

### Session -17

Extrusion is a process which combines several unit of operations including mixing, cooking, kneading, shearing, shaping and forming. Extrusion cooking, which is a continuous, **high-temperature short-time process**, has become popular economical process to formulate new engineered foods. Extrusion can be seen as an example of a size enlargement process, in which granular or powdered foods are re-formed into larger pieces.

Types of product	Example
Cereal-based products	Expanded snack foods, RTE and puffed breakfast cereal , Weaning foods Pre-gelatinized and modified starches, dextrins , Crisp bread and croutons , Pasta products ,Pre-cooked composite flour
Sugar-based products	Chewing gum , Liquorice , Toffee, caramel, peanut brittle, Fruit gums
Protein -based products	Texturised vegetable protein(TVP) , Semi-moist and expanded pet foods and animal feeds and protein supplement , Sausages products, frankfurters, hot dogs, Surimi , Caseinates ,Processed cheese
<b>Adapted from Harper (1979), Harper (1987), Heldman and Hartel (1990) and Best (1994).</b>	

#### Extrude

The verb “extrude” describes a process of shaping by forcing softened or plastized material through dies or holes by pressure. A food extruder is a device that facilitates the shaping and restructuring process for food ingredients.

#### Extrusion cooking

Extrusion cooking is a modern HTST (High Temperature Short Time) process is being increasing used in food and technical industries. New product are being created and well-know ones are copied and made more advantages by replacing conventional machine and equipment by a extruder cooker, which are carrying out many of the physico-chemical process. Cooking extruder used as HTST piece of equipment for the processing of vulnerable food material.

Their function is to rupture cell walls by heating and shearing, making the cell contents available for mixing and reaction with other components.

**The extruder function is to denature the raw material, in order to make them available for safe digestion.** In combined product industries, like the pet food industry, the summation of starch and protein-processing is executed in cooking extruder simultaneously and much emphasis is put on controlling reactions while mixing operation are executed in the extruder equipment.

The extruder still offers a small reaction volume, which can be very well controlling vapour pressure, the residence time and the viscosity of the confectionery mix in the extruder. It is the infinite flexibility of extruder design, which make them attractive as versatile production equipment in the confectionary industry. Continuous high temperature short time extrusion cooking is not a new technology as such but an understanding of it, is of current interest. Over the last fifty year there has been an art of food extrusion and much work has done on an empirical basic studies dealing with the thermoforming of plastics. Only in recent time some of the basic thermo-mechanical transformation of food ingredients in the extruder have been understood.

#### 2.3. Principle of extrusion cooking

From an engineering point of view, a cooking extruder is a combination of a pump and a heat exchanger. The raw material is fed in to the extruder through the hopper and forced forward, toward the die, by the rotation of the one or more screw. The barrel wall is generally heated by electric heater or by oil jackets, although for simple starch gelatinization adiabatic extruder are also used. The heat is provided purely by viscous dissipation. The main purpose of extrusion is cooking, sterilisation, expansion, dehydration, stabilisation of food product.

#### 2.4. Purpose of extrusion

1. **Sterilization:** The heat and pressure produced in the extruder can be utilized for bacterial, mold and yeast destruction.

2. **Expansion:**The continuous pressure cooking and sudden release of pressure allows the gelatinization of starch cells, oil rupture, and shaping and texturizing the product.

3. **Dehydration:**Within certain parameters , a 50% loss in moisture can be achieved through the extrusion process.This allows for dehydrating many product, which have too high a moisture level for storage.

4. **Stabilization:**The use of heat and pressure can be used to inactivate enzymes that would occur in rice bran and in various other ingredients causing rapid destruction of the nutritional properties.

#### **Advantages of extrusion cooking**

- **Versatility:** A wide variety of food can be produced on the same basic extrusion system using numerous.
- **High productivity:** An extruder provides a continuous processing system having greater production capability than other cooking/forming systems.
- **Low cost:** Labour and floor space requirements per unit production are smaller than for other cooking/forming systems enhancing cost effectiveness.
- **Product shapes:** Extruder can form product shape, not easily formed by using other production methods.
- **High product quality:** The High Temperature Short Time (HTST) heating process degradation of food nutrient by heat while improving digestibility by gelatinising starch and denaturing protein. The short, high temperature treatment also destroys most undesirable factors in food. Some of these heat de-naturable factors are anti-nutritional compound such as trypsin inhibitors, hemeagglutinisers, gossypol and undesirable enzymes such as lipase, lipoxidases, microorganisms and other food borne pests.
- **Energy efficient:** Extrusion processing system operates at relatively low moistures while cooking food products. Lower moisture reduces the quantity of heat required for cooking and re drying the product after cooking.
- **Production of new foods:** Extrusion can modify vegetable protein, starches and other food material to produce a variety of new food products. Production of ready to eat (RTE) products.
- **No effluents:** The lack of process effluents is important advantages since stringent control are being placed upon food processors to prevent their releasing pollutants to the environment.

