Original Article

Effect Of Different Extrusion Techniques On Pharmaceutical Properties And Bioactive Compounds Of Barnyard Millet

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INTRODUCTION

Extrusion

Due to the sharp rise in diseases linked to modern lifestyles, consumers in this century are investigating new norms of food consumption. The growth of new food markets that offer innovative, high-quality foods is a result of worries about the quality and safety of food. Unlike to past generations of consumers, today's consumers enjoy affordable, healthy, wholesome, delicious, and aesthetically pleasing food (Zambrano, et al 2019). Extrusion is derived from the Latin word "extrude," which meaning to thrust or drive out. Any component or substance (metal, plastic, or a combination of materials) is fed through a nozzle or an opening in the appropriate cross-section while being subjected to high pressure and temperature. This process is known as extrusion. This method is known as "food extrusion" in the food business (Riaz, 2019). Extrusion is heavily dependent on a wide range of factors, but the raw material is the most important constraint, just like with other advances in food preparation. To achieve end result qualities, it is essential to consider the physical and synthetic arrangement (moisture content, starch, proteins, lipids, and sugar content, as well as pH) of the raw material. When the qualities of raw materials are slightly altered, unpleasant results can result, costing time, energy, and money. Regarding the limits of interaction, the item's qualities can be affected by changes in barrel temperature and pressure, screw setup and turn speed, die diameter, and shear power (Steel et al., 2012). Rich in protein and starch ingredients are plasticized and cooked in a cycler to obtain a pre-defined shape using extrusion cooking, a mix of temperature and mechanical treatment. Hence, the ingredients are fed through the nozzle hole at the extruder outlet to produce the finished good (Harper et al, 2019). The texture, fluid flow, and size reduction of food are altered during a quick, high-temperature procedure called extrusion. It affects the final product through plasticizing, shearing, cooking, combining, transferring mass and heat, and shaping and moulding (Aktas-Akyildiz *et al*,2020). It has been utilized to deliver an assortment of strength food sources including pasta items and ready- to- eat breakfast cereals, child food varieties, nibble food sources, texturized vegetable protein, dried soups and dry refreshment blends, as it not just further develops edibility (Singh *et al*, 2010). Extrusion cooking is a thermo-mechanical criteria that possess many benefits, the significant one being that taking care of the ingredients that go through variousphysiochemical and biochemical unit tasks like mixing, kneading and shearing and also undergoes the gelantization of starch, destruction of microorganisms, aflatoxin, inactivation of antinutrients like tannins (Liang *et al*, 2012). According to research, trypsin inhibitors, phytates, and lipases and lipoxidases are only a few of the anti-nutritional elements that high temperature extrusion processing destroys (Gu et al,2020). In extrusion handling, the limits are divided into extrusion handling boundaries (input), extrusion system parameters (dependent), and product parameters. This is known as multiple input and multiple output (MIMO) (output) (Gu *et al*, 2017).

