CHAPTER 4

FOOD EXTRUSION TECHNOLOGY – AN OVERVIEW

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INTRODUCTION

As generation changes, changing in lifestyle and limited free time has brought a lot of behavioural changes toward foods. Now a day's consumers do choice for convenient ready to eat and ready to cook food with nutritionally rich and therapeutic benefits. Thus, to fulfil the demand of consumer, extrusion technology is used. Extrusion technology has become an important technique in food processing industries as it one of the cost-effective methods. Extrusion processing is defined as the process by which moistened, starchy and proteinaceous food materials are plasticized through a die by a combination of moisture, pressure, heat and mechanical shear. The extrusion process is an effective continuous process in which few unit operations like mixing, shearing, heating, pumping, forming, and sizing combines uniquely to from the products.

THE PROCESS OF EXTRUSION

Extrusion is a process used to create products of a fixed cross-sectional profile. Food extrusion is a form of extrusion used in food processing. It is a High Temperature Short Time (HTST) process. 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 are then cut into a specific size by blades. The machine which forces the mix through the die is an extruder. The mix which is obtained is known as extrudate. The extruder consists of a large, rotating screw which is fitted to a stationary barrel, at the end of which is the die (Kendall et al., 2010).

Extrusion enables mass production of food by a continuous, efficient system that ensures uniformity of the final product. Food products manufactured using extrusion usually has high starch content. These include some pasta, breads, many breakfast cereals and ready-to-eat snacks, confectionery, premade cookie dough, some baby foods, full-fat soy, textured vegetable protein, some beverages, and dry and semi-moist pet foods. In the extrusion process, raw materials are first ground to the correct particle size, usually the consistency of coarse

flour. The dry mix is passed through a pre-conditioner, in which other ingredients are added depending on the target product; these may be liquid sugar, fats, dyes, meats or water. Steam is injected to start the cooking process, and the preconditioned mix (extrudate) is then passed through an extruder (Chen et al, 2011).

The extruder consists of a large, rotating screw tightly fitting within a stationary barrel, at the end of which is the die. The extruder's rotating screw forces the extrudate toward the die, through which it then passes. The amount of time the extrudate is in the extruder is the residence time. The extruded product usually puffs and changes texture as it is extruded because of the reduction of forces and release of moisture and heat. The extent to which it does so is known as the expansion ratio. The extrudate is cut to the desired length by blades at the output of the extruder, which rotate about the die openings at a specific speed. The product is then cooled and dried, becoming rigid while maintaining porosity. The cooking process takes place within the extruder where the product produces its own friction and heat due to the pressure generated (10–20 bars). The process can induce both protein denaturation and starch gelatinization under some conditions (Petitot et al., 2009).

The extrusion cooking technology is applied to the development of instant functional foods. It has advantages of low cost, sustainability, and versatility for production of a wide variety of food products. For formulation of functional foods, bioactive compounds are added to base mixtures, the main sources being fruits, vegetables, cereals, oleaginous plants, legumes, and industrial food by-product such as pomace

During the extrusion cooking process, ingredients are mixed, conditioned, and transformed to a melt fluid, thus causing degradation or a release of functional compounds because of structural and chemical changes caused by the effects of some process variables such as temperature, moisture content, screw speed, and inherent factors such as geometrical configuration of the extruder (Singh et al., 2007).

Knowing the factors affecting the different components that form a food matrix, such as composition, intrinsic characteristics (pH and ionic strength, among others) combined with some extrusion process variables may help a technologist to influence the characteristics or final properties of the desired product. In addition, the presence, incorporation, and stability of bioactive compounds for the development of functional extruded products are topics that must be studied to meet consumer demands (M N Riaz et al., 2000).

The processing methods designed to produce functional foods are diverse and technologically different because they depend on the type of product to be developed.

