EXTRUSION PROCESS FOR PRODUCING DIRECT EXPANDED READY TO EAT FOOD CEREALS

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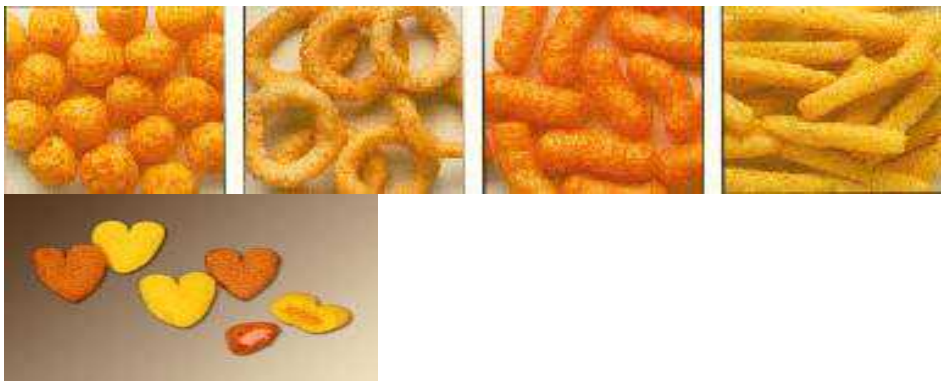
Extrusion is a continuous process for producing a shape of constant cross-section, and has been employed for producing products from polymers (thermoplastic) as well as food cereals. It is employed for food processing applications like, Snack food including Breakfast cereals, for producing flat or crisp bread and such other.

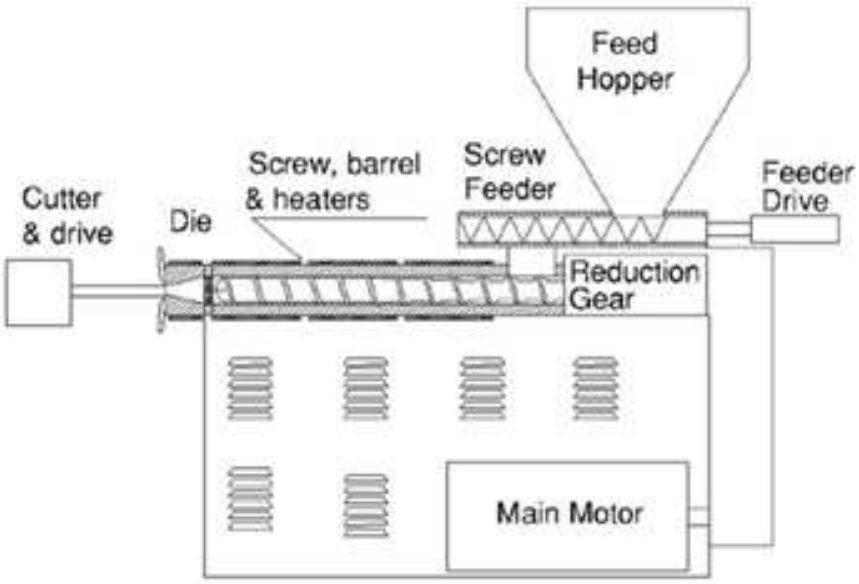
Majority of Food Extruders in use today are of single screw type, although use of Twin screw Extruders is now growing due to number of advantages. Figures below examples of direct expanded food cereals:



The single screw extruder is a bioreactor which transforms variety of raw food materials like maize, starch, wheat, rice, soy, etc. into products such as Snack foods, pet feeds, pasta products, etc.
The single screw extruder consists of a precision screw rotating inside a smooth bore or grooved barrel (pipe). The mechanical energy for rotation is supplied from a Reduction gear and variable speed electric motor. The barrel is usually heated by electric heater bands wrapped around the barrel. There is a vertical feed hopper with volumetric screw feeder (variable speed drive is provided for this to control the flow rate of food materials) for controlling the amount of food materials entering the Extruder. The Exit end of the barrel is fitted with some sort of restriction (breaker plate) and suitably shaped die orifices through which the extruded product passes out to atmosphere.
Extruder used for producing Direct expanded products usually have L/D length of 10:1 or 12:1 and screw speeds in excess of 200 RPM to provide high shear and friction energy and short residence times for the food materials.

