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Types of Extruders used for Extrusion Cooking - A Review

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A B S T R A C T

Extrusion cooking technology is very efficient state-of-art technology adopted by snacks food industries. 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 extruder). Screw extruders are most likely used now days to obtain various shaped products like precooked and modified starches, ready to eat breakfast cereals, infant formulae, extruded snacks, etc. It was concluded that the twin screw extruder has better mixing ability and higher pumping efficiency than single screw extruder.

Introduction

Extrusion cooking technology became very popular due to its nature of versatile, handy, and low cost. It is very efficient state-of-art technology successfully adopted by various snacks food industries to formulate the attractive and marketable extruded snacks. Better product quality and no process effluents are achieved by this technology (Harper and Clark, 1979; Camire *et al.,* 1990). It is the high temperature, high pressure, short time continuous process in which several unit operations such as conveying, mixing, shearing, heating, and shaping involved to achieve various shaped products. Variety of ready to eat food products different in shape, size and texture, are obtained by quick and easy extrusion processing. Precooked and modified starches, ready to eat breakfast cereals, infant formulae, snack foods, fat replacer, gluten free, phenolic rich, low-glycemic and functional foods can also produced by extrusion cooking.

Extrusion cooking was first introduced in food and feed processing in the late 1950s (Caroline *et al.,* 2012). The word "extrudate" emanates from the Latin word "ex" (out) and "trudere" (to thrust) (Kehinde Adedeji Adekola, 2016). The porous and crunchy textured extrudates obtained by extrusion

cooking process under high temperature and high pressure in barrel-screw section in extruder (Patil *et al.,* 2005). Low moisture, starchy / proteinaceous food materials are used to prepare the extruded snacks by extrusion cooking process (Maurya and Said, 2014). Obtained desired final product depends on mechanical shear generate in extruder. for example, low shear required for pasta and processed meat products production (cold extrusion) meat analogues and some pet foods are produced with medium shear; and expanded snack products, breakfast cereals and textured vegetable proteins are produced with high shear (thermoplastic or hot extrusion) (Caroline *et al.,* 2012).

Extrusion cooking can be defined as the process in which moistened starchy or proteinaceous raw food materials convert into melting or plasticising stage due to heat, resulting in functional modifications (molecular transformation and chemical reactions) (Havck and Huber, 1989; Castells *et al.,* 2005). Shear and frictional forces are also responsible for heat generation friction in the extruder (Deshpande and Poshadri, 2011). Modification in raw food materials i.e. structural, chemical, and nutritional transformations such as starch gelatinization, degradation of vitamins, complex formation between amylase and lipid, protein denaturalization, inactivation of anti-nutritional factors (Alonso *et al.,* 2000), formation of flavors, increase of mineral bioavailability and increase in dietary fibre solubility occurred during extrusion (Camire *et al.,* 1990, Camire, 2003; Singh *et al.,* 2007 Riaz *et al.,* 2009). Increase in protein and starch digestibility in kidney beans through extrusion cooking reported by Alonso *et al.,* (2000).

Previously, many researchers have prepared the cereal based extruded products as nutritional supplements or functional foods by the enrichment of different fruits and vegetable as well as their by-products such as apple pomace, pear, orange, cauliflower trimmings, blackcurrant, cherry, fenugreek leaves, peas, onion, carrot pomace, roots and tuber crops as sources of high dietary fibers, mineral and vitamins.

The acceptability of extrudates is very much dependent on their functional (physical, biochemical) properties like water absorption, water solubility and oil absorption indices, expansion indices, bulk density and viscosity of the dough. These properties are influenced by operational parameters such as extrusion screw speed, feed rate; barrel temperature and die head temperature as well as feed parameters such as feed moisture content, blend ratio (Hernandez-Diaz *et al.,* 2007). Different types of extruders and their application were covered in this review paper.

Application of different types of extruders in extrusion technology

There are three types of extruders used by food manufacturers in snacks industries. These are piston extruders, roller-type extruders, and screw extruders (Alam *et al.,* 2016). Screw extruders are most likely used now days. On the basis of screw design, two types of extruders are most commonly used: Single-screw extruder and Twin-screw extruder.