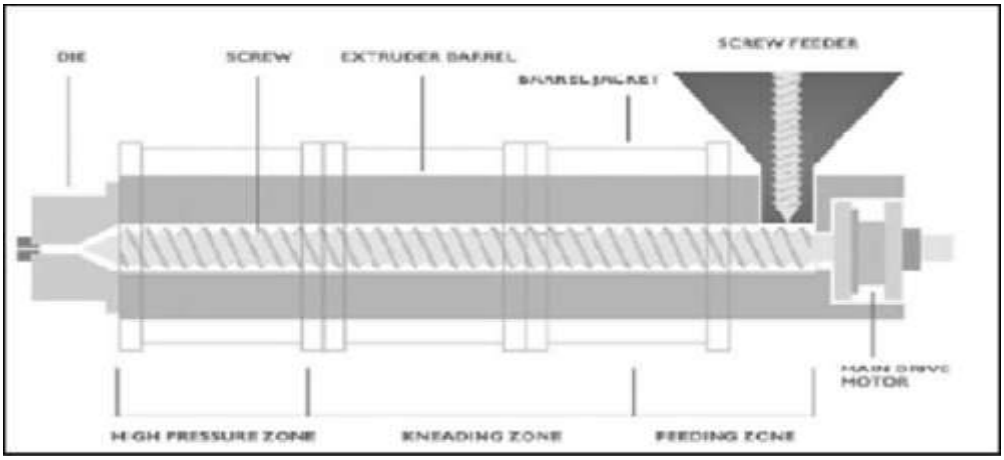
Barnyard millet

Especially in the dry and semi-arid regions of Africa and Asia, millets are one of the major cereal grains consumed worldwide (India and China). Due to their nutritional value and agro-industrial significance, they are of utmost interest (Zhu et al,2018). Millets come in seven primary varieties, each with unique colours, shapes, sizes, and growing regions. These grains are the oldest and, most likely, the first cereal grain used by humans for domestic use. These are round cereals with little seeds that are members of the Poaceae family (FAO,2020). The sixth highest yielding grain in the world is millet. According to estimates, 3,10,19,370 tonnes of millet were produced globally in 2018. Nonetheless, India is the world's largest millet producer, followed by Niger, Sudan, and other countries (FAOSTAT2020). Millets typically comprise 7–12% protein, 2% fat, 6–75% carbs, and 15–20% dietary fibre. They are also rich in phenolic compounds,

minerals, and vitamins (Hasan *et al*,2019). Many possible health benefits, including antioxidant and anti-microbial activity, can be induced by millets' bioactive components (Singh *et al*, 2016). A review found that by removing antinutrients, soaking could increase protein digestibility from 62.3 to 76%. Due to the fact that these antinutrients can attach to proteins and the molecules that breakdown them, inhibiting how easily proteins are digested (Azadi *et al*,2016). Millets have gained recognition for their positive role as a functional meal thanks to phytochemicals that promote health. Millets for celiac disease are a wonderful choice for those who are sensitive to gluten. They boost digestibility because they don't produce acid or trigger allergies (Saleh *et al*,2013). The general water prerequisite for millets is exceptionally low during its short development period. These are drought resistant with a delayed storage period whenever put away as entire grains. Subsequently, millets are reflected as yields of food security attributable to their maintainability in harsh agro-climatic conditions (Devi *et al*,2014). "Millets are rich wellspring of numerous important components for example, iron (2.2–17.7 mg/100 g), calcium (10–348 mg/100 g), phosphorus (200–339 mg/100 g), zinc (32.7–60.6mg/100 g) and nutrients like niacin (0.09–1.11 mg/100 g), riboflavin (0.28–1.65 mg/100 g) and thiamine (0.15–0.60 mg/100 g) which render them an ideal energy food (Tomer *et al*,2018). The proximate values of a specific variety of Barnyard millet showed that the crude protein, fat, fibre and total ash content were significantly higher than the paddy rice. Additionally, the glycemic index of Barnyard millet is 39.5 was fundamentally lower thanthat of rice (73.9) and considered the best substitute for diabetic patients (Shweta *et al*,2018)".

Principle of extrusion

Extrusion cooking is a high-temperature, brief-duration (HTST) method that reduces microbial contamination and inactivates enzymes. Extrusion processes follow the same guidelines for all types: raw materials are inserted into the barrel and screw(s) of the extruder, after which food is transferred along the barrel. The volume is constrained and the food's protection from deterioration is increased as the barrel descends, thanks to smaller flights. As a result, it expands and compresses as it fills the barrel and the intervals between the screw flights (Bordoloi,2014). The screw works the substance into a semi-strong, plasticized mass as it advances up the barrel. The process is called extrusion cooking if the food is heated to a temperature exceeding 100 °C (or hot expulsion). The temperature rises quickly in this situation due to frictional heat and any additional warmth that is used. The food is then transferred to the area of the barrel with the smaller flights, where strain and shearing are also increased. Once the meal finally arises under tension, it extends to the final shape and cools quickly as moisture is streaked off as steam. At this point, it is constricted via one or then again more confined apertures (dies) at the release end of the barrel. Shapes that can be formed include bars, rounds, doughnuts, tubes, strips, squirls, and shells. A large variety of low thickness, prolonged nibbling food variations and ready to eat (RTE) puffed cereals are included in ordinary goods (Ganguly,2014).