Pasta Extruder is a cold forming machine, with the Extruder being used just to pump the ingredients through a shaping die. There is no external heating by heaters on this machine.

See diagram below:



Schematic of single screw high shear extruder used for producing direct expanded food product

Common Direct Expanded products are Corn Curls, Corn cylinder (Collet as it is commonly called), Potato sticks, Onion Rings, etc. The product is made in several shapes from simple to three dimensional interesting shapes including animal and funny figures, etc. Recently, flat bread or crisp bread, which was traditionally produced by rolling and sheeting the dough followed by baking, is produced using Snack food extruder replacing traditional methods of production. The extruded crisp bread can be produced to any texture, toasted and even sandwiched with various fillings to broaden the possibilities. By virtue of their light weight, crisp bread appeal to weight watchers. Most common is flat rectangular shape.

This article deals with the production of Direct expanded products only which are processed usually on modern Single screw Cooker Extruder of the “High shear, short residence time” (HSST) category meaning the food materials are processed at very high shear rates and temperatures inside the extruder are high (150-170 ° C) and the screw runs at high speeds (screw speeds in excess of 200 RPM are common) to maintain short residence time of product inside the extruder. Brief detail about the Twin screw Extruder in Food Industry is also included below.

Nowadays, direct expanded product consists mainly of Corn curls, Collet, Onion rings, Potato sticks or fingers and such other. The chief ingredient for the first three types is degermed corn meal (coarse and

medium granulation sizes being commonly used for best results). Potato sticks are made using mainly potato granules and corn meal.

Direct expanded product or 2nd generation Snack Food gets its name because it is formed on Extruder, and expands immediately, as it emerges from the die, requiring only additional drying or frying to bring down the moisture content and is ready for consumption. While the 3rd generation snack food (pellet) is made in 2 stages, Extrusion(cooking at high shear) followed by additional low shear processing or cooling to extrude out through the low shear extruder, without any expansion. The pellet needs to be fried at high temperatures for final expansion and consumption. Pasta products like Vermicelli are usually processed using Cold forming or Low shear Extruder generating very little shear to the food materials and serve to pump the ingredients through a shaping die.

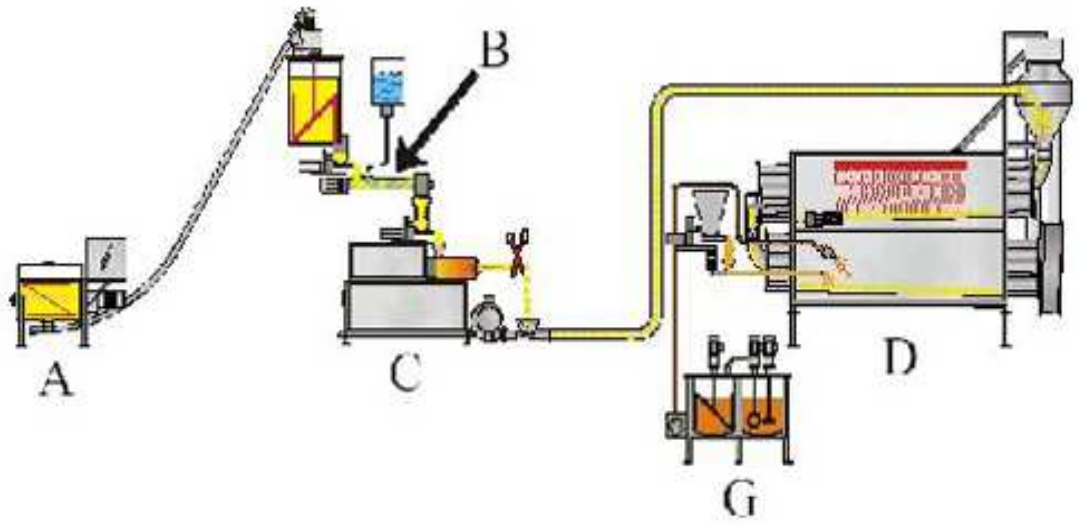
Direct Expanded product are usually light- meaning they have low bulk density (typically 50-160 g/l), and are coated with flavours and seasonings for additional taste and mouth feel.

