Introduction and Principles of Extrusion

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What is Extrusion?

- Extrusion: Process of Extruding
- Extrude: to force, press, or push out to shape by forcing through a die.
Extrusion
Food Extrusion is a process in which food/feed ingredients are forced to flow under one or several conditions of mixing, heating and shear, through a die that forms and/or puff-dries the ingredients.

Definition of Extrusion Cooking
A continuous process by which moistened, expansile, starchy, and/or proteinaceous materials are plasticized and cooked by a combination of moisture, pressure, temperature, and mechanical shear.

Definition of Extrusion Cooking
A tool used to introduce thermal and mechanical energy to food and feed ingredients, forcing the basic components of the ingredients, such as starch and protein, to undergo chemical and physical changes. Meanwhile, forming a predetermined shape.
What is Extrusion?
Cooking under pressure, moisture & elevated temperature

Functions That An Extruder Can Provide
- Texture Alteration
- Thermal Treatment
- Partial Dehydration
- Homogenization
- Protein Denaturation
- Gelatinization
- Destruction of micro-organisms and some toxic compounds

Texture Alteration
Partial Dehydration

Thermal Treatment
- Heat generated in conjunction with pressure and moisture achieves cooking, deactivation of anti-nutritional factors, protein denaturing and starch gelatinization

Mixing & Homogenization
Advantages of Extrusion Cooking

- Ample variety of foods are feasible
- Only changing the ingredients
- Operation conditions of the extruder
- Extrusion process is remarkably adaptable to accommodate the demand by consumers for new food products

Adaptability

- Ample variety of foods are feasible
- Only changing the ingredients
- Operation conditions of the extruder
- Extrusion process is remarkably adaptable to accommodate the demand by consumers for new food products
Product Characteristics

A variety of shapes, texture, color and appearances can be produced, which is not easily formed using other production method.
Energy Efficient
Extruders operate at relatively low moisture while cooking food products, so less re-drying is required.

Low Cost
Extrusion has lower processing cost than other cooking and forming processes. We can save 19% raw material, 14% labor, and 44% capital investment. Extrusion processing also need less space per unit of operation than other cooking system.

New foods/feeds
Extrusion can modify protein (vegetable and animal), starches (almost all sources), and other food material to produce a variety of new and unique food products.
**High Productivity & Automated Control**

An extruder provides a continuous high throughput processing and we can have a fully automated controls for these extruders.

**High Product Quality**

Since extrusion is HTST heating process, it minimizes degradation of food nutrients, while improving the digestibility of proteins (by denaturing) and starches (by gelatinizing).

**Quality -- Continue**

Extrusion cooking at high temperature also destroy the antinutritional compound, i.e. trypsin inhibitors, gossypol, hemagglutinings, and undesirable enzymes, such as lipases, lipoxidases and microorganisms.
No Effluent
Very few process effluent are produced.

Classification of Extruders

Single-Screw Extruders
Twin Screw Extruders

Typical Products
- Energy Pellets
- Expanded Pellets
- Shredded Plastics
- Foundry Scrap
- Aggregate
- Full-Fed Qty

Single Screw Extruder Characteristics
- Capacity: up to 22 metric tons/hour
- Screw Speed: 250 - 770 rpm
- Length-to-Diameter: 20 - 14
- Choke Zone: Venturi, Screw Filler
- Segments: Cover, ::, Cover, 6-Mold Lines.
Preconditioning

- Hydrate raw material particles
- Heat raw material particles
- Mix raw materials added in separate streams

Extruding

- Extruder barrel
- Heads
- Screws
- Die/knife

Single screw extruders

- Segmented
- Jacketed
The All-in-one Machine

Categories of SSE
- Cold Forming Extruder (Pasta-type)
- High-Pressure Forming Extruder (Cereal and Fried Snack Foods)
- Low-Shear Cooking Extruders (Meat like Snack)
- High Shear Cooking Extruders (Pet Foods, RTE, TVP)
- Collet Extruder: (Puffed Snacks)

Twin Screw Extruder
Twin Screw Extruder

- Generally one and one-half time more expensive than single screw extruder for the same capacity
- Yet the degree of quality control and processing flexibility they offer can make them attractive to food/feed