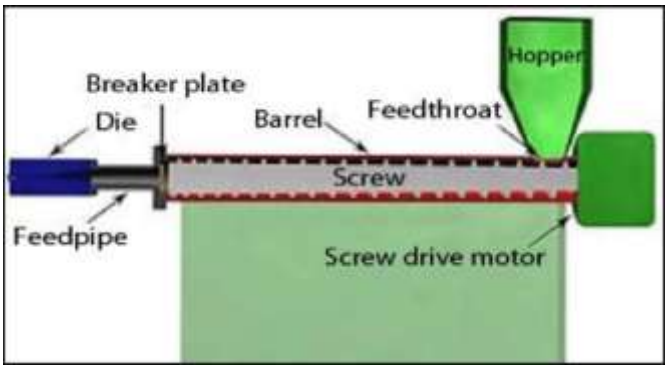


Extruder and its classification

Extruder is hardware which is utilized for extrusion handling. Food extruders might beintended to play out a few unit activities simultaneously, including blending or homogenization, shearing, starch gelatinization, protein denaturation, texturization, compound inactivation, thermal cooking, pasteurization, lack of hydration, shaping and size reduction (Akhtar *et al*,2015). Extruders are made out of five primary parts: (I) the pre- conditioning system; (ii) feeding system (iii) the screw or worm; (iv) the barrel or sleeves (v) the die and the cutting mechanism. They can vary with screw, barrel and die setup. The choice of every one of these things will rely upon the natural substance utilized and the eventual outcome wanted (Neeraj *et al*,2020).

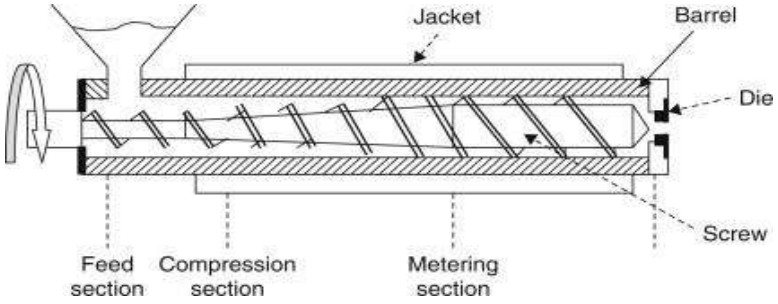
1. Pre – conditioning - Pre-conditioning is finished with steam or water and blended physically. This is applied when dampness substance around 20 to 30% and long residence occasions of the material are utilized. Preconditioning favors uniform molecule hydration, diminishes maintenance times inside the extruder and expands throughput, because of a decrease in the wearing of barrel and screw parts increment the existence of the gear and lessen the expenses of energy engaged with the interaction (Neeraj *et al*,2020).
2. Feeding system - Taking care of natural substance into extruder ought to be steady and non-hindered for a proficient and uniform working of the extrusion process(Neeraj *et al*,2020).

3. Screw - Screw pass on material into the extruder barrel, shearing and guarantee end result quality (Neeraj *et al*,2020).
4. Barrel or sleeves - It is partitioned into taking care of, manipulating and sleeves they are regularly jacketed to allow circling of steam or superheated oil for warming or water or air for cooling, subsequently empowering the exact change of the temperature in the different zones of the extruder (Neeraj *et al*,2020).
5. Die and cutting mechanism. The die serves two primary purposes: shaping the final product and increasing safety and resistance to material flow inside the extruder, which increases internal tension. The pass on may be introduced in a variety of layouts and opening arrangements. The cutting process should enable obtaining final results of uniform size. The cutting edges' cutting edge pivot speed determines the size of the item. The configuration of this system is flexible (Rao *et al*,2015).

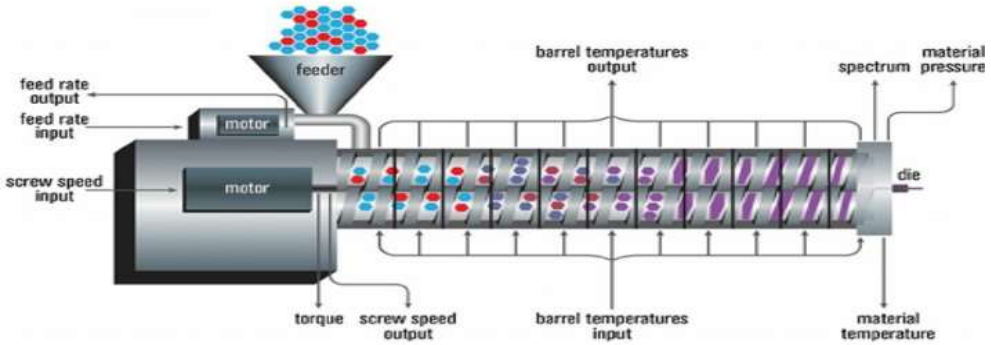


Method of construction

1. Single-screw extruder — A single pivoting screw is housed in a metal barrel in a single screw extruder. The most often used single scews are available in a variety of patterns and have a consistent pitch. The container located in the feed region is used to supply the raw materials, and the material is then transferred to the progress segment by a pivoting screw. A rise in the material's temperature is caused by the progress area's shallower screw channel and compressed material. Gelatinization of starch results in increased material strength. By the metering region and forced through the die opening, it is transported farther (Thejaswini *et al*,2015).