Direct Expanded foods are processed using specially designed High shear, short residence time (HSST) Extruders with short L/Ds (12:1 or 10:1), fitted with specially designed wear-resistant cooking screw & barrel unit. The screw functions to cook (gelatinize) the food materials with moisture, mix the ingredients properly and pump the hot mass through suitable Restrictor plate and dies. The raw ingredients contain moisture usually less than 20% on wet basis, and are processed at high tempt. (150-188 deg.) and high shear rates inside the extruder. The super heated water is held as liquid inside the extruder because of high pressures, but flashes off the product immediately as pressure drops to normal atmospheric at the die exit surface, causing the product to expand or puff-up immediately. It is cut by die face cutter into small lengths. The expanded product, still contains moisture at 6-8% and is dried out in continuous belt dryer which brings down the total moisture content to around 1-1.5%. Drying times are short due to low product density. Drying times vary between 4-6 minutes and tempt. 180° C. They should be allowed to cool to 75-91° C before application of seasonings.

For additional taste and mouth feel, the product is sprayed with oil and dry seasoning and flavour dusted in a specially designed coating Drum unit. Alternatively oil, flavours, spices, etc. are mixed together in a tank and the slurry then applied to the snack as it is tumbled in a flavour applicator reel. The oil and coatings usually make up for 35% of product weight.

In designing the extrusion dies for shaping, one must bear in mind a list of effects leading to distortion of the extruded shape, as the product expansion immediately at the die surface, tends to balloon the product and round out the shape, all shapes want to inflate as sphere when they expand. There is additional effect of elasticity or product “rebound” when the applied stresses on viscous mass are relieved on emergence at the die. All these factors have to be taken into effect while designing the die shape.

Equipment & Processing steps in making a direct expanded product:
See layout of typical Snack Food line for Direct expanded product below:



A) Blender with transfer screw B) Continuous Pre Moisturiser C) Extruder D) Dryer & Coater G) Coating mass supply

Blender:
This usually takes the form of a Ribbon Blender. The mixing tool inside the vessel is in the shape of spiral ribbon which rotates through a reduction gear and electric motor. All the dry ingredients along with liquid ingredients viz. Emulsifier, Lipids, Moisture (water), etc. are loaded in measured amounts in the blender and mixed for required time. Since moisture content for expanded product is low (less than 20%), it can be added to the blender with dry ingredients. This is batch mixing process.
Conveyer: This is usually in form of inclined screw conveyor rotated by a geared motor which transfers the pre blended raw-materials from the blender to Extruder hopper.
Extruder:
The Extruder has a hopper fitted with horizontal Auger screw run by a variable speed motor. The volumetric feeder constantly supplies preset amount of raw-materials into the Extruder inlet and over the extrusion screw running inside a grooved, electrically heated barrel, which takes away the materials continuously over processing zones and forces in through the dies into desired shape. Product temperature at die exit can be as high as 190 deg.
Use of twin screw extruders is growing rapidly in food industry as explained below.
In past, special Collet Extruder, specifically designed only for producing Corn curls from straight corn meal were used for producing this product. This consists of a very short screw & barrel and set of rotating (rotor) and stationery (stator) plates between which the product is sheared and passes out through slots as “curls”, hence the name, which are usually of much higher density and fried to reduce the final moisture content before application of seasonings. The extruder has no heating provision and the product gets sheared and temperature rises because of mechanical working of the ingredients between the plates. This Extruder is almost superseded with Modern High shear Cooking Extruder which has versatility and immense product possibilities.
Cutters:
Automatic cutters are of die-face cut variety and usually consist of set of rotating knife through a variable speed motor. Three dimensional cutting blades are more sophisticated and need additional knives mounted at proper angles to form three dimensional effect cut figures.