#### **Steps in extrusion processing**

Typically extrusion cooking processing condition may vary depending on the type and amount of starches used. Generally, temperature in the extruder-cooking zone will range from 80° to 150°C and barrel temperature in the forming zone will range 65°and 90°C. Extrusion moisture content will range from 10% to 15% with a residence time of 20 to 30 seconds. Number of factor affects the final product. They include extrusion temperature, screw speed, screw design and moisture content of the feed products. Major steps in extrusion are as follows:

Mixing of fish flour with other cereal flours, and food ingredients as per requirement

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Adjustment of moisture for 10% to 15% of mixture

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Extrusion cooking

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Mechanical drying at 60°C to reduce the moisture of extrude product

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Frying the extrude product and addition of Indian spices

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Packing the product in Aluminum Laminated Polyethylene packing material

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Storage and marketing

**Products include low density expanded snack foods and puffed snack food.**

#### **OPERATING CHARACTERISTICS**

The most important operating parameters in an extruder are:

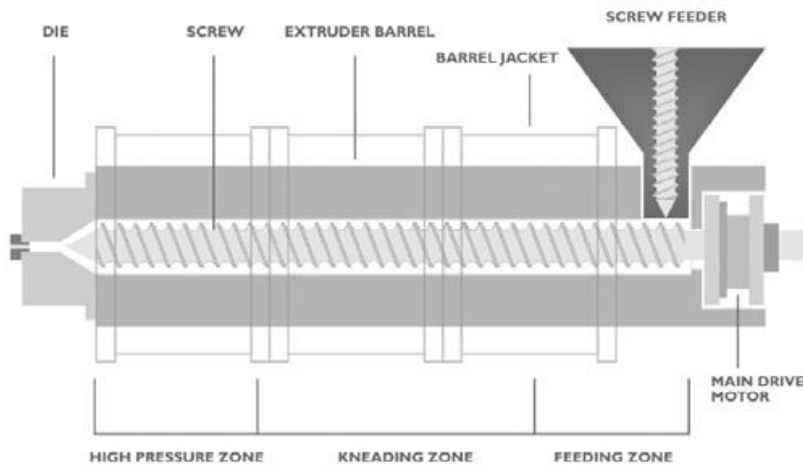
- Temperature
- Pressure
- Diameter of the die apertures
- Shear rate.

The shear rate is influenced by the internal design of the barrel, its length and the speed and geometry of the screw. Most research to model extruders has been done with single-screw machines because twin-screw extruders are substantially more complex. In operation, the single-screw extruder acts as a type of pump, dragging the food through the barrel and increasing the pressure and temperature before the food is forced through the die. For optimum pumping, the food should stick to the barrel and slip freely from the screw surface (Heldman and Hartel. 1997). However, if food slips on the barrel it does not move through the extruder and is simply mixed.

#### 4. Type of Extruder Machine

Extruders are composed of five main parts:

- 1) The pre-conditioning system,
- 2) The feeding system,
- 3) The screw or worm,
- 4) The barrel,
- 5) The die and the cutting mechanism.



**Fig. 1: Schematic representation of an extruder including its main parts and zones.**

Extruders are classified according to the method of operation (cold extruders or extruder-cookers) and the method of construction (single or twin-screw extruders).

The principles of operation are similar in all types: raw materials are fed into the extruder barrel and the screw then convey the food along it. Further down the barrel, smaller flights restrict the volume and increase the resistance to movement of the food. As a result, it fills the barrel and the spaces between the screw flights and becomes compressed. As it moves further along the barrel, the screw kneads the material into a semi-solid, plasticized mass. **If the food is heated above 100°C the process is known as extrusion cooking (or hot extrusion).** Here, frictional heat and any additional heating that is used cause the temperature to rise rapidly. The food is then passed to the section of the barrel having the smallest flights, where pressure and shearing is further increased. Finally, it is forced through one or more restricted openings (dies) at the discharge end of the barrel as the food emerges under pressure from the die, it expands to the final shape and cools rapidly as moisture is flashed off as steam. Due to the difference between pressure inside and outside of the barrel, the material expands, and according to the die shape and the cutter blade action, it creates a pellet of varying size, shape and density. A variety of shapes, including rods, spheres, doughnuts, tubes, strips, squirls or

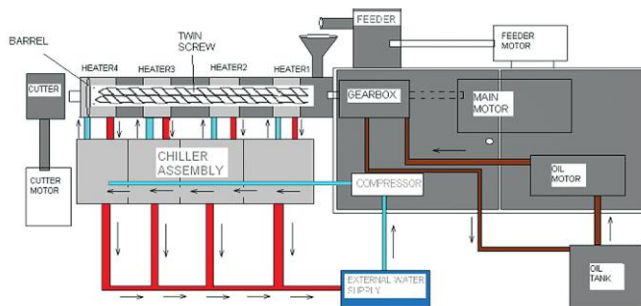
shells can be formed. Typical products include a wide variety of low density, expanded snack foods and ready-to-eat (RTE) puffed cereals.