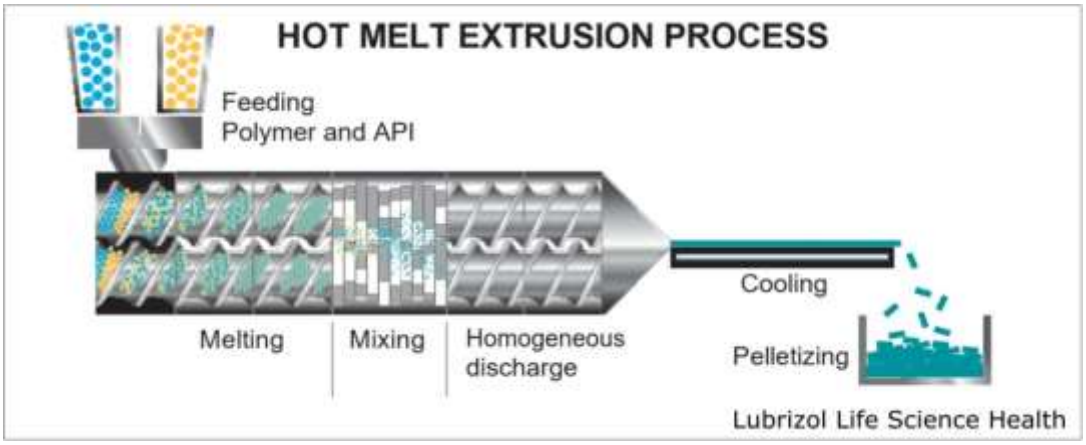
2. Twin-screw extruders - This type of extruder has two identical screws that are the same length and pivot inside a barrel that looks similar; the internal surface of the barrel is normally smooth. It is more complicated than single screw extruders and offers far greater adjustability and control. Twin-screw extruders are used for high moisture extrusion, more complicated goods that contain higher amounts of fibres, lipids, and other ingredients, and other components. Four different setups are possible depending on the location of the screws and the direction of their pivot: Coaxial screws (I), coaxial non-intermeshing screws (II), counter-axial intermeshing screws (III), and counter-axial non-intermeshing screws (Maurya *et al*,2014).



Types of extrusion

1. Hot-melt extrusion- The beginning of Hot-dissolve expulsion (HME) was first settledin the plastic industry during the nineteenth century, and today, its application has overgrown with in excess of 100 scientific papers distributed in the logical writing. HME is currently a comprehensively utilized handling innovation in the drug area (Divya *et al*,2021). Attributable to the potential benefits of HME, it has developed as an elective stage to conventional strategies utilized for the assembling of different strong oral, topicals, and parenteral definitions. With the consistently expanding advancements in the field of HME, today, the handling of thermosensitive materials or thermally unsteady specialists, like thermosensitive medications, amino acids, or proteins, is presently feasible with further developed steadiness. Drug businesses actually face a few challenges in creating drug conveyance frameworks concerning low therapeutic adequacy, remaining solvents, harsh tasting drugs, and so forth These obstacles are currently effectively tended to by HME innovation (S.Huang *et al*,2017). The HME cycle includes the utilization of an extruder for the dissolving and blending of the materials, auxiliary equipment for downstream handling, and different other controlling instruments to assess the gear's smooth working just as guaranteeing the best nature of extrudates. The materials are normally brought into a taking care of container that is considered as a section highlight the barrel. These materials then, at that point, enter a passing on/blending region containing barrels with either a solitary screw or twin screws. At last, the material is expelled through a pass on and formed into the ideal shape (Tambe *et al*,2021).

