Extrusion Technology used for novel Foods Production

[1]Javeed Akhtar , [2]Sheeba Malik, [3]M.A. Alam

[1]Ph.D Scholar, Department of Post Harvest Process and Food Engg.,College of Technology, G.B.P.U.A&T Pantnagar, India
[2]M.Tech Student, Department of Post Harvest Process and Food Engg.,College of Technology, G.B.P.U.A&T Pantnagar,India,
[3]Assistant Professor, Sam Higginbottom Institute of Agriculture, Technology and Sciences Allahabad, U.P. India

***Abstract* - For the purpose of making different uses of food material for the development of extruded foods are produced using single and twin extruders. Extrusion cooking is a useful and economical tool for processing of novel food. This high temperature, short time processing technology causes chemical and physical changes that alter the nutritional and physical quality of the product. Extrusion processing of food ingredients characteristically depends on associating process conditions that influence the product qualities. The process parameters are optimized for extrusion of food material in order to obtain the maximum nutritive value by inactivating the anti-nutritional factors. The processing conditions such as moisture content, temperature and time are controlled to avoid over heating or under heating which otherwise would result in a product of lower nutritional quality.**

***Keywords:* Extrusion processing, single and twin extruder, operating condition of extruders and extruded novel foods.**

I. INTRODUCTION

. Extrusion technology has been used for processing of food for many years. Food products like ready-to-eat cereals, some snacks, dry or semi moist pet foods, confectionery products, macaroni products, and texturized soy protein products can be made with extrusion cooking. Texturized soy protein products such as meat analogs have been considered the most creative use of soy protein [18].Extrusion cooking is a specialized form of processing, which is unique in food and feed processing because of the conditions that are used to transform the raw materials. It is a relatively low moisture process compared with conventional baking or dough processing. Normal moisture levels used are in the range of 10–40% on a wet weight basis. Despite these low moistures the mass of raw materials is transformed into a fluid and subjected to a number of operations to mix and transform the native ingredients into new functional forms. Under these unusual process conditions the physical features of raw materials, such as the particle size, hardness and frictional characteristics of powders and the lubricity and plasticizing power of fluids become more important than in other food and feed processes. Extrusion technologies have an important role in the food industry as efficient manufacturing processes. Their main role was developed for conveying and shaping fluid forms of processed raw materials, such as dough and pastes. Extrusion cooking technologies are used for cereal and protein processing in the food and, closely related, pet foods and feeds sectors. The processing units have evolved from simple conveying devices to become very sophisticated in the last decade. Today, their processing functions may include conveying, mixing, shearing, separation, heating or cooling, shaping, co-extrusion, venting volatiles and moisture, flavor generation, encapsulation and sterilization. They can be used for processing at relatively low temperatures, as with pasta and half product pellet dough, or at very high ones with flatbreads and extruded snacks. The pressures used in extruders to control shaping, to keep water in a superheated liquid state and to increase shearing forces in certain screw types, may vary from around 15 to over 200 atmospheres.

The most important feature of an extrusion process is its continuous nature. It operates in a dynamic steady state equilibrium, where the input variables are balanced with the outputs. Therefore, in order to obtain the required characteristics in an extrudate, the multivariate inputs must be set at the correct levels to give the dependent physical conditions and chemical process changes within the barrel of the machine. These dependent system variables determine the extrudate variables, which are reflected in the product variables. Once the relationships between the independent variables and the dependent variables within the processor are established for an individual product type, they must be maintained close to their optimum levels, in a small processing window, to ensure that the extrudate variables are also kept at the required levels.

Extrusion cooking has gained in popularity over the last two decades for a number of reasons:

A. **Versatility:** a wide range of products, many of which cannot be produced easily by any other process, is possible by changing the ingredients, extruder operating conditions and dies
B. **Cost: extrusion** has lower processing costs and higher productivity than other cooking and forming processes
C. **Productivity:** extruders can operate continuously with high throughput
D. **Product quality**: extrusion cooking involves high temperatures applied for a short time, retaining many heat sensitive components of a foods
E. **Environmentally-friendly:** as a low-moisture process, extrusion cooking does not produce significant process effluents, reducing water treatment costs and levels of environmental pollution.

