of extrusion in producing items such as pasta, ready-to-eat cereals, and textured vegetable proteins. While the paper underscores the benefits of extrusion, including improved efficiency and product diversity, it also notes the challenges like high initial costs and nutrient degradation.

Mendis *et al.* (2014) designed an automated low-cost string hopper machine for medium-scale industries. The machine, which requires intricate preparation, was designed to reduce labor costs and improve efficiency. The machine significantly reduced production time, maintained traditional quality, and was cost-effective due to locally sourced materials. The research highlighted the potential for further innovations in automating traditional food production processes, balancing modernization with cultural preservation.

Shanmugam *et al.* (2023) focuses on creating an automatic machine for making idiyappam, a traditional South Indian dish. The goal was to make the process faster, reduce the need for manual labour, and ensure consistent quality. The researchers designed and built a prototype, testing and improving it to ensure it worked well. They found that the machine made idiyappam quickly, with consistent quality, and required less manual work. This makes the machine useful for small and medium-scale food producers, helping them increase production and reduce costs. The study showed how automating traditional food preparation can improve efficiency and maintain the quality of traditional dishes.

Perera (2019) worked on improving a semi-automatic string hopper machine to make it more efficient, reduce manual labour, and keep the quality of the string hoppers high. The research involved evaluating the current machine, making design changes, and testing a new prototype. These changes resulted in faster production, less need for manual work, and consistent quality. The improved machine is more suitable for small to medium-scale food producers, helping them work more efficiently and cut costs. This study shows how improving existing machines can bridge the gap between manual and fully automated processes while maintaining traditional food quality.

Suresh (2021) developed a pneumatic extruder to make fortified rice noodles, called idiyappam, aiming to improve the traditional method. The study focused on creating a machine that enhances efficiency, consistency, and nutritional value. The research included designing the extruder, adding nutrients to the rice flour, and testing the machine to find the best settings. The results showed that the extruder significantly reduced production time, produced noodles with consistent quality, and increased nutritional content. The machine proved practical for small to medium-scale production, offering an effective solution for food makers. This study showed the potential of using pneumatic technology in food processing, leading to better efficiency and quality. It opened the door for future improvements and wider use of such machines in traditional food production.

CHAPTER 3

MATERIALS AND METHODS

This chapter describes the details of the design and development of a cold extruder that utilities the torque of DC motor for the preparation of normal idiyappam (string hoppers) and other cold extruded products etc. The materials used for fabrication of the cold extruder and the instrumentation employed for measurements of parameters are explained.

3.1. Materials used for the development of cold extruder

3.1.1 Procurement of raw materials

The major requirements for the preparation of idiyappam are rice flour. For excellent idiyappam, ensure the usage of high-quality rice flour, preferably homemade from a reputed brand. The major criterion is the freshness of the rice flour. Hot water was used to make the dough. The ratio of water to rice flour is crucial. Gradually water was added while stirring until the mixture had a soft, flexible consistency. Pinch of salt, oil and ghee was added to enhance the flavour and texture for the dough.

3.1.2. Conceptual design

The mainframe of the system was fabricated out of galvanized iron which consists of a vertical section and horizontal plane. The vertical section holds the DC motor and the cylinder used for the preparation of the idiyappam. Ball bearings (2 No. s) that are attached on the top frame facilitate the to and fro motion of the cylinder, which is hung by a metallic chain. The back-and-forth movement of the bearing-cylinder system enables the wide radial movement of the cylinder, thus facilitating large scale applications. The galvanized framework provides the base strength for the machine. A depth of 40mm is occupied by the hole to fill the plate. The total length of the cylinder taken for the machine is 680mm where 130mm is the length of the motor and rest is the length taken for the threaded rod and piston to move down during the operation. The cylinder is attached to a chain of length 50mm where the other side of the chain is attached to the bearing. The usage of chain helps in the holding of the cylinder even when the product is loaded and it also emphasis easy movement of the cylinder. The whole frame of the machine was built using galvanized iron which indeed provides strength to the machine and also it is cheaper.