Advantages of Twin Screw Extruder

They can handle:
- Viscous, oily, sticky or very wet material and some other products which will slip in SSE, (It is possible to add up to 25% fat in a TSE)

Advantages of Twin Screw Extruder

Less wear in smaller part of the machine than in SSE.
Wide range of particle size (from fine powder to grains) may be used, whereas SSE is limited to a specific range of particle size.
**Advantages of Twin Screw Extruder**

TSF produce a more uniform flow of product through the barrel due to the positive pumping action of the screw flights. Because of the self wiping characteristics clean up is very easy.

**Disadvantages of Twin Screw Extruder**

Cost 1.5-2.0 X SS
Maintenance 2X
Types of TSE

1. Non-intermeshed, co-rotating
2. Non-intermeshed, counter rotating
3. Intermeshed, co-rotating
4. Intermeshed, counter rotating

Types of Extruders

- Single screw
- Twin screw
  - Wet extruders
  - Dry extruders

Wet Extrusion

- Wet extrusion requires:
  - Steam injection
  - Drying after extrusion
Dry Extrusion

- Dry extrusion capitalizes on the heat generated through friction as the sole source of heat to cook and dehydrate the product.

Selection of an Extruder

- The choice of an extruder type should depend on:
  - The type of raw material to be used
  - The desired product
  - The processing rate
  - The investment cost
  - Operating cost

Terminology

*Feedstock:*

Material processed in extruder.
**Terminology**

**Preconditioner:**
Moisture-heat equilibration unit ahead of extruder - May precook

**Terminology**

**Screw:**
Member that conveys feedstock

**Terminology**

**Interrupted, cut flight screw**
Screw with flight section missing
**Terminology**

*Pitch:*

![Diagram of a screw extrusion machine](image)

**Terminology**

*Shearlock, steamlock, shear ring:*

Ring that locks worm segments together, and also increases product shear

![Image of shear lock](image)

**Terminology**

*Vent:*

![Diagram of extrusion screw with moisture removal](image)
Elements for generating screw profiles and pressures

Terminology

**Barrel:**
Shell around Screw

Terminology

**Shear:**
Working, mixing action that homogenizes and heats conveyed product
**Terminology**

**L/D**

*Length to Diameter Ratio* (1:1 to 1:25)

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**Terminology**

**Compression Ratio C.R**

It is the volume of the full flight of the screw at the feed opening divided by volume of the last full flight before discharge. Typical CR is 1:1 to 5:1

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**Extruder Dies**

- Provides resistance at discharge of extruder
- Shapes product
Factors to Consider in Selecting an Extruder

- Type of product(s) to be made
- Size of plant sustainable by market
- Capital availability and recovery period
- Local backup expectations and capabilities of manufacturer
Factors

- Relative energy requirements: local cost of steam, electricity, other energy forms
- Flexibility is costly
- Hardened wearing parts for sustained usage - screw tips, barrel sleeves, die inserts

Factors

- Extruders don’t run well when starved
- Used extruders/plants are available

Extrusion “Rules of Thumb”

Formulation:

- Sufficient starch/protein required to give desired expansion, texturization, cohesion
- Over 5-6% fat interferes with texturization/expansion. Products preferably coated after extrusion and cooling
Rules of Thumb

- Addition of antioxidants, flavors, heat-labile vitamins, deferred until after extrusion and cooling

**Size Reduction**
- Largest particle less than 1/3 diameter of die opening
- Might be done less expensively in hammer/roller mills than in extruder

Rules of Thumb

**Feeding the Extruder:**
- Might be a problem with extremely powdery ingredients, heavy or sticky doughs.

**Extruder Discharge:**
- Density depends on temperature, pressure, moisture content and formula

Rules of Thumb

- Protein texturization need laminar flow before discharge
- Approximately 4-7% moisture flash-off at die

**Cooking**
- Might be done less expensively in a preconditioner (5-10 x holding time)
Rules of Thumb

Coating and Enrobing
Preferred place for addition of heat-sensitive material

Cleaning
Long runs favored, disassembly reasonably of large machines difficult.

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