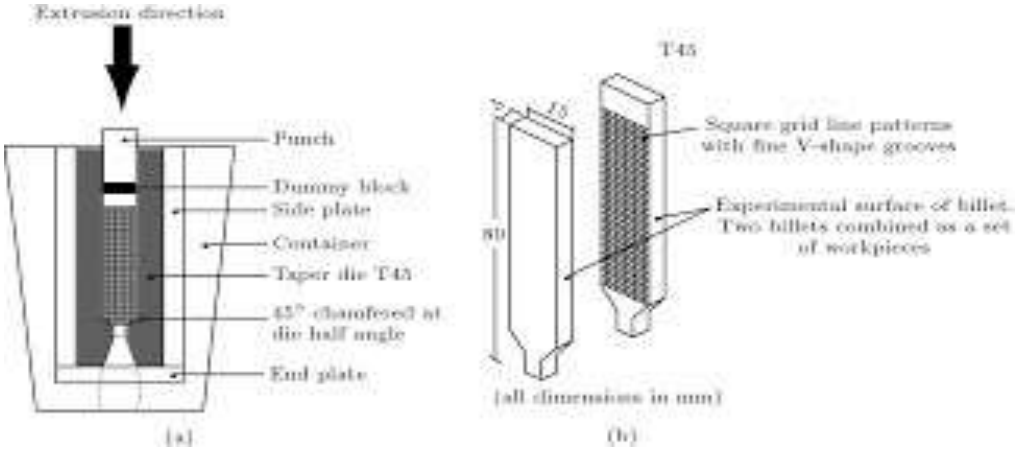
However, a few formulations like salts, co-precious stones, strong scatterings, granules, semi-solids, nanosystems, and microsystems that don't need forming/molding can be handled without bites the dust. There might be a warming/cooling framework for barrels, a passing on framework, a dissolvable vehicle siphon for cooling, cutting, anda forming gadget as subordinate hardware. The controlling gadgets comprise of temperature checks, an extrusion force monitor, a screw-speed regulator, and a pressure marker (Tambe *et al*,2021). The fundamental models for a wide range of extruders are that they ought to pivot the single/twin screws at proper utilitarian speedwhile offsetting force and resultant shear rate produced from the expelling material and the sort of screw utilized (Snowden *et al*, 2012).



2. Cold extrusion – is utilized to tenderly blend and shape batter, without direct warmingor cooking inside the extruder. In food handling, it is utilized fundamentally forcreating pasta (Neeraj *et al*,2020). The expansion index of the examples created by cold extrusion was essentially low at a similar barrel temperature and therefore mass thickness was altogether more prominent than those delivered by ordinary extrusion. Mass densities in the examples created by cold extrusion additionally altogether diminished when feed material moisture diminished from 25% to 20% (Boyaci *et al*,2012). In cold extrusion, there was huge difference between thiamine content of extrudates created at 20% and 25% feed moisture. Riboflavin content of extrudates created by cold extrusion at 20% and 25% feed moisture were not fundamentally not quite the same as one another. For both feed moisture levels thiamine and riboflavin substance got in traditional extrusion at 80º C and cold extrusion were not essentially unique (koksel *et al*,2012).

The raised cooking temperatures utilized in ordinary extrusion lead to discoloration of whey proteins from the Millard response, racemization of protein during cross- connecting, obliteration of the sulfur-containing amino acids, cysteine and methionine, and different issues. In cold extrusion warming of food is done up to 100ºC called as cold extrusion. In Cold extrusion, food temperature is consistent which is accustomed to forming and blending of food including meat items and pasta. Temperature under 100º C is likewise utilized for low tension extrusion. Chilling, baking or drying strategies are utilized for the safeguarding of cold expelled items. While extrusion cooking kills contaminating microorganisms and safeguard the dry food items for longer period. Packaging of dry items forestalls the oxidation and dampness ingestion while storage. Cold extruders are proper for small scale industry and furthermore for household use.

Extruder cookers are utilized by large scale industries since they are high in cost. The essential utilization of cold extruders is in pasta creation, yet equivalent machines are used to outline roll batter into different shapes. A pasta extruder is used to make a widescope of pasta using combination delivered utilizing durum wheat flour (or 'semolina') and eggs. By adding tomato purée or spinach paste coloured pasta also made.



Effect of extrusion on nutritional properties

Effect on protein and amino acid- Extrusion cooking technology increases the extruded food item's protein absorbability. The lysine-rich ejected foods organized from cereals are high in lysine, an important amino acid. As a result, it is imperative that the lysine is protected during the expulsion approach.

Carbohydrates

Sugar - The best source of rapid energy is sugar, which includes lactose, fructose, and sucrose. Sugar imparts the food item's sweet flavour. Sugars are in charge of the few chemical reactions that take place during the extrusion process. Controlling the sugar throughout the extrusion process is crucial to maintaining the nutritional value and organoleptic qualities of the extruded food product. A small amount of sugar is lost during the extrusion process. It is caused by the transformation of sucrose into fructose, glucose, and the maillard reactions with protein and sugar. By removing some oligosaccharides, the character of some food products made from vegetables is altered.