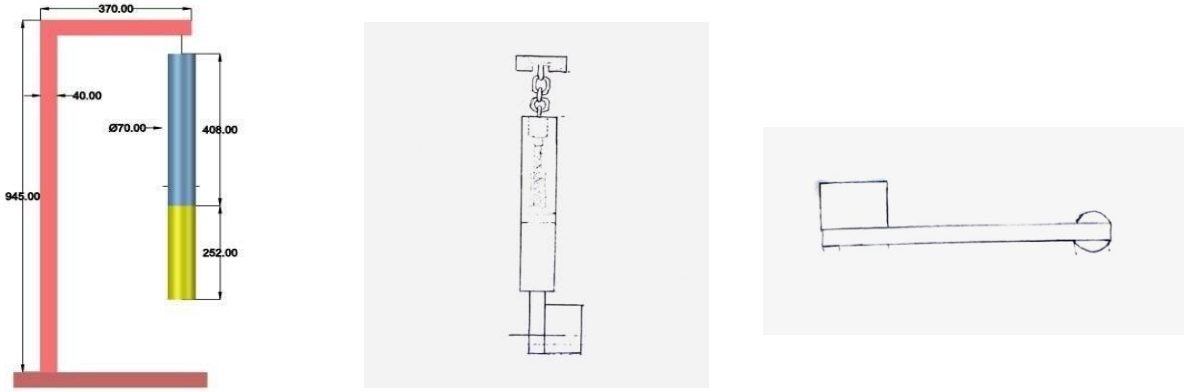

Plate 1. Front view, side view, and top view of portable cold extruder

3.1.3. Raw material

The extruder was developed using stainless-steel (SS 304) cylinders due to their corrosion resistance, smooth surface, and non-reactive nature. This food-grade material ensures high hygiene standards and easy cleaning, while also reducing the need for frequent replacements. Its non-reactive nature prevents unwanted flavours or contaminants from contaminating food. Stainless steel versatility in cooking, cooling, and freezing processes, along with its polished appearance, aligns with regulatory standards and consumer safety.

3.1.4. Motor unit

Motor unit consist of D C Motor, piston, switch, battery, programmer. The whole unit is enclosed in a cylindrical pipe. The bottom part has the locking system to attach the feed unit.

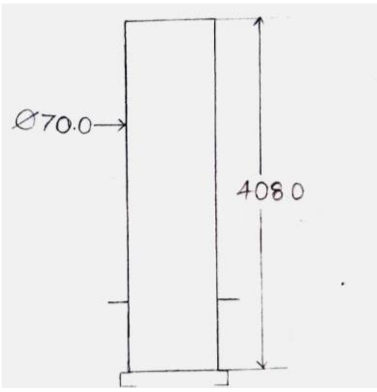

Plate 2. Motor unit

3.1.5. D C motor

A DC motor converts electrical energy into mechanical energy through magnetic fields. Its rotation direction can be controlled by reversing the voltage polarity. DC motors have good speed regulation and high starting torque, making them suitable for applications requiring start-up under load. They are highly efficient, but efficiency may be affected by factors like friction, heat, and losses in electrical components. DC motors are compact and lightweight, making them suitable for portable and space-constrained applications. In this study, a permanent magnetic motor of 12V and 110-120 rpm was used.

The length of the motor was taken as 130mm which includes 80mm length of the body of the motor and rest 50mm is the length of the shaft. The DC motor was welded to the cylinder of 70mm diameter**,** and the shaft was attached to the thread of length 300mm. The torque for the DC motor can be found out through the equation:

$$T = K.I_a\,.\Phi.\sin\theta$$

Where,

T is Torque

K is Constant related to motor's design

I_a is Armature Current Φ

is Magnetic Flux

θ is angle between magnetic field and armature current

Plate 3. DC Motor

3.1.6. Piston

Piston is used to pressurize the dough through the die. It has two parts: Piston rod & Base plate. Piston rod is a stainless-steel square pipe of length 250 mm. A base plate of diameter 70 mm is attached to it. A threaded rod facilitates the upward and downward motion of piston.