Food Extrusion is a process that converts raw material into a product with desired shape and form by forcing the material through a small opening using pressure. The process involves a series of unit operations such as mixing, kneading, shearing, heating, cooling,

shaping and forming. Many food products are manufactured by extrusion cooking, a process that uses both thermal energy and pressure to convert raw food ingredients into unique products such as breakfast cereals, pastas, pet foods, snacks ,meat products. The origins of the extrusion process are closely associated with polymer science and technology. In the mid-1850s, extrusion was used to produce the first seamless lead pipe. The first man-made thermoplastic, celluloid, was manufactured in the 1860s based on a reaction between cellulose and nitric acid. The manufacturing of Bakelite in 1907, and the protective coating resin, glyptal, in 1912, was dependent on extrusion processing. Formal applications of extrusion processes to foods began in the 1930s and evolved over the following 50 years, as equipment for extrusion processing increased in capabilities and complexity. In general, all extrusion systems contain five key components. These components are:(i)Primary feed system consisting of a container and delivery system for the primary ingredients involved in the process, (ii)Pump to move all ingredients through the steps associated with the extrusion process (iii) Reaction vessel where key actions such as mixing, kneading, shearing, heating, and cooling occurs.

II. ADVANCES IN FOOD PROCESSING

During the recent years a number of technologies in food processing have been emerged and made an impact on the availability and variety of food products. Food extrusion is one of these new multipurpose food processing techniques. More possibilities are offered in the field of food processing by the application of extrusion technology to modify physicochemical properties of food components. The extruded food, besides its preserved and frequently even enhanced biological value, can be characterized by physicochemical properties superior to the original raw material. Extrusion cooking is defined as a unique tool to introduce the thermal and mechanical energy to food ingredients, forcing the basic components of the ingredients, such as starch and protein, to undergo chemical and physical changes. Extrusion combines several unit operations including mixing, cooking, kneading, shearing, shaping and forming so it is a highly versatile unit operation that can be applied to a variety of food processes. Extrusion has for years provided the means of producing new and creative foods. One major advantage of extrusion cooking is the capability to produce a wide range of finished products with minimum processing times and by using inexpensive raw material.

III. TYPES OF EXTRUDERS

There are several different types and Design of extruders available in the market. This may cause a difficulty for food or feed manufacturers to select a proper extruder for specific type production. In general, extruders are divided into two major categories: single-screw and twin-screw.

(A) SINGLE SCREW EXTRUDERS

Single-screw cooking extruders have compressive screws with decreasing channel depth turning at high speeds to increase shear and mechanical energy input for heating. Heating of a product is induced by the resulting friction. The barrel is jacketed for steam to allow additional contact heating in the metering section. To increase capacity and efficiency, it is common to preheat ingredients in a pre-conditioner by adding steam before they enter the extruder. Categories of single-screw extruders include [9]:

(i) Cold forming (Pasta-type) extruder: Deep flight, smooth barrel, low shear speed.(ii) No cooking extruders: Used for pasta, pastry dough, cookies, egg-rolls, ravioli, processed meat and certain candy.(iii) High-pressure forming extruder: Grooved barrels to prevent a slip at the wall and greater compression in the screw design. Used for pre-gelatinize cereal and fried snack foods (iv) Low-Shear cooking extruders: Moderates shear machines with high compression machines and grooved barrels to enhance mixing. Soft-moist foods and meat like snacks such as simulated jerky. (v) Collet extruders: High shear machines with grooved-barrels and screw with multiple shallow flights. Used for puffed snacks and expanded curls or collets. High shear cooking extruders: High shear machines, with screws of changing flight depth, HTST devices. Make pet food, aquatic feed, ready-to-eat cereal, candy, crisp breads, precooked food ingredients, pre-gelatinized corn flour, dried food mixes, instant beverage powder, croutons and breading, crackers and wafers, enzymes' deactivations of full fat soy flour, imitation nuts, famine relief feeding, texturized vegetable protein(TVP), and deactivation of enzymes in cereal and oilseeds. The first major commercial application of the single screw extruder in the food processing industry was the conversion of semolina into pasta. This low shear, low temperature forming process first found commercial production in the 1920's and 30's and remains a standard production process yet today. Conventional pasta products are processed with an extruder only to the level necessary to bind the moistened mass together and produce the desired shape.

