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Revolutionizing Food Processing: The Emergence of Extrusion Techniques

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Abstract:

Food extrusion technology is emerging as a critical solution that meets modern consumer expectations for convenient and nutrient-dense solutions, particularly as the world's population grows and the need for sustainable food production methods increases. Extrusion is a mechanical, continuous process that combines several unit activities, including mixing, cooking, and shaping, to produce various food products. This adaptable and affordable technology improves the overall nutritional profiles of products by enhancing their texture and digestibility as well as their ability to incorporate different nutrients and flavours. Extrusion-based 3D printing, hot-melt extrusion, supercritical fluid-assisted extrusion, and other innovative developments are broadening the technology's potential applications in the production of pet foods, snacks, cereals, meat substitutes, and value-added goods from food waste. While the approach has several advantages, including cheaper processing costs, reduced energy expenditure, increased shelf life, and waste minimization, it does have some drawbacks, including the possibility of product colour fading and nutritional degradation. In the long term, food extrusion technology has a lot of potential for creating novel, sustainable food solutions that satisfy changing customer needs for quick, nutritious food items. Extrusion is predicted to become more and more important in determining the direction of sustainable food production as research and development continue.

Keywords: Designer food, Value addition, new product, Texture, Noval technique, Waste minimization, Consumer demand

Introduction to Extrusion Technology:

As the world's population grows, the necessity for sustainable food production methods becomes more critical. Because of gender equality and the rise in single-person homes, modern lifestyles are significantly different. There is a growing need for high-protein, plant-based

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foods and novel food technology as a result of people being busy and frequently lacking the time to prepare meals. Particularly for baby foods, consumers choose solutions that are both enticing and healthful. (Ramachandra *et al*, 2015). These aesthetically pleasing and practical "designer foods" are made possible by food extrusion technology.

A common manufacturing technique is extrusion, which involves pushing material through a die to produce objects with a predetermined cross-sectional profile. This method is crucial for producing complicated forms efficiently in a variety of industries, such as food, polymers, and metals. In the food business, food extrusion technology is essential because it makes it possible to produce a wide range of goods effectively and efficiently. Food extrusion technology, renowned for its effectiveness and adaptability, also provides several long-term advantages. This article explores food extrusion's advantages, uses, and manufacturing methods. It emphasizes the technology's importance in modern food production and how it might help create a more sustainable food system. Extrusion decreases lipid oxidation, and denaturation of proteins, and gelatinizes carbohydrates while also reducing anti-nutritional factors. Furthermore, it is regarded as a flexible, affordable, and highly effective technology in the food processing industry producing a broad variety of value-added, nutritionally rich products. (Pansawat *et al*., 2008).

It is one of the modern food processing methods used to create a range of nutritionally rich value-added products, supplementary foods and snack meals. Extruded goods are safer against microbes, have a longer shelf life, contain more nutrients, and have a lower moisture level (Pathak and Kocchar, 2018). Extrusion is significant because it can minimize waste and generate homogeneous products at rapid production speeds. Novel extrusion technologies are causing the industry to advance significantly in ways that improve product quality, sustainability, and efficiency.

Food Extrusion:

Food extrusion is a continuous, mechanical, size-enlargement process that creates a variety of products by combining several unit activities, such as cooking, kneading, shearing, shaping, and forming. In applications involving food, screw extrusion is prevalent (Karwe, 1992). This machine turns raw ingredients into finished food products by using pressure and heat. Versatility in extrusion makes it possible to make pet foods, pasta, cereals, and snacks (Table 1). Numerous intricate alterations are brought about by extrusion cooking, including

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hydration, starch gelation and shearing, fat melting, protein denaturation or reorientation, plasticization of the material to form a fluid melt, creation of glassy states, and expansion and solidification of foods (P.J. Fellows, 2022).