Dryer:
It is continuous running Belt type with steel perforated belts, arranged for single or multiple passes to dry the extruded product down to 1-1.5% moisture content (wet basis). The dryer is used for producing baked collet and other products of low bulk density, while a fryer would be required for frying product with high density, e.g Corn curls produced on collet extruder is usually fried in a fryer to reduce the moisture level.

Coating unit:
This is used to spray oil on the expanded product and dusting suitable seasoning, salt, etc. on the product for additional mouth feel and crunch. In some units, the dryer and coating unit are combined.

Processing:
Raw-materials: De germed Corn meal is used either alone or along with carriers like Rice flour, Tapioca, Potato granules, etc. Wheat is not normally used, except in small amounts, as the gluten prevents complete expansion of the product. Other carriers include sorghums, soya grits, dried vegetable flours.
Water (Moisture) is required in concentration of less than 20%, typically 16%, on wet basis.
Emulsifiers are special form of lipids with higher melting points, to provide lubrication in the processing equipment, e.g. Monoglyceride. (0.5% max.) It prevents materials from sticking to the processing equipment.
Vegetable oil is used less than 1%. High concentration than this can prevent drag flow, resulting in slippage of material inside the extruder, and result in extruder instability and also less expansion.
Starch is the main component of cereal grains and is main contributor to a product texture. Different types of raw starch e.g corn or potato, modified starch, pre-gelatinized starch are used.
Nucleant (0.75-1%), which remain insoluble in the product in processing and provides surfaces at which bubbles may form during release of water vapor. e.g baking powder (sodium bicarbonate) Usage above 1% will impart distinct flavour associated with sodium bicarbonate.
Fibres: Wheat or Oat bran can be used to modify the final density , product expansion and cell size.
Salt (as per taste), sugar, etc.
All the dry ingredients are blended and then mixed with water to pre-moisten the dries. For best results, water should be distributed evenly. Enough water is added to bring the moisture content to 14-16% on wet basis).
With corn curls or collet, there is only one dry ingredient, corn grit or meal. In this case the blending step is for pre moistening only. For other products, such as potato sticks, several other dry ingredients are used. A Ribbon blender is used for blending of all ingredients.
With Twin screw Extruder, the need for pre-moistening is eliminated because water can be added to dry mix, by direct metering into extruder barrel. The twin screw will provide enough mixing to mix the water. Dry ingredients can also be separately metered into twin screw extruder.
All dry ingredients are weighed on a scale and then added into the blender. Dry ingredients are added first and blended, followed up by adding the liquid ingredient (water) and further mixing. Blending time is typically 5-20 min.
Conveying: The premixed materials with moisture are conveyed from the blender to the feed hopper through screw conveyor or vacuum transfer system.
Metering: The ingredients are next metered into the extruder through volumetric feeder run by variable speed motor for speed control. The extruder for expanded products is usually run in strave-fed manner,