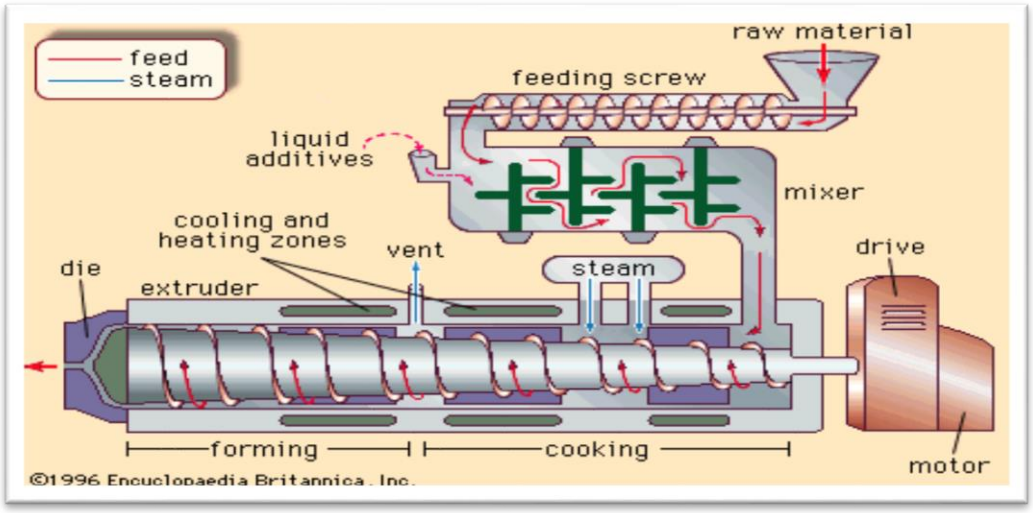

Figure 1 single screw Extruder

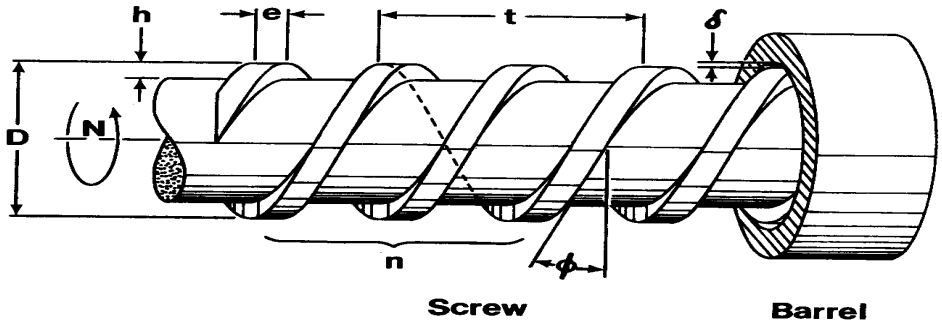

Figure 2 Design of screw extruder

D= screw diameter
h= channel depth
t= pitch

$$\phi = \tan^{-1}\left(\frac{t/2}{D}\right)$$

ϕ=screw helix angle (a function of diameter and pitch)

(B) TWIN SCREW EXTRUDERS

Twin screw consists of two parallel screws in a barrel with a figure-eight cross section. The use of twin-screw extruders for food processing started in the 1970s, with an expanding number of applications in the 1980s. Twin screw extruders are generally one and one-half times or more expensive than single a screw machine for the same capacity [14]. Yet the degree of quality control and processing flexibility they offer can make them attractive to food industries. Twin screws produce a more uniform flow of the product through the barrel due to the positive pumping action of the screw flights. Some other advantages of twin screw are: Handle viscous, oily, sticky or very wet material and some other products which will slip in single screw extruder, (it is possible to add up to 25% fat in a twin screw extruder), Less wear in smaller part of the machine than in single screw extruder., Wide range of particle size (from fine powder to grains) may be used, whereas single screw is limited to a specific range of particle size., Because of the self-wiping characteristics cleanup is very easy. Four types of twin-screw extruders are possible (i) Non-intermeshed, co-rotating. (ii)Non-intermeshed, counter rotating (iii) Intermeshed, co-rotating (iv) Intermeshed, counter rotating.

From these four types of twin-screw extruders, co-rotating, intermeshed screw type has found the widest acceptance in food industry.

Table 1 Operating condition of different extruders for different foods

Extruders	Feed Moisture (%)	Product Temperature(oC)	Screw Speed (rpm)	Typical Products
Twin-screw cooking	11-35	80-200	200-500	Puffed snacks RTE cereals
High-shear cooking	15-20	120-180	350-500	Modified starch ,Pet food
Low-shear cooking	11-16	170-200	300	Puffed snacks
High-pressure forming	25	65-80	40	Cereal pellets ,Half product snacks
Pasta press	32	30-52	30	Pasta