Types of Extruders:

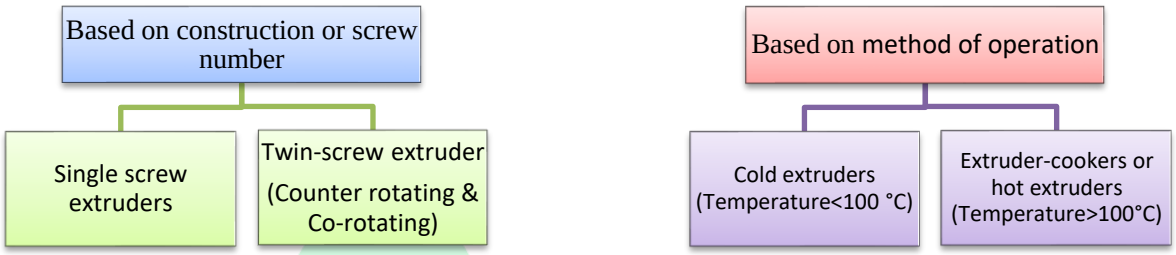

Table 1: Examples of extruded foods

Starch-based products	Protein-based products	Sugar- based products
Extrusion cooking:	Extrusion cooking:	Extrusion cooking:
High shear: • Puffed and expanded snack foods • Ready – to – eat and puffed breakfast cereals • Crispbreads and croutons • Crackers and wafers • Coextruded/filled snack foods *Medium shear:* • Breads, including flatbreads, breadsticks, Breadcrumbs, Cornflakes, Chocolate-filled snacks, Biscuits *Low shear:* • Pre-gelatinised and modified starches, Weaning foods • Instant rice and noodles	*Medium shear:* • TVP(Texturized Vegetable Protein) or meat analogues *Low shear:* • Processed cheeses	*High shear*: • Hard-boiled confectionery *Low shear*: • Toffees, Chocolate, Caramels, Chewing gum, Marshmallows, Fruit gums and jellies, Fudge, Liquorice, Nougat, Praline

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Cold extrusion:	*Cold extrusion:*	
• Pasta products • Pastry and biscuit doughs	• Fish pastes, Sausages, frankfurters and hot dogs, Surimi	

Principle of Extrusion cooking:

The raw materials enter the extruder barrel, where the screw(s) push the food along. As it moves down, smaller flights limit its movement, causing it to fill the barrel and compress. The screw then mixes the material into a semi-solid mass. Food is heated above 100°C, called extrusion cooking (or hot extrusion). The heat from friction and any additional heating quickly raises the temperature, allowing starches to gelatinize and expandable components to stretch. Then, food moves to the part with the smallest flights, which increases pressure and shearing. Finally, it's pushed through narrow openings (dies) at the end. As it exits under pressure, it expands into its final shape and cools quickly as moisture evaporates as steam (Bordoloi and Ganguly, 2014).

Essential sections of an extruder: There are 3 main sections of the extruder as depicted in Fig. 1.

Feed section	• Raw materials are introduced and transported
Compression section	• Reduces particle size and increases temperature and pressure to create a uniform dough-like consistency
Metering section	• Responsible for regulating the flow of material into the die, ensuring precise control over the extrusion process & maintaining product quality

Basic elements of proper extrusion cooking*:*

1. **Continuous Material Feeding:** Granular or milled substances should be continuously fed into the extruder at the appropriate rates.
2. **Pre-conditioning Process:** The materials must be pre-conditioned using steam at a controlled temperature ranging from 82°C to 99°C under atmospheric pressure.
3. **Even Moisture Distribution:** Moisture needs to be applied uniformly to the product.
4. **Dough Formation:** The machinery should convert the granular or floury materials into a dough at temperatures between 82°C and 110°C.

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5. **Final Temperature Increase:** The temperature of the dough should be increased to between 115°C and 200°C in the last 10 to 30 seconds of the extrusion process to cook and expand the product.
6. **Shaping and Cutting:** The extrudate should be formed into the desired shape and size using a nozzle or die at the end, and then it should be cut into specified lengths.
7. **Drying and Cooling Process:** Lastly, the extrudate must be dried and oiled.