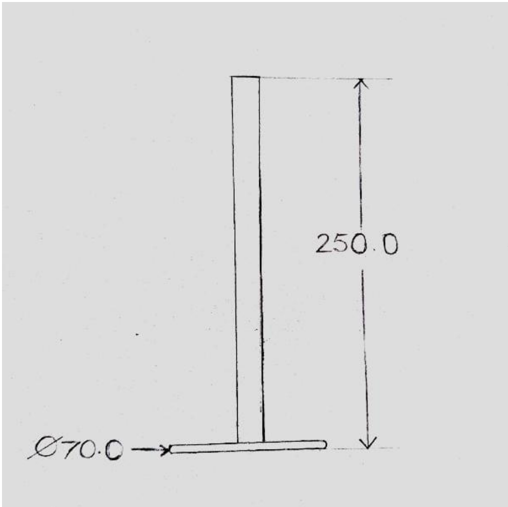

Plate 4. Piston

3.1.7. Feed unit

Prepared dough is loaded in this unit. Stainless steel cylinder of diameter 70 mm and a length of 252 mm. Die of diameter 70 mm and 0.2 mm thickness is provided at the bottom. It has a lock system at top to attach to the bottom of motor section.

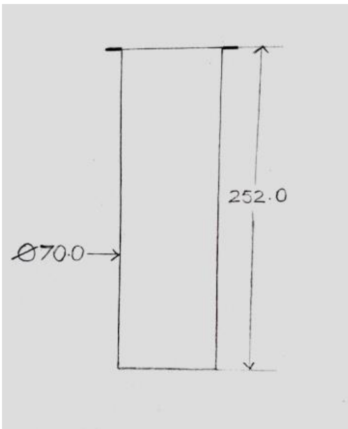

Plate 5. Feed unit

3.1.8. Battery

12V battery is used for the development of the cold extruder. In this system the DC motor is rotated by the power of the battery. A 12-volt battery is a common type of automotive battery used to power vehicles, boats, and various other applications. The battery is kept at the base of the machine and it is behind the vertical stand.

3.1.9. Cutting

Cutting is done with the help of a press cutter. The cutting process begins with the design phase, where engineers and designers create detailed plans for the machine. This includes specifying the materials to be cut, the type of cutting tool to be used, and the desired precision of the cuts. In the development of the cold extruder, we have to cut down materials such as stainless-steel, galvanized iron etc.

Plate 6. Press cutter

3.1.10. Welding

The welding machine plays a pivotal role in the fabrication of a machine, serving several essential functions throughout the process. welding machine is used to join various components of the machine together. This includes welding together structural elements, frames, and other parts to create a unified and robust structure. Here in this study the galvanized iron used as the frame of the machine is welded accordingly by the use of the welding machine. The locking system of the stainless steel is also welded with the aim creating an easiness in the operation of the cold extruder.

CHAPTER 4

RESULTS & DISCUSSION

This chapter outlines the results on the development of portable cold extruder. The evaluation of the process demands various parameters such as capacity of the machine, weight of the machine, bulk density etc.

4.1 Design calculations

Bulk density refers to the mass of a material per unit volume when it is in a loose, granular, or powdered state. It was often expressed in units such as kilograms per cubic meter (kg/m^3) or pounds per cubic foot (lb/ft^3). The bulk density of a material is a critical parameter in various fields, including engineering, construction, agriculture, and materials science. Bulk density, is defined as the mass of many particles of flour material divided by the total volume they occupy.