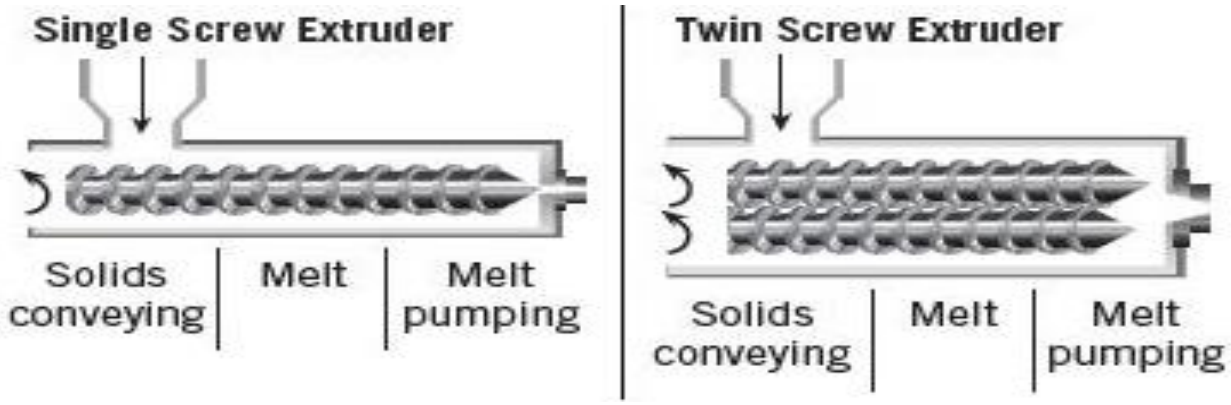

Figure 4 Cross -section of single and twin extruders

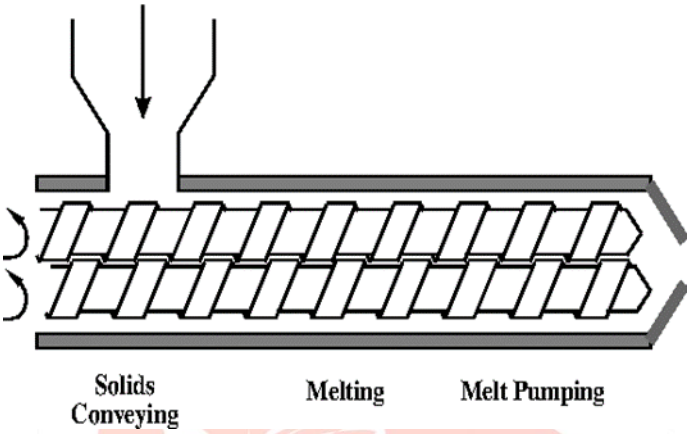

Figure 3 Twin screw extruder

IV. EFFECTS ON FOOD COMPONENTS DURING EXTRUSION COOKING

(i) Carbohydrate
(ii) Proteins and Amino acids
(iii) Lipids
(iv) Dietary Fibers
(v) Vitamins
(vi) Mineral
(vii) Non-nutrient healthful components of foods and Ant nutrients

V. WORKING AND FUNCTION OF EXTRUDERS

Food extruders can perform one or several functions at the same time while processing food or feed.
(a) Agglomerating ingredients: Human food, pet food, aquatic and livestock feed ingredients can be compressed and agglomerated into separate pieces in an extruder process. (b) Degassing of ingredients: Snack food, feed and pet food ingredients that contain gas pockets can be degassed by extrusion processing. (c) Dehydration: During normal extrusion processing of feed or pet food moisture loss of 4-7% can occur depending upon the initial moisture contents.(d) Enzyme in-activation: By using extruders different enzymes present in the ingredients can be in-activated, like lipase enzyme in rice bran.(e) Expansion, puffing: Snack food, pet food or aquaculture feed density (i.e, floating and sinking) can be controlled by extruder operation conditions and configuration.(f) Grinding: Ingredients can be ground to some extent in the extruder barrel during processing of snack food, pet food and livestock feed.(g) Homogenization: An extruder can homogenize by restructuring unattractive ingredients into more acceptable forms during processing of human food, pet food, aquatic and livestock feed.(h) Mixing: A variety of screws are available for all kind of extruders which can cause the desired amount of mixing action in the extruder barrel during extrusion processing.(i) Pasteurization and sterilization: Ingredients can be pasteurized or sterilized using extrusion technology during processing of human and pet food.(j) Protein denaturation: Animal and plant protein can be denatured by extrusion cooking to make it more digestible for human and animals.(k) Shaping products: A special configuration within the extruder barrel can create the desired shearing action for a particular human and pet food, aquatic and livestock feed.(l)Shearing: A special configuration within the extruder barrel can create the desired shearing action for particular food and pet feet.(m) Starch cooking: Extrusion cooking improves starch gelatinization from all sources, i.e. tuber or cereal during the processing of food and feed.(n)Texture alteration: The physical and chemical texture can be altered in the extrusion system during processing of food, pet food, aquatic and livestock feed.(o)Thermal cooking: The desired cooking effect can be achieved in the extruder during processing of human food, pet food, aquatic and livestock feed.(p)Unitizing: Different ingredient lines can be combined into one product to give special characteristics by using an extruder for pet food, aquatic and livestock feed.