There are 3 major type of extruder used in the food industry:

1. **Piston extruder**- consist of single piston or multiple sets of pistons that deposit a process amount of product on to conveyers or trays.
2. **Roller type extruder** - They are used to form the shape of a product. A roller consist of two counter rotating roller that either turn at similar or differential speeds. This process is also referred as calendaring in that dough industry
3. **Screw extruder**- Utilize single, twin or multiple screws rotating within a metal cabinet called the barrel. The screws convey the material formed and though a small orifice called die which can take on many shapes and sizes.

### Operating characteristics, design and construction of twin screw extruder

The most important operating characteristic in an extruder are temperature, pressure, diameter of the die apertures, shear rate. The shear rate is influenced by the internal design of the barrel, its length and the speed and geometry of the screw.



### Twin screw extruder schematics

Twin screw extruder offers an increased range of cooking application and allow for better control and operating flexibility than other type of extruder machine. The equipment consists of a cylindrical twin screw that rotates in a grooved cylindrical barrel, made from hard alloys or hardened stainless steel to withstand the frictional wear. The length to diameter ratio of the barrel is between 2:1 and 25:1. The pitch and diameter of the screw, the number of flights and the clearance between the flights and the barrel can each be adjusted to change the performance of the extruder. The twin screw is driven by a variable speed electric motor that is sufficiently powerful to pump the food against the pressure generated in the barrel. The twin screw speed is one of the main factors that influence the performance of the extruder. It affects the residence time of the product, the amount of frictional heat generated, heat transfer rates and the shearing forces on the product. Typical screw speeds are 150–600 rpm, depending on the application. **Compression is achieved in the extruder barrel by back pressure, created by the die and by increasing the diameter of the screw and decreasing the screw pitch, using a tapered barrel with a constant or decreasing screw pitch, placing restrictions in the screw flights.**

## INFLUENCE OF PROCESS ON RAW MATERIAL PROPERTIES

### 1. Starch

It is also important to consider ingredients properties during extrusion. Each individual starch source has its strong point. The fine main cereal grain starch options include rice, (long, medium or short grain) wheat (soft, hard) corn (white or yellow), barleand soats. The main objective of extrusion of starch are apart from **shaping to break down the starch granules and to gelatinize their** contents. As a result of the moisture added during the process, **the starch particle swell and owing to thermal influence, loss their rigidity, part of the amylose diffuses out.** The high shear in the extruder rupture the particle so that all the amylose and amylopection becomes available to form an amorphous

mass. Although some degradation of the large molecules can occur during extrusion, no monosaccharides are believed to be formed because of the short residence time at the high temperature.

## 2. Protein

The main function of extrusion in protein processing is to **denature and to texturize**. As a result of the high temperature and shear forces in the extruder, the intramolecular bonds in the protein molecule are broken and the protein denatures. Subsequently, these bonds can recombine with their counter parts from other molecules thus forming an intermolecule **cross-linked network in the form of strands**. The shear forces in the extruder will align these strands to give the product the desired texture. For good alignment and structure, the flow conditions in the die are very important.

## 3. Stability of end products

Various enzymes and microorganisms can spoil food products if they are not inactivated or killed during processing. Lipase and lipoxygenase may, for example, easily cause off-flavours. Myrosinase may release the toxin isothiocyanate, and nutrient destruction can occur through various residual enzymatic activities. Enzyme inactivation therefore contributes to the storage stability and safety of the product. **The influence of extrusion condition on enzyme inactivation increases with increasing extrusion temperature, shear, and pressure.**

<p><b>6. APPLICATION OF EXTRUSION PROCESS IN FOOD SYSTEM</b></p> <ul style="list-style-type: none"> <li>• Confectionary product</li> <li>• Beverage product</li> <li>• Breakfast cereals</li> <li>• Snacks</li> <li>• Texturized plant product (Texture vegetable protein)</li> <li>• Blended products</li> <li>• Pasta products</li> <li>• Restructured muscle foods</li> <li>• Instant soup and gravy bases</li> <li>• Conventional bakery products</li> </ul>	<ul style="list-style-type: none"> <li>• Pet foods</li> <li>• Animal feed</li> <li>• Sugar decrystallization</li> <li>• Modified starches and starch degradation products</li> <li>• Protein modification</li> <li>• Conversion of cellulose</li> <li>• Meat analogs</li> <li>• Frozen products</li> <li>• Instant noodles</li> <li>• Non-traditional Application of extrusion</li> </ul>
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