Food Extrusion Process:

1. **Ingredient Preparation**-The process begins with the careful selection, mixing of raw ingredients, which typically include grains, proteins &flavourings. This mixture is essential for achieving desired taste and texture.
2. **Extrusion**-Combined ingredients are fed into the extruder & subjected to high temp. and pressures, causing mixture to cook & expand. Die shapes the product, resulting in various forms- puffs or shapes.
3. **Cooling and Packaging**-After extrusion, the products are cooled and then packaged for distribution. This step is crucial for maintaining freshness and quality (Fig. 2).

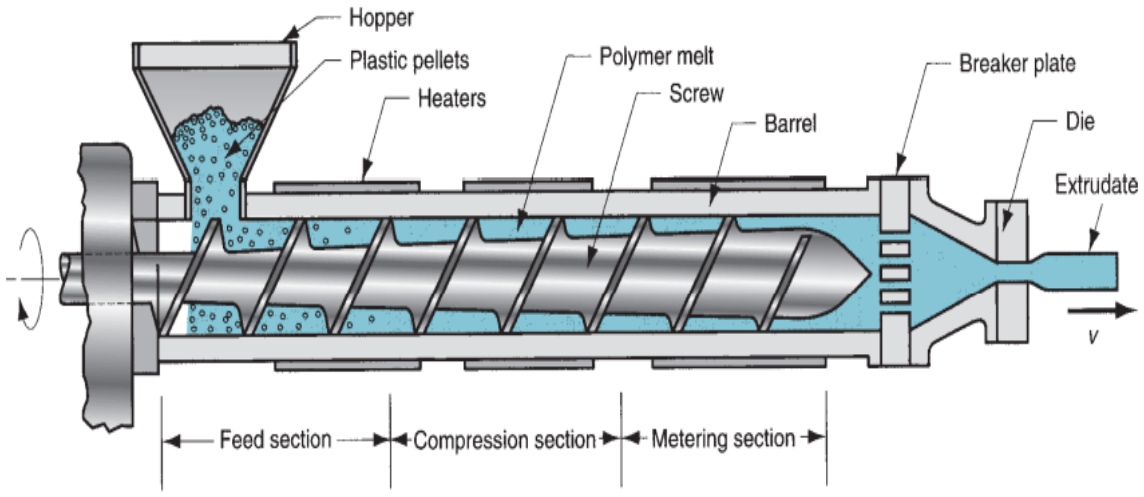

Fig 1: A typical extruder (single screw)

Figure 2– Flow chart of extrusion process

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Benefits of extrusion:

- Extrusion cooking is a one-step process. A number of operations are simultaneously carried-out in one piece of equipment. These operations include preparation (conditioning, formulation, modification, cleaning, etc.) Before extrusion and various finishing operations applied to the extrudate after extrusion (drying, frying, addition of flavouring ingredients, etc.).
- Extrusion is a continuous process.
- The extruder machine requires little floor-space.
- Extrusion requires little labour.
- The extruder is versatile. The same equipment with slight modifications may be used for achieving different objectives or for processing many different products.
- Extrusion cooking can be used for the disinfection and sterilizing the product and inactivating heat-resistant toxins, such as aflatoxin.
- The energy expenditure of cooking extrusion is usually lower than that of alternative processes (Harper,1981).
- Extrusion has lower processing costs and higher productivity than other cooking and forming processes.
- Extrusion cooking involves high-temperature short time (HTST), retaining many heat-sensitive components of a food and minimizes nutrient and flavour losses (Fellow, 2000).
- As a low-moisture process, extrusion cooking does not produce significant process effluents.

Hence the adoption of novel food extrusion technologies offers several benefits, including improved texture and digestibility, nutritional enhancement, scalability & efficiency, and sustainability. These make it a valuable tool in the quest for a more sustainable food system.

Limitations of extrusion:

1. Fading of product colour due to expansion on excessive heat.
2. Due to the elevated temperatures and low moisture conditions, different chemical reactions such as non-enzymatic browning and caramelization can occur.

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3. Temperature treatment of food material containing proteins and reducing sugars usually leads to a deterioration of the nutritional characteristics of proteins (lysine).