VI. DEVELOPMENT OF NOVEL FOODS USING EXTRUSION TECHNOLOGY

There are many different types of products are possible by used of extrusion technology as follows

A. Snack foods Production

Today's extrusion technology in the snack-food industry are very much used for development of variety of snack food. The modern industrial snack was created in the early1940s with the manufacture of the first directly expanded snack from maize. In this process raw maize grits are fed into an extruder at low moisture to create a very hot melt within the barrel at temperatures of 140 to 180ºC. It was found that a snack product could be created by releasing a continuous stream of the hot melt fluid from a small hole. As the pressure is released the melt stream generates water vapor and expands in microseconds to form a foam, which can be cut into portions by a rotating knife. The ribbon of foam is cut into short lengths of highly expanded crispy snack known as corn curls or puffs. Third-generation snack products or pellets are not new to the snack-food industry. In fact, they have been very popular in many regions of the world. Extrusion systems for the production of third-generation snacks are efficient, economical to run and result in a product with built-in marketing flexibility due to long shelf-life and high bulk density prior to frying or puffing. Supercritical fluid injection, coupled with the continuous twin-screw extrusion cooking process, opens many opportunities for new engineered processing techniques for developing new products and product concepts. This supercritical fluid extrusion technology is a patented process that already has resulted in new developments in cereals, confectioneries, pastas, flavorings, pharmaceuticals, snacks and other products left only to the imagination[13].

B. Healthy snacks production

An integral component in any snack line is an applicator/dryer. Originally designed for sugar coating and frosting breakfast cereals, this system has gained significant value in the snack-food industry as a superior method of coating snack products with colors and flavors. Snack producers introducing low-fat snacks to the marketplace commonly include applicator/ dryer processing components. This equipment is used in conjunction with fat free gums, which serve as the adhesion agent instead of fat, to greatly reduce the total caloric content from fat in the finished product. This technology makes it possible to add sweeteners and savory spices without adding fat [7].

C. Breakfast cereals production

With increasing consciousness about healthy eating and changing lifestyles, cereals, especially extruded cereals, are becoming a standard feature in many households. "rice crispies", "fruit flavored rings", "chocolate flavored cereal flakes" are some of the more commonly known extruded cereals. Directly expanded extrusion-cooked breakfast cereals are prepared by extrusion technology as cereal flours and/or grits are cooked with other ingredients and with very low moisture content (usually below 20%). The process may use single- or twin-screw extruders, the configuration and operating characteristics of which generally lead to highly mechanical cooking. In pellet-to-flakes extrusion-cooked breakfast cereals preparation, cereal flours and/or grits are cooked with ingredients and at a moisture level in the range of 22–26%. They are usually processed in twin-screw extruders, the configuration and operating characteristics of which lead to a lower mechanical component of cooking, reinforcing the thermal component as opposed to the previous processing conditions. Extrusion cooking has been sparked to a great extent by the perfection of twin screw extruders. This development redirected and brought under control the tremendous excesses in shear imparted to the grain formula during extrusion cooking in single screw extruder. The flexibility in set-up of the screw elements in a twin screw, along with greater flexibility in screw speed and heat input, have brought the extrusion cooking process under very exacting control[4].

D. Baby foods production

Extrusion cooking is a new method for preparing baby foods. The type of extruders used, the particle size of the rice flour, the moisture content of the rice water mixture, and the extrusion conditions are some of the important factors influencing the properties of extruded rice baby foods.

E. Fortified ready to eat rice production

Fortification of ready-to-eat rice with vitamins, minerals, and flavor compounds is now a very common practice. The usual approach is to add the minerals and more heat-stable vitamins such as niacin, riboflavin, and pyridoxine to the basic formula mix, extrude and then spray the more heat-labile vitamins such as vitamin A and thiamin on the product after extrusion before drying.