Starch- Starches are exposed to warm mechanical shear, strain up to 103 psi, and warming throughout the extrusion process. Glucose units found in starch are linked together by glyosidic bonds. The starch particles are amylose and amylopectin. The thickening and gelatinization of the cooked paste are caused by amylopectin and amylose. By keeping the die damp and at a low temperature, the atomic weight of the starch granules in wheat flour is reduced.

Dietary fiber- Because extrusion reduces the sub-atomic weight of hemicellulose and gelatin particles, it increases the water solubility of sugar beet products. Dietary fiber's composition changes when an item is handled by a twin screw extruder. It was found that wheat will have more dietary fibre due to the higher temperature. Barley that has been extruded for cooking contains a lot of nutritional fibre. Waxy barley's soluble dietary fibre content is raised by adding more complete dietary fibre.

Lipids - Lipids are necessary for the extrusion interaction and may be found in fixes as well because they can be introduced remotely. The force is reduced when the amount of lipid in the barrel decreases. Because of the insufficient tension, this will lead to the formation of unpleasant products. The high temperature experienced during extrusion will cause lipid discharge. When cell walls are mechanically disrupted during extrusion, lipid will also be supplied.

Extrusion at global level and national level

The developing makers information on the expected advantages of utilizing drug HME over ordinary handling strategies is the vitally main impetus for worldwide market development.In the production of HME, the utilitarian boundaries are adjusted rapidly. Due to the accessibility of a wide assortment of screw plans and bite the dust plates, there is flexible utilization of the extrudates. Inferable from these highlights and benefits, HME has acquired huge energy in increasing, eventually prompting market development. The worldwide business market for drug HME was close to US$26.6 mn in the year 2015. It has been guage that this market will presumably ascend with the worth of US$36.4 by 2024, enlarging at a Compound yearly development rate (CAGR) of 3.90% over the period from 2016 to 2024. The chance in the worldwide market is relied upon to increment at a CAGR of over 4.7% during a similar period. The drug HME market has been partitioned into five areas like Asia Pacific, North America, Europe, Latin America, and Middle East Africa. North America had the greatest piece of the pie in 2018 among every one of the nations and is expected to leadthe market over the gauge time frame. It is normal that Europe will be the second biggest market throughout the impending years, following North America as far as benefit. With the perspective on expanding fame for upgraded clinical offices and gear, the HME market in Europe has been developing consistently. Rising R&D drives and creating wellbeing care offices in arising economies like “China, India, and Japan, Asia Pacific” are probably going to raise the drug HME market in the Asia Pacific soon. The various business HME inferreditems accessible in the market means that this methodology can effectively open the entrywayfor gigantic items for a wide scope of utilizations with further developed adequacy (Tambe *et al*,2021).

Extrusion techniques and physical properties

The protein content has a significant impact on the extruded product's hardness. If an unrefined substance has a high protein concentration, it will form a stiff network and produce a less extended item, increasing cut protection. The hardness of the extruded product is also influenced by feed moisture and barrel temperature. The highest strength needed for a test to enter the extrudate is hardness. It seems sense that an extrudate with a high thickness and limited expansion would be difficult. The breaking strength of extruded products is improved by increasing the moisture content of the raw material, whereas the breaking strength is decreased by increasing temperature (A.K. Maurya *et al*,2014). Depending on the viscoelastic characteristics of the melt, expansion occurs to varying degrees in both radial and axial bearings. Further drying is typically required to produce the delicate, fracturable surface of these products. Vaporization of moisture and chilling of the extrudate serve to transform the item from a liquid to a rubbery condition. Items frequently exhibit a porous, open architecture that gives them a "crunchy" surface when obtained at high temperatures and rapid expulsion process times (Prashant *et al*,2014).

CONCLUSION

Extreme versatility in the development of low-cost, highly nutritious, and accommodating food items is provided by extrusion handling. The ejected foods can take the place of regular, conventional food sources, which are less nutrient-dense. By reducing antinutrients like phytic acid and tannic acid, the extrusion technique improved the products' nutritional value while also enhancing their protein absorbability and cell-reinforcing properties. This discovery has contributed significantly to the creation of a wide range of food sources and ingredients due to its positive effects, such as the destruction of antinutritional factors, increased soluble dietary fibres, decreased lipid oxidation, and decreased contaminating bacteria. High barrel temperature, feed moisture, raw material (mostly protein and starch), and screw speed are the main extrusion handling variables that affect the physical and chemical properties of the final product. Extrusion cooking alters the ingredients, including protein, starch, salt, and fibre, and can have an impact on the expulsion framework factors and product attributes, including surface, design, development, and tactile qualities.

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