TYPE OF EXTRUDERS AND EXTRUSION CONDITIONS
I. INTRODUCTION

The different types of extruders and extrusion conditions are discussed for optimizing the extrusion conditions for soybean and pet food extrusion. Process of extrusion describes the features of extrusion including the various steps involved in extrusion technology. Based on their classification extruders are reviewed and extrusion-cooking advantages are highlighted over conventional cooking methods.

The extrusion mechanism can be stated as process that combines various unit operations, including mixing, homogenization, kneading, heating, shearing, cooking, cooling, shaping, degassing, and forming. Basically, it is a simple piston contained within a cylinder, which is capped with a shaping orifice referred to as the die. When the material is loaded into the cylinder, the piston moves forward creating pressure at the die, and hence the material emerges in its shaped form from the die. This type of extrusion operation is batch process in nature because the piston must be retracted periodically to permit refilling of the chamber. The extrusion process can be made continuous by replacing the piston with a helical screw. Material is fed continuously into an inlet hopper and pushed forward by the rotation of the screw. The rotating screw moves material from inlet to the discharge point. As the material reaches the die, the pressure increases to the level required to propel the extrudate through the die orifice. These type of screw extruders can be either single or multi screw in design.

II. PROCESS OF EXTRUSION:

All extruders, in general will have a common processing features. Extrusion can be briefly described as a process where the material which is moistened, expandable in nature along with the proteinacious materials are plasticised and cooked in a tube by combination of moisture, pressure, temperature and mechanical shear. Extrusion is a processing technique that involves the addition of thermal and mechanical energy to an uncooked mass such as soybean, wheat flour etc., Extrusion processing is used to restructure the starch and protein based material to manufacture quality products. It involves compressing, working raw materials e.g., flours, starches, proteins, salt, fat, vitamins and minerals and
other ingredients to form a semi-solid mass under a variety of controlled conditions. This is accomplished by feeding the raw material into a hopper, which introduces the raw material between a rotating screw and a stationary barrel. The friction between the material and screw surface results in increase in temperature. This temperature, which is generated within the system, helps the material to absorb heat. As the material is constantly exposed to this temperature, cooking takes place in presence of moisture. The result is cooked and/or shaped product. The high shear and temperature conditions inside the screw channel result in the mixing of the material and leads to the chemical reactions that constitute the cooking process. Some of the changes that occur include: gelatinization of starch molecules, cross-linking of proteins, and the generation of flavors. Depending on the requirement, heat can either be applied directly or indirectly. Extrusion processing can be schematically shown as follows.

Fig. 1. General Cooking extrusion Process
The information on ingredients is discussed in chapter-05. The extrusion process related details are detailed as follows.

2.1 **Pre-conditioner:** In pre-conditioning process, raw ingredients are uniformly moistened or heated by contact with water or live steam for hydration to required moisture before pumping into inlet of the extruder. Pre-conditioning can be done in atmospheric or pressurized chambers. Pre-conditioners act as cooking chambers with high temperature and long residence time. It will impact little shear to the ingredient and does not contribute much to reform the molecular confirmation of feed ingredients. It will deliver uniformly, pretreated ingredients to the feeder of the extruder.

2.2 **Screw:** Major transformation of molecular confirmation of raw or preconditioned food ingredients takes place in the screw. Heat is added by mechanical energy or by the heat transfer through the barrel jackets or transportation of direct steam. Energy can enter the extruder in three ways.

- **Convection:** Steam contributes part of the cooking energy by convection
- **Conversion:** Friction between the screws and barrel on the ingredients will generate heat. Here mechanical energy is converted to heat.
- **Conduction:** Additional energy may be supplied by conduction of external heat through the extruder barrel.

2.3. **Die:** Diameter of the die influences the shape and texture of the extruded material. Tapered die holes will reduce backpressure requirements and create smoother product surface and cause less damage to the extruded ingredients. Teflon coated inserts are also used to create a smoother surfaced product.
III. CLASSIFICATION OF EXTRUDERS:

Depending upon the processing conditions, moisture, functional or thermodynamic characteristics, extruders are classified into three categories.

i) Autogenous: Here heat is generated from viscous dissipation of mechanical energy. Example; Cooking and Snack extruders.

ii) Isothermal: Heat is controlled from auxiliary sources through heating or cooling jackets on the barrel ex., Farming extruders.

iii) Polytrophic: Heat input comes from the combination of viscous dissipation of mechanical energy and auxiliary sources such as heat transfers. Example; cooking extruders.