4.1.1. Bulk density

To find the bulk density of dough, begin by preparing a uniform dough sample, ensuring it was free from significant air pockets by gently kneading or pressing it. Next, take a graduated cylinder or a measuring cup, and lightly grease the inside if necessary to prevent the dough from sticking. Fill the container with dough, pressing gently to eliminate air gaps, and level the surface with a spatula. Note the volume from the container's markings. Weigh the dough using a scale, first measuring the empty container if needed and then subtracting its weight to obtain the dough's mass.

$$\textbf{Bulk density}(\rho) = \frac{\textit{Mass of the product}}{\textit{Volume occupied by the product}}$$

Initially, the bulk density of the product was determined using the equation for finding bulk density and it was found to be 1.17 g/cm^3, which was the volume occupied by the product per unit mass.

$$= \frac{92}{78.5} = 1.17\ g/cm^3$$

4.1.2. To find volume with respect to bulk density

Given weight (60.8 g), height (3 cm), and radius (7 cm), the volume of a single hole was calculated and then the total volume required to fill 32 such holes are calculated as follows

Weight = 60.8 g

Height = 3 cm

Hence,

Radius = 7 cm

Assume that height to fill 1 hole = 2 cm

Therefore, to fill 32 holes = 64 cm

Bulk density = 1.17 g/cm³

With the mass given (2000 g) and the bulk density, the volume occupied by the mass of the product, accounting for a 5% headspace can be obtained.

Mass = 2 kg = 2000 g

$$\text{Volume} = \frac{Mass}{Bulk\ Density} = \frac{2000}{1.17} = 1709.4 \approx \mathbf{1710\ cm^3}$$

Considering, headspace of 5%

0.05 * 1710 = 85.5 cm³

After considering the headspace, it was found that the total volume was of 1800 cm³.

Total Volume = 1710 + 85.5 = 1795.5 **≈ 1800 cm³**

4.1.3. Determination of height with respect to volume

$$\text{Height} = \frac{Volume}{\pi r^2} = \mathbf{46.79\ cm}$$

Finally, the height required to accommodate this volume is obtained, which turns out to be approximately 46.79 cm. Therefore, this result implies that to accommodate a mass of 2000 grams of the product with a bulk density of 1.17 g/cm³ and considering a 5% headspace, a container with a height of approximately 46.79 cm would be required.

4.2. Fabrication

4.2.1. Motor unit

Motor unit consist of D C Gear Motor, piston, switch, battery, programmer. The whole unit was enclosed in a cylindrical pipe. The bottom part has the locking system to attach the feed unit. It was made of stainless steel and has a length and diameter of 408mm and 70mm.

Plate 7. Fabricated motor unit

4.2.2. Feed unit

Stainless steel cylinder of diameter 70 mm and a length of 252 mm was made to feed the dough. A die of 70 mm in diameter and 0.2 mm in thickness was provided at the bottom to provide the shape of the string hopper. A lock system was provided at top to attach to the bottom of motor section.

Plate 8. Fabricated feed unit

4.2.3. Piston

Piston consists of two parts, piston rod & base plate. Piston rod was stainless-steel square pipe of length 250 mm. A base plate of diameter 70 mm was attached to it. A threaded rod facilitates the upward and downward motion of piston.

Plate 9. Fabricated piston

4.2.4. Portable cold extruder

Frame was made up of GI square pipe of dimension 40 mm. Horizontal arm holds the motor and feed units using a chain and bearing mechanism. The bearing enclosed in the arm facilitates the translational motion of motor and feed units. The vertical arm provides required height for easy operation. The product tray was held firmly by the base of frame.

Plate 10. Portable cold extruder

CHAPTER 5

SUMMARY & CONCLUSION

The project aims to develop a portable cold extruder using a DC power source, benefitting the household applications. The moveable cylinder simplifies cold extrusion process, making it suitable for large-scale production, by improving efficiency and user-friendliness.