meaning the screw volume is greater than available horsepower or torque from installed motor. It means extruder is fed at a rate less than it is capable of taking away.
Extrusion: The Single screw High shear Extruder relies on the drag flow for conveying the material forwards away from the inlet or feed hopper. The screw has three zones: Feed, Kneading/Compression and Meter/Final cooking zones. At the feed zone the pressure is lowest and the bulk density of raw-materials is less. It is to be understood, that, a single screw extruder relies on frictional forces between the barrel and material to transport the material forward to other zones. Hence, to increase the friction force, modern extruders are usually provided with longitudinal grooves spaced around the periphery of inner barrel walls to provide a rough surface and maximum forward transport of food materials. As the material passes through Kneading zone, it is compressed and cooked due to heat being supplied from the external heaters round the barrel, as well as mechanical working action (friction) of the screw at high speed (speeds greater than 200 rpm are common). The raw-materials becomes less viscous or sticky in this zone. As the materials passes through the cooking zone, it gets gelatinized (cooked) and the pressure and temperature is highest in this zone. This zone might contain mixing device such as pins, slots, etc. which force the product to take a circuitous path to mix the ingredients thoroughly inside the extruder. Modern extruders have multi flighted screws, as opposed to single flight to improve the stability of operation and even discharge pressure resulting in consistent flow of product. Due to high pressure inside the extruder, the superheated water present in the material remains as liquid. The plastic, dough mass passes through additional Restrictor plate and shaping dies, and the product expands immediately after exiting from die due to superheated water passing out of the product, as steam, because of sudden drop in pressure.
The continuously emerging product is cut into small length by rotating knives against the die surface. The speed of rotation of cutting knives will determine the length of product.
Extruder operating conditions are used to control the density and texture of the direct expanded product. The process variables which can be independently controlled are: moisture, feed rate, barrel temperature, screw speed. The die restriction (e.g no. of holes) can also be considered an independent control of the extrusion process but is usually not adjustable while the extruder is running.
In some machines, the discharge of the screw has a conical end and has a matching conical cup in front of the screw though which the product passes. The axial gap between the conical screw dip and the inner conical surface of the conical cup can be varied by axial adjustment of the screw thus changing the extrusion pressure.
Drying
To reduce the final moisture content in the expanded product, it is necessary to dry (bake) the same at temperatures of 180° C for 4-6 min. to bring down the moisture content to 1-1.5%. As said before, it is employed for product of high shear extruder with light density (baked collet).

Fried Collets:
Corn curls are the original direct expanded snack product. They are made on specially designed single screw Collet Extruder designed, usually for handling such type of product, consisting of a short screw & barrel and unique assembly consisting of a stationery plate or “stator” and a rotating plate or “rotor”. The rotor spins at very high speed and the food material is sheared between the two plates causing rise in temperature of product and characteristic shape or “curl” as the product passes out of the stationery plate or stator slots. The expansion takes place as the product emerges out of the die as superheated water flashes off as steam out of the product. Operating pressures in this machine are inherently less (about 700 psi) hence the expansion less compared to product obtained on high shear single screw

extruder, making the product density inherently higher or a “heavier” product. Hence product is more suitable for frying than baking. The capabilities of such extruder is usually low. This is an adiabatic device meaning entire heat required for the gelatinization of meal comes from frictional heat due to shearing of material between the two plates. The curling takes place due to the flow of corn between the stationery and rotating plate, leaving it twisted and collapsed at places.
The puffed corn pieces are fried to reduce the moisture level from 8-10% down to 1.5-2% for texture and stability.
Most collet extruders have “choke-fed” opening, meaning there is no volumetric feed control like modern high shear snack food extruders. The ingredients are gravity fed into the collet extruder. The only variable (in operation) which is usually controlled on the Collet extruder is the gap between the two plates which determine the shear being imparted to the material. Quality can also be controlled by control of moisture in the corn meal and by controlling the granulation size of corn meal, coarse variety being generally preferred to provide the necessary amount of high shear to be imparted in less processing zone.

Baked Collets:

The category of baked collets would include products which are direct expanded and baked (or dried) rather than fried. This includes baked cylinder collets, onion rings and potato sticks. It is produced using modern, high shear cooking extruder. Such extruder produces light density product with complete expansion, than collet extruder, hence it is ideally suited for baking as frying would make the product absorb oil like sponges.
Potato sticks products are made using 65% potato granules and 35% corn meal. The baked collet is then coated with oil, salt and other flavours.
Following parameters can be controlled on high shear cooking extruder (in operation)

1) Moisture content 2) Corn meal flow rate 3) barrel temperatures 4) screw speed 5) die restriction (no. of holes and size, etc.)