Key Innovations in Novel Extrusion Techniques:

Recent developments in extrusion technology have been concentrated on enhancing the process's capabilities and efficiency. Among the most commercially successful technologies, extrusion is increasing in demand in the diverse fields of the food industry, including food processing, digital food marketing (3-D printed food), and food packaging. These are some notable significant advancements in the modification of extruders for the commercial application in food processing sectors. The novel innovations include:

- **Hot-melt extrusion**: Hot-melt extrusion finds application in developing food with taste-masking properties of functional components and with high repeatability targeted delivery with widespread application in meat replacements, cheese, cocoa etc.
- **Supercritical fluid-assisted extrusion**: The supercritical fluids assisted extrusion is used to develop products rich in nutrients that are heat sensitive.
- **Extrusion-based 3-D printing**: Extrusion-based 3-D printing is the latest trend focusing on digitalizing the commercial food market with nutritionally personalized and geometrically complex food products. Extrusion is applied in the food packaging sector as biodegradable polymers replace synthetic petroleum products. These novel technologies in the extrusion have a promising future for the commercialization of both products and technology.

Applications of Novel Extrusion Technology:

Novel extrusion technologies find applications across a variety of industries. Its adaptability allows manufacturers to innovate and cater to diverse consumer preferences. Extrusion technology plays a pivotal role in the food processing industry, contributing significantly to the production of extruded foods for human consumption - snacks, cereals, and pasta with enhanced textures and flavours, pet foods, and the value addition of food wastes and by-products (Fig. 3). This innovative method not only offers an efficient and cost-effective means of producing diverse range of extruded food items but also facilitates the reintegration of food processing by-products and residues into the overall food stream, emphasizing its economic and sustainable contributions to the field of food processing.

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The food industry uses food extrusion, a flexible and creative processing method, to produce a range of goods that improve in terms of convenience and nutritional value. Using this process, raw materials are pushed through a die to create products like dairy, meat substitutes, breakfast cereals, and snack foods. Ready-to-eat (RTE) cereals, for example, are made possible by sophisticated extrusion technologies that optimize production and enable the addition of healthy components like whole grains and legumes, which increase fiber and vital vitamins.

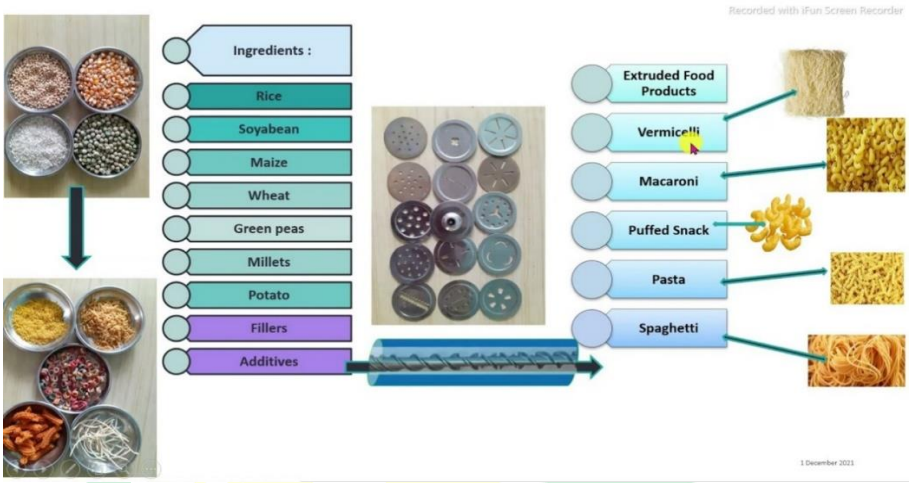

Fig. 3: Extruded products produced from using different die

Extrusion is used in the candy industry to make chewy items like licorice and fruit gums. It can be used to change the texture and shape of the product by adjusting the formulation. In an attempt to satisfy the growing demand for plant-based solutions, meat substitutes, which are typically manufactured from soy protein or gluten also use extrusion to simulate the feel of traditional meats. Extrusion technique is used to make pet food and animal feed, which ensures that different animals receive the best nutrition possible, in addition to food intended for human consumption. Moreover, by turning by-products from the processing of fruits, vegetables, and grains into desirable extruded foods, the technique is essential in lowering food waste. All things considered, food extrusion is a crucial process in contemporary food production since it not only improves product quality and diversity but also fosters sustainability by effectively using available resources (Sule et al.,2024).