Consequently, there are different kinds of functional food products such as beverages and semisolid or solid foods. Extrusion cooking can be defined as a continuous process in which materials, such as proteins and starches, are plasticized to form a fluid melt in a chamber or barrel as a result of high temperature, pressure, and shear stress, causing the material to be conveyed and forced to flow through a die of specific shape. During processing of materials, raw materials are conditioned (cleaning, classification, grinding, and conditioning to required moisture levels) and mixed with various ingredients such as bioactive compounds to produce diverse types of products of different shapes (Navale et al., 2015).

Raw materials are fed into the extrusion equipment, where they are mixed and subjected to heating and friction. The solid phase is transformed into fluid melt at high temperature and pressure and forced to flow through the die. The processing conditions are determined by independent and dependent variables of the system. The independent variables are those that can be controlled, such as feed composition, moisture content, and rate of feed, screw speed, and barrel temperature. The dependent variables are those that assume a certain value that depends on the magnitude of an independent variable. These include the properties of extrudates, such as viscosity, which is affected by the composition, moisture content, temperature, and shear rate associated with the screw speed (Athar et al, 2006).

The flow rate is associated with configuration of the screw barrel, screw speed, viscosity, and pressure drop in the system; other properties that can be included here are pressure exerted on the system, power, specific energy, residence time, and product characteristics (texture, gelatinization, color, water absorption index, expansion index, density, and chemical composition, among others) (Maurya and Said, 2014).

TYPE OF EXTRUSION

1. **Cold Extrusion**

It is used to gently mix and shape dough, without direct heating or cooking within the extruder. In food processing, it is used mainly for producing pasta.

2. **Hot Extrusion**

This generally consist of thermo-mechanically transform raw materials in short time and high temperature (HTST) conditions under pressure. It is used mainly to produce textured food and feed products, such as ready-to-eat breakfast cereals, snacks etc (Maurya and Said, 2014).

3. Friction Extrusion

There's also friction extrusion. Invented by The Welding Institute in the 1990s, this modern extrusion process involves the automatic rotation of the metal slugs or billets based on the position of the die.

4. Micro Extrusion

Finally, micro extrusion is a relatively new type of extrusion process that's characterized by the ability to create small, micro-sized objects (J Akhtar et al., 2015)

EFFECTS OF EXTRUSION COOKING

(i) Changes in physical parameters

The changes in colour of product could be due to the non-enzymatic browning by Millard reaction between proteins and reducing sugars that occurs due to the high temperature. The process conditions used in extrusion cooking high barrel temperatures and low feed moistures favours the Millard reaction and also decreases the nutritional availability of lysine. Increasing protein content at constant feed moisture content causes an increase in brittleness, hardness and crispness but decrease colour intensity (Camire, 2007).

(ii) Changes in composition:

Extrusion results in changes in the chemical components of food. The changes are described below.

DIETARY FIBER

Fruit and vegetables contain large amounts of dietary fibre (DF), which benefits the physiological activities of humans by decreasing cholesterol levels, reducing hyperlipidemia and hypertension, and maintaining gastrointestinal health. Moreover, DF in vegetables and

fruits has a higher insoluble/ soluble dietary fibre (IDF/SDF) ratio. In particular, SDF is more effective than IDF in maintaining systemic health. An extrusion technology was successfully applied to orange pomace to increase its SDF fraction under optimal conditions. The increase in SDF content in the extrusion was mainly contributed by redistribution of IDF to SDF, which was likely due to modification of the cell-wall structure during extrusion, where degradation of IDF generally occurs (K K Sandey, 2018). **Protein**

The change in the screw-speed during extrusion leads to the variation in shear forces which play an important role in changing the nutritional value of proteinaceous materials. Researchers found behaviour of molecular aggregation and chemical cross-linking of soybean protein at both low and high moisture content during extrusion. The results showed that, hydrophobic interactions, hydrogen bonds, disulfide bonds, and their interactions collectively hold the structure of protein extrudate regardless of the location and moisture level in the extruder and the contribution of non-covalent bonds during process also exceeds covalent bonds to bring about the change. Denaturation of proteins at high temperature during extrusion cooking inactivates anti-nutritional factors (such as antitrypsin factor, lectins, etc.) and improves digestibility. The extrusion of soy protein reduces the undesirable volatile compounds and the bitter taste (Maurya and Said, 2014). Very high drying temperatures have shown to decrease in protein digestibility and lysine bioavailability (Singh et al., 2007).