Food Extruders can also be classified by their method of pressure development, positive displacement or viscous drag. Extruders can be classified as single or twin screw based on the design pattern.

- Single screw extruders
- Twin-screw extruders.

These extruders run on variable operational costs, but both types of extruders have distinctive features that make them suitable for applications where limited process requirements are available, example: extrusion at farms etc.,
Fig-02: Single screw Extruder
3.1 Single-Screw Extruders:

'Single screw Extruders' as represented in fig-01 are low-cost operative machines designed to use for simple operations such as dry extrusion, simple formulations and on-farm processing of farm ingredients. Operation of these extruders is simple and has been described by Wilson and Tribelhorn\(^3\). The single screw extruders operate at low moisture and generally autogenous.

3.2 Twin-Screw Extruders:

These extruders have more number of possible configurations giving the way for products to attain different shapes with co-rotating or counter rotating screws. These screws can be either intermeshing or non-intermeshing.

The intermeshing can be defined as a gap between the screws where the material flows and compressed. Since the two screws have flight configuration in such a way, that natural steam lock is formed which is independent of the material flow. This formation of natural steam lock makes the extruder to run as a positive pump.

The non-intermeshing screws cannot achieve the higher shear as the channels of one or both screws may have open segments. This problem can be over come using mechanical steam locks.

The advantages of Twin Screw Extruders are

- Precise control of product characteristics
- Extrusion of heat sensitive products
- Reduced volatilization of flavors
- Extrusion of ingredients which require additional moisture
- Better mixing characteristics.
Twin-screw extruders can be further subdivided into several classifications:\(^{1,6}\)

- Co-rotating intermeshing,
- Co-rotating non-intermeshing
- Counter rotating inter-intermeshing
- Counter rotating non-intermeshing
- Conical intermeshing

IV. EXTRUDER COOKING vs. CONVENTIONAL COOKING:

Extrusion is the most common processing method utilized in the manufacturing of pet foods. Extruders are used as cookers and are designed to operate at high shaft speeds\(^1\). Extrusion cooking has been defined as ‘the process activity by which hydrated, expandable, starchy and proteinaceous materials are mixed and cooked in cylinder by a amalgamation of moisture, pressure, temperature and mechanical shear\(^4, 5\). Products produced using ‘Extruder Cookers’ have developed the qualities of products produced by other similar processing technologies and products engineered by exceptional formulation techniques and equipment configuration to meet the consumer latest demands and growing market expectations.

Extruder cooking is used in place of conventional cooking method for many reasons.

i. **Versatility:** Extruder allows cooking and processing of different formulated products with only one machine.

ii. **High productivity:** Has greater production capability than other cooking/foaming system.

iii. **Low cost:** Labour and floor space requirement per unit of production is smaller.

iv. **Manpower:** Modern process controls helps in further reducing the manpower requirements for production operations.

v. **Product shapes:** Different types of shaped products are obtained using the extruders that are not easily produced using other production methods.
vi. **Quality products:** High temperature, short time process minimizes the nutrient degradation while destroying the most microorganisms or other pests.

vii. **Production of new products:** Extruders can modify vegetable proteins and starch. Extrusion breaks down starch into simpler units and improves the digestibility and palatability and helps to produce new food products.

viii. **No effluents:** Involves dry processing yielding little or no waste and no hazardous materials.

ix. **Anti-nutritional factors** - High temperature and pressure destroys anti-nutritional factors and ruptures oil bearing cells in short duration thus prevents untoward effects and improves the digestibility, palatability and stability.

x. **No Wastage of Feed/food** - Pellets are firm and do not break or don’t get powdered during transport, storage or feeding.

xi. **Process** operations are continuous.

All extruders, in general will have a common processing features. Extrusion processing is used to restructure the mixture of ingredients such as starch and protein based material to manufacture quality pet products. Soyabean and mixture of other ingredients for pet food were extruded using Single screw extruder as explained in 1.3 of chapter-3.
References:


5. Anonymous, Galen J. Rokey Feed Tech Volum:3 and Number:4.


8. Nancy C. Flores, Andrew D. Clarke, Fu-Hung, December, extrusion processing of rice or corn flour with mechanically deboned turkey, journal of food quality, 1992, volume 15 issue 6 page 399, issue 6 – 408.