In addition quality can be controlled by granulation size of corn meal. Coarse or medium grits are suitable for desired quality levels- fine grits result in extruder instability and surging in outputs.
For controlling the product length, the speed of rotation of cutting knives is usually adjusted.

Crisp and flat bread:

The raw-materials include flours and various powder ingredients, whole grains/meals, sugar, dried milk powder, salt, vegetable oil, moisture (10-15%), protein, fat, fiber, etc. which are pre blended and transferred to the extruder to cook at high temperatures (120-180°) and extruded out of a rectangular opening to yield a light, crispy product. Increasing the protein, fiber and fat content tend to reduce the expansion of product which yields a harder bite and texture, while increasing levels of starch in the formulation increases the expansion and yields s softer bite. It is also a direct expanded product. The continuously extruded flat product is cut into lengths by the cutter and then dried and toasted to 4% final moisture content. Occasionally, the flat strand is continuously extruded into an oven at tempt. Of 350 °C. This baking or toasting time is short, from 5-15 sec achieving the desired colour development and moisture (4-5%). A device at the end of the toaster cuts the crisp bread into small lengths which are then transferred by conveyors for packaging.

Twin screw Extrusion of Food Cereals:

A single screw Extruder has a single screw rotating inside a stationery barrel and relies on frictional forces to transport the material forward for maximum throughputs. There are three types of flows

associated with single screw extruder viz. 1) Drag flow 2) Leakage flow 3) Pressure flow. The drag flow is because of the friction between the material and inner barrel flows with the material being conveyed forwards due to rotating action of screw. The small amount of leakage flow tends to reduce the net output because of the leakage taking place in clearance between screw & barrel, hence only necessary amount of clearance is kept between the screw and barrel. The Restrictor plate consisting of breaker plate and dies provide a restriction against which the extruder screw must pump the material. These restrictors build up the pressure inside the extruder- useful for better mixing of products, but resulting in net loss of output available from extruder due to pressure build-up. The food materials are usually sticky while processing and tend to adhere to the rotating screw again reducing the output available from the extruder. A single screw extruder is usually considered a poor mixer and it is not possible to add dry or liquid components in the extruder barrel. Hence all components are mixed in a blender prior to entry into the extruder.

Direct expanded products made from Wheat, Rice and high potato loadings are difficult to run on single screw extruder which usually results in incomplete puffing. This needs increased L/D lengths, or a twin screw extruder for good results.

The Twin screw Extruder consists of 2 screws fully intermeshing with each other and rotating inside figure “8” shaped barrel. The screws usually rotate in same direction (Co-rotating).

The inherent construction of the TSE makes the machine operate like a positive pumping device, irrespective of the die restrictions. Thus higher throughputs are possible.

The 2 screws are self-wiping with minimal adherence of material to the screws, and material changeovers are fast without much wastage. Cleaning is simplified because screws are self-cleaning.

The material is alternatively exchanged in the free spaces of screws as it is conveyed forward and mixing is homogenous and controlled. It means all or some of the dry & liquid ingredients can be added through the barrel through volumetric/gravimetric feeders and metering pumps, thus avoiding pre blending of ingredients.

The other important advantage of TSE over SSE is that the former is usually made with modular twin screw & barrel, i.e the twin screws comprise of separate individual elements designed for specific purpose, e.g conveying screws, kneading paddles, mixing elements, discharge screws, etc. They can be assembled on central shafts to assemble the whole screw as per requirement. For e.g for more shear and mixing, the configuration of the kneading paddles and mixing elements can be suitably adjusted. If the material degrades or overcooks, the length (L/D) of the screws & barrel can reduced as per requirement. Due to modular construction of TSE, replacements are also simplified and less costly compared to single screw Extruder.

Product from Wheat & Rice which are difficult to run on single screw extruder can be efficiently run on twin screw extruder.

TSE gives high output (approx.2.5 times) than that obtainable from single screw extruder of equal size.

End of the Article.

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