Conclusion:

Food extrusion technology is a revolutionary and incredibly effective food production technique in the modern era. Its many uses enable the production of a wide range of food

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products that satisfy changing customer demands for sustainability, convenience, and nutrition. This technology allows for the introduction of healthy nutrients and Flavors into food products while also improving their texture and digestibility through the use of sophisticated processes like hot-melt extrusion and supercritical fluid-assisted extrusion. Extrusion's integration in multiple industries, such as animal and human food, demonstrates its adaptability and promise to reduce food waste by transforming byproducts into products with additional value.

Food extrusion is positioned as a major actor in reducing the environmental effect of food manufacturing due to its low energy consumption, potential for waste reduction, and use of biodegradable ingredients, all of which are contributing to the growing demand for sustainable food systems. As the food industry changes quickly, extrusion technology will remain relevant because to its potential for increased productivity and higher-quality products. All things considered, food extrusion is essential to creating wholesome, enticing, and creative food solutions that support more sustainable food systems in the future.

Future aspects in Extrusion Technology:

The future of extrusion technology is promising, with ongoing research focusing on enhancing the capabilities of existing processes and also meeting global food production challenges and consumer demands. It holds promise in developing functional foods enriched with nutrients tailored for specific health benefits. It emphasizes sustainability by utilizing agricultural by-products and improving energy efficiency. The rise of plant-based alternatives will enhance the creation of realistic meat substitutes using diverse protein sources. Additionally, extrusion can advance biodegradable packaging materials, addressing environmental concerns. Finally, its integration with 3D printing technologies could revolutionize food design and customization.

References:

Dehghan-Shoar, Z., Hardacre, A. K., & Brennan, C. S. (2010). The physico-chemical characteristics of extruded snacks enriched with tomato lycopene. *Food Chemistry*, 123(4), 1117–1122.

Fellows, P. J. (2022). *Food processing technology:* Principles and practices (5th ed.). Woodhead Publishing.

Gopalakrishna, S., Jaluria, Y. and Karwe, M. V.1992. Heat and mass transfer in a single screw extruder for non-Newtonian materials. *International Journal of heat and mass transfer*, *35*(1): 221-237.

Guy, R. (2001). Extrusion cooking: Technologies and applications. In Woodhead Publishing (pp. 111–116). Cambridge.

Pansawat, N., Jangehud, K., Jangchud, A., Wuttijumnong, P., Saalia, F. K., Eitenmiller, R. R., et al. (2008). Effects of extrusion conditions on secondary extrusion variables and physical properties of fish, rice-based snacks. *LWT - Food Science and Technology*, 41(4), 632-641.

Pathak, N., & Kochhar, A. (2018). Extrusion technology: Solution to develop quality snacks for malnourished generation. *International Journal of Current Microbiology and Applied Sciences*, 7(1), 1293-1307.

Ramachandra, H. G., & Thejaswini, M. L. (2015). Extrusion technology: A novel method of food processing. *International Journal of Innovative Science, Engineering & Technology*, 2(4), 358-369.

Ryan, L., Thondre, P. S., & Henry, C. J. K. (2011). Oat-based breakfast cereals are a rich source of polyphenols and high in antioxidant potential. *Journal of Food Composition and Analysis*, 24(7), 929–934.

Sandey, K. K., Goel, B., Karthikeyan, S., et al. (2020). Extrusion technology in dairy industry: A mini review. *Indian Journal of Pure and Applied Biosciences*, 8(5), 90–97.

Sandip, C. (2022-2023). Food extrusion technology.

Strahm, B. S. (2006). Meat alternatives. In M. N. Riaz (Ed.), Soy applications in food, pp. 135–154. CRC Press.

Sule, S.,Okafor, G. I., Momoh, O. C., Gbaa, S., & Ahunna, O. (2024). Applications of food extrusion technology. *MOJ Food Process Technols*, 12(1),74-84.