Moscicki and Zuilichem (2011) reviewed that single-screw extruder was first time used in 1935 for plasticising thermoplastic materials, while twin-screw extruders, both co-rotating and counter-rotating, were used in the mid-1930s for the development of food products. After that, single-screw extruders came into light for the production of spaghetti and macaroni-type products used by pasta industry.

Single screw extruder

Single screw extruder has simple design, low operating and capital cost. But it has some operational drawbacks such as poor mixing ability. That is why premixing of ingredients and feeding conditioning is necessary before extrusion process (Martha *et al.*, 2017). It consists of feeder, extruder barrel with single screw, temperature and pressure control unit, motor and gear unit. This type of extruder has three sections in screw- barrel unit: feed zone; compression zone; melting or plasticizing zone and at the end of the barrel, die has located. Materials flow in forward direction inside the barrel and it fills the barrel and space between the screw flights and gets compressed, causes the increase in shear and frictional forces. The increase in resistance in movement occurred due to screw flights. Melting/plasticizing and degradation of starch molecules occur in the third zone. Further the plasticized food material is forced through a restricted opening i.e. die. Puffed, porous structured finished products are the results of rapid expansion of melted material which comes out from die head. This expansion is due to sudden decrease in pressure and immediate vaporisation of moisture (about 40-60%) of melted materials (Kanojia and Singh, 2016; Patil *et al.*, 2005).

Davidson *et al.*, 1984 found that shear degradation of fully-cooked wheat starch (amylo-pectin) was highly susceptible through single-screw extrusion. Rodis *et al.*, 1993 studied the effect of extrusion temperature and feed moisture content on the corn starch in single-screw extruder. They found that fragmentation of corn starch occurred at temperatures higher than 100°C and moisture levels lower than 30% due to shear and thermal energy. Effect of sucrose on starch conversion of maize and wheat based extrudates studied by Carvalho and Mitchell, 2000. They claimed that high sucrose concentrations could be the limiting factor in single-screw extrusion cooking because of increase in dough viscosity.

Twin screw extruder

Twin screw extruder has better mixing ability and higher pumping efficiency with the limitation of high mechanical complexity, capital and operational cost (Martha *et al.*, 2017). Pair of parallel screws rotates inside a barrel. According to the direction of rotation of the screws, it is classified as in two ways: Co-rotating (screws rotate in same direction) or Counter-rotating (screws rotate in the opposite directions). Co-rotating twin screw extruder is commonly used in food industry due to its efficiency, self-cleaning mechanism, and processing uniformity. Product and process parameters can be easily controlled by it.

Tonya Schoenfuss (2013) developed non-fat dry milk powder (NDM) blended modified corn-starch based expanded puffed products in twin screw extruder. Effect of processing parameters on texture quality of wheat starch based extruded snacks developed in twin screw extruder was studied by Brncic *et al.*, 2006.The processing behaviors of starch film using a twin screw extruder were studied by Bing *et al.*, 2009. They evaluated the process ability of corn starch with different amylose /amylopectin ratio by a twin-screw extruder with a slit die.

Effect of extrusion cooking on extrudates' properties

Effect of extrusion cooking on the characteristics of extruded products can be identified by the degree of modification on structure and texture of extrudate. Consumer acceptability of the extruded products very much depends on their qualitative properties. These properties depend on various factors

such as extrusion operational parameters (temperature, screw speed) and feed parameters (feed moisture content and blend ratio), geometrics of extrusion equipment (screw profile, size and shape of the die, and length and diameter of the barrel), Martha *et al.,* (2017).

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. Extrusion cooking is very much showing the significant effect on the qualitative properties such as physical and textural properties of extruded products. Extrusion cooking technology, its application with the use of different types of extruders is covered in this review. It can be concluded that twin screw extruder has better mixing ability and higher pumping efficiency than single screw extruder. Qualitative properties of extrudates highly affected by extrusion operational parameters and feed parameters.

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