- The aim of the study was to develop a portable cold extruder.
- Dimensions and capacity of the machine were calculated using specific product mass and bulk density.
- Bulk density of product was determined to be 1.17 g/cm^3.
- 60.8 grams of dough volume was required to fill 32 holes.
- The diameter of each hole was 7 cm, and its height was 3 cm.
- Product volume was found 1800 cm^3 after 5% headspace, 1710 cm^3 for a 2000 g bulk.
- Height of the feed container was determined as 46.79 cm.
- The motor unit, made of stainless steel, includes a DC Gear Motor, piston, switch, battery, and programmer, enclosed in a cylindrical pipe with a locking system and has a length and diameter of 408mm and 70mm respectively.
- A 70mm stainless steel cylinder with a 252mm length and 0.2mm thickness bottom was fitted with a die and a top lock system for motor section attachment.
- The piston consists of a 250mm stainless-steel square pipe piston rod and a 70mm diameter base plate, with a threaded rod for upward and downward motion.
- The 40mm GI square pipe frame features a horizontal arm for motor and feed units, a vertical arm for easy operation, and a base for securing.
- The cylinder can be moved according to convenience for cold extrusion product preparation.
- The machine was a motorized equipment, suitable for large-scale production of extruded products like idiyappam.
- The developed machine simplifies extrusion for medium-scale industries and households.

REFERENCES

- Abhinav Mishra, A. M., Mishra, H. N., & Rao, P. S. (2012). Preparation of rice analogues using extrusion technology.
- Alam, M.S., Jasmeen Kaur., Harjot Khaira., & Kalika Gupta (2015). Extrusion and Extruded Products: An overview, Critical Reviews in Food Science and Nutrition, 56(3): 445-473.
- Dalbhagat, C. G., Mahato, D. K., & Mishra, H. N. (2019). Effect of extrusion processing on physicochemical, functional and nutritional characteristics of rice and rice-based products: A review. *Trends in Food Science & Technology*, *85*, 226-240.
- Mendis, B. D. N., Medagedara, N. T., & Wijewardene, D. C. (2014). Design of automated low-cost string hopper machine for medium scale industry. *International Journal of Scientific and Research Publications*, *4*(10), 4-6.
- Perera, P. (2019). Modified version of Semi-Automatic String Hopper machine. In *Symposium NERD Center*.
- Rossen, J.L., Miller, R.C., (1973). Food extrusion. Food Technol. 27: 46-53
- Shanmugam, A., Muralidharan, N., Pratheep, V. G., Thangarasu, S. K., Tamilarasi, T., & Heeraj, A. (2023). Automatic idiyaapam maker machine. *Materials Today: Proceedings*, *81*, 783-786.
- Shelar, G. A., & Gaikwad, S. T. (2019). Extrusion in food processing: An overview. *The Pharma Innovation Journal*, *8*(2), 562-568.
- Suresh, D. (2021). *Development and evaluation of a pneumatic extruder for production of fortified rice noodles (idiyappam)* (Doctoral dissertation, Department of Processing and Food Engineering, KCAET, Tavanur).
- Zibaee, A. (2013). Rice: importance and future. *J. Rice Res*, *1*(10.4172).

ABSTRACT

The aim of this study was to develop a novel portable cold extruder, powered by a DC power source, aimed at addressing the limitations of existing extrusion machines. The primary objective was to design a low-cost, innovative solution that simplifies the extrusion process and enhances productivity for medium-scale industries and households.

The portable cold extruder features a movable cylinder that allows for convenient preparation of a variety of cold extruded products. The motor unit, a stainless-steel design, features a DC gear motor, piston, switch, battery, and programmer. It's enclosed in a cylindrical pipe with a locking system. The feed unit, a 70mm stainless steel cylinder, has 252 mm length and 0.2mm thickness at the bottom. The GI square pipe frame has a horizontal arm and a vertical arm for support. This motorized equipment is engineered to support large-scale production, particularly of traditional products such as idiyappam, which are typically labour-intensive and time-consuming to produce using conventional methods.

By integrating user-friendly and efficient design elements, the new extruder eliminated many drawbacks associated with traditional extrusion techniques, thereby offering a practical solution for both medium-scale industrial applications and home use. The machine's portability and low energy requirements further enhance its suitability for diverse operational environments.

In conclusion, the newly developed portable cold extruder represents a significant technological advancement, providing a cost-effective, efficient, and scalable option for producing high-quality extruded products. This innovation holds the potential to revolutionize extrusion processes in various settings, promoting increased productivity and ease of use.