Carbohydrate

During extrusion process, starch undergoes various structural changes including gelatinization, melting, and fragmentation and the extent of the transformation depends upon pressure, temperature, moisture content, and shearing force. Control of sugars during extrusion is critical for nutritional and sensory quality of the products. It is reported that sugar losses in extrusion and it may be explained based on the conversion of sucrose into glucose and fructose (reducing sugars) and loss of these reducing sugars during Maillard reactions with proteins. The destruction of these flatulence-causing oligosaccharides might improve the nutritional quality of extruded legume products (Singh et al., 2007).

Lipids

The changes in physicochemical properties of lipids during extrusion are complex and vary with the hydrophilic–lipophilic balance of lipids, amount, type and the materials being extruded. These are due to the binding of lipid with starch. High temperature decreases the

factors that favours free fatty acid development and oxidation of fatty acids because of the reduction in lipase and lipoxygenase activity (Agarwal and Chauhan, 2019).

Minerals and vitamins

Extrusion cooking have significant effect on the stability of vitamins in extruded snack food for example low feed moistures and higher barrel temperatures can lead to loss of ascorbic acid. They observed that extrudates obtained from short barrel (90 mm) extruders had a higher retention rate of B vitamin group (44–62%) compared to 20% for long barrel extruders. The stability of fat-soluble vitamins such as vitamin A and E are also impacted by the high temperature, short-time extrusion cooking (Tiwari and Cummins, 2009).

Anti-nutrients

Nutritional quality of legumes - cereals mixtures could be limited by the presence of anti-nutrients such as phytic acid, tannic acid, trypsin inhibitors, which inhibit protein digestibility. Extrusion process caused a significant reduction in phytic acid content ranged from 40.64% to 46.07% and tannic acid content ranged from 40.46% to 44.88% of the germinated dehulled chickpea incorporated corn blends (M N Riaz et al., 2000).

Antioxidant and total phenol content.

The antioxidants are substances that prevent the oxidation of the molecule especially, fat and fat containing foods. The antioxidant activity of most foods is mainly caused by phenolic compounds. extrusion process caused a significant increase in total phenolic content and antioxidant of the extrudates by 1.92 –7.94% and 1.07 –5.55%, respectively. This may be attributed to the increased release of the bioactive compounds from the cell wall matrix due to extrusion process thus accessible in the extraction (Zielinski et al., 2006).

Advantages and disadvantages of extrusion processing

Advantages of extrusion

Extrusion processing has continued to gain popularity as one of the most energy efficient and environmentally friendly processes for a wide range of food products. Extrusion cooking is thus one of the preferred food-processing techniques due to its continuous process with high productivity, high temperature and short time cooking period while destroying both harmful microbial organisms and anti-nutrient enzymes, resulting in significant nutrient-retention products with longer shelf life. Furthermore, nutritious foods can be designed through extrusion to meet societal needs in addressing malnutrition and food and nutrition insecurity.

Disadvantages of extrusion

Food processing includes a costly initial financial investment, and careful selection of process parameters such as moisture content, feed particle size, feed rate, screw speed, temperature, screw configuration and die shape to avoid reactive and harmful substance formation. Apart from the initial seed funding, the bulk of the disadvantage is purely technical know-how that can be obtained through short training courses.

CONCLUSION

Extrusion cooking technology is very efficient state of art technology adopted by snacks food industries due to its nature of versatile, handy and low cost. It is high temperature, short time high pressure, continuous process. Unit operations involved in extrusion cooking process are conveying, mixing, shearing, heating and shaping. Various types of extruders used by food manufacturers in snacks industries such as piston extruders, roller-type extruders and screw extruders (Single screw extruder and twin-screw extruders). Twin- screw extruder has better mixing ability and higher pumping efficiency than single screw extruders.

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