F. Extruded biscuits with high quality

Developments in extrusion cooking have led to some biscuit-like products or pieces. Where these are broad, flat and light in texture they offer interesting alternatives to plain crackers. Extrusion cooking is attractive to the manufacturer because of the relatively low capital cost of the plant and a great reduction in space required compared with conventional biscuit-making equipment. Where the appearance of the product is not critical the technique is particularly useful because difficulties of baking and drying are tackled in a more efficient manner.

G. Meat analog

An extrusion process utilizing one or two extruders in a serried can be employed to convert vegetable protein source directly into simplified verities of meat analogs. These meat analogs have remarkable similarity in appearance, texture and mouth feel to meat. Extrusion technology can form a fibrous matrix (analog) almost indistinguishable from meat and consumed as it is.

H. Meat extender

Meat extenders produced from the extrusion processing of defatted soy flour or flakes and soy concentrated, and they represent the largest portion of textured protein. Meat extenders are rehydrated to 60-65% moisture, blended with the meats or meat emulsions, to food product to a level of 20-30% protein.

I. Stabilization of Rice bran

Extruders are used to stabilize the rice bran just after milling and to reduce the FFA of rice bran oil. This stabilized rice bran can be used in human food and animal feed.

J. oil expelling

The extruder offers a convenient way of cooking the beans and breaking down the oil-bearing tissues in a fraction of the time required for conventional conditioning methods. The beans remain in the extruder system for less than 30 seconds at a temperature of approximately 135°C. The short cooking time at high temperature is adequate to satisfactorily destroy anti-nutritional agents such as the trypsin inhibitor and not so long as to damage important nutritional components such as protein [17].

K. Recycling food waste from food industry

Extrusion technology is used for the recycling of industrial and restaurant food wastes. The method of recycling waste food materials into useful byproducts comprising the steps of drying by dehydrating for a time interval necessary to reduce the moisture content to less than 25%, extruding food materials in an oxygen-free atmosphere at an elevated temperature level sufficient to sterilize food materials, cooling food materials, and thereafter tumbling and drying food materials to reduce said food materials to particle form. Following are the areas of food industries where extrusion technology can be employed such as Beverages powders, Boiled sweets, Breads (miscellaneous, expanded, dense),Breading substitute, Candy sticks, caramel, chewing gum, Chocolates, cocoa and crump, Crisp bread,Confectionery,Cooked grains (barley, corn/sorghum, mixed),Dairy products, Dried food mixes, Egg rolls, Fabricated potato chips, Flavoring, food additives, Frozen confectionery,Fudges,Full fat and partially de-fatted soy flour, Imitation nuts,Pasta products (noodles, spaghetti, macaroni),Pastry dough, Precooked and modified starches, Pressed tablets, pretzels, Protein (textured and gluten) Soup and gravy mixes, Sugar crust liqueurs, three dimensional confectionery and toffees etc.

VII. ADVANTAGES OF EXTRUSION TECHNOLOGY

There are many advantages of the extrusion technology as compared to the other traditional foods processing methods include:

Adaptability: The variety of products are feasible by changing the minor ingredients and the operation conditions of the extruder. Extrusion process is remarkably adaptable in being able to accommodate the demand by consumers for new 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. Less space: Extrusion processing need less space per unit of operation than other cooking system. New foods: Extrusion can modify protein (vegetable and animal), starches (almost all sources), and other food material to produce a variety of new and unique snack food products. High productivity and automated control: An extruder provides a continuous high throughput Processing and we can have a fully automated control for theses' 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). Extrusion cooking at high temperature also destroys the anti-nutritional compound, i.e. trypsin inhibitors, and undesirable enzymes, such as lipases, lipoxidases and microorganisms. No effluent: No or very few process effluents are produced.

VIII. CONCLUSION

The extrusion technology is used as a advance processing of various foods, is growing in food industry for produced the novel food products with high quality. Food Extrusion is a thermo mechanical process where shaping of a dough like food material is obtained by forcing it through a die. Extruders are high temperature short time (HTST) that can transform a variety of food raw materials into novel food products. Extrusion has a wide range of applications and continuous production capabilities to meet new market challenges, which make them attractive to processors and markets. Food extrusion is increasing the application in the food industry, such as the production of ready to eat cereals, pasta, snacks, pet food, fish foods, and confectionary products. The production of multidimensional third generation snacks using extrusion are efficient, economical to run and result in a food product with built in marketing flexibility due to long shelf life and high bulk density. Studies to emphasize the importance of the reduced the cost of production of foods product using extrusion processing.

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