



EXTRUSION OF FOODS

There are two types of extrusion process: cold extrusion, which mixes and shapes foods such as biscuit dough and pasta without cooking them; and hot extrusion (or extrusion cooking), which is used to produce a wide range of products, including crisp snackfoods, sugar confectionery and soya-based weaning foods. Both use equipment known as an 'extruder'. This equipment has a screw inside a barrel that conveys materials along the barrel and kneads the food into a semi-solid, plasticised mass. In cold extruders the material is not heated but simply formed into shapes (including rods, tubes, strips or shells), when it is forced through openings in a 'die' at the discharge end of the barrel. In extruder-cookers the material is heated by friction and/or supplementary heaters in the barrel and it emerges from the dies under pressure. Some snackfood products expand rapidly and have a light, crisp texture, caused by steam being flashed off due to the sudden pressure drop when they emerge from the die.



Figure. 1: Mixing pasta dough, extruded spaghetti, dies for pasta machines, pasta extruder, (Fords Food Equipment at www.freshpastamachines.co.uk/lillo_due_pasta_machine.html)

Cold-extruded products are preserved by chilling, baking or drying, whereas extrusion cooking destroys contaminating micro-organisms and the dry products have a long shelf life. They are packaged to prevent them picking up moisture and to prevent oxidation during storage. Cold extruders are suitable for all scales of operation from household- to small-scale, but extruder-cookers are much more expensive and are likely to only be affordable by larger-scale producers.

Cold extrusion

The main application of cold extruders is in pasta production, although similar machines are used to form biscuit dough into different shapes. A pasta extruder (Figure 1) is used to make many different types of pasta (Table 1) using dough made from durum wheat flour (or 'semolina') and eggs. Coloured pasta can also be made by adding tomato purée or spinach paste.

technical brief

Type of pasta	Description
Bucatini	Hollow spaghetti
Casarecce	Short curled up pasta
Chitarre	Square spaghetti
Fettuccine	Long flat pasta
Fusilli	Short twists
Lasagne	Sheet pasta
Linguine	Long thin oval pasta
Macaroni	Short hollow smooth pasta
Pappardelle	Long wide flat pasta
Penne rigati	Short hollow ridged pasta, angled cut
Reginette	Long flat wavy edged pasta
Rigatoni	Short hollow ridged pasta, straight cut
Rotelle	Wagon wheel shape pasta, with ridged rings and spokes
Spaghetti	Long round
Tagliolini	Long thin flat pasta

Table 1. Types of pasta (Product information from Fresh Pasta Machines at www.freshpastamachines.co.uk/pasta_machines.html)

Different sizes of equipment are available, from small manual machines that are used in micro-scale production and food service outlets, to larger electric machines. The equipment has a mixing chamber, extruder barrel and a die for the desired pasta shape. There is debate over the best material for dies, with some equipment manufacturers using stainless steel or plastic, and others preferring bronze dies, which they claim imparts a rough surface to the pasta that holds sauce better than pasta made by other methods. Shapes are cut to the appropriate length as they emerge from the die, except rigatoni, which is extruded in long lengths and then cut to the correct size (straight for rigatoni or angled for penne rigati). Pasta is cooked immediately in food service outlets, or dried by processors for retail sale. It can also be frozen for up to six months.

Hot extrusion

Extruder-cookers may be single- or twin-screw machines. Twin-screw machines have approximately twice the capital and maintenance costs of single screw machines and are unlikely to be affordable by most small-scale processors. Single-screw extruders (Figure 2) are therefore described in this section. Processors, who wish to make extruded products such as or chocolate-filled snackfoods, gums and jellies, marshmallows, cornflakes, or instant rice or noodles, should discuss their requirements with manufacturers of twin-screw extruder-cookers.

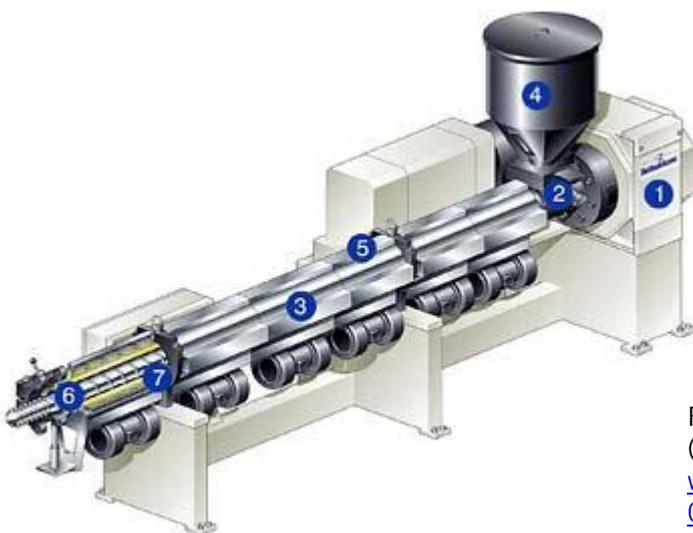


Figure 2: Single-screw extruder (Reifenhäuser Group at www.reifenhäuser.com/en/extruder/p0056_ein_module.asp)
 1 Drive unit, 2 Barrel inlet, 3 Temperature control, 4 Feed hopper and dosing unit, 5 Vacuum venting, 6 Barrel, 7 Screw.

The two factors that control the type and quality of foods that are produced by hot extrusion are the operating conditions in the extruder barrel and the mixture of ingredients that is used.

Operating conditions

The important operating conditions are the temperature and pressure in the barrel, the diameter of the die apertures and the product shear rate. The shear rate is influenced by the speed and geometry of the screw (size, number, pitch and diameter of the flights), and by the internal design of the barrel, including grooves in the barrel, or restrictions (known variously as 'throttle rings', 'kneading discs', or 'shearlocks'). Additional heating may be provided by a steam-jacketed barrel, a steam-heated screw, or electric heating elements around the barrel.

'High-shear' extruders have high screw speeds and shallow flights to create the high pressures and temperatures needed to make expanded products; 'medium-shear' extruders are used to make texturised proteins and semi-moist foods; and 'low shear' extruders have a deep-flighted screw that operates at low speeds in a smooth barrel to create low pressures for forming meat products or gums. The selection of the correct type of extruder for a particular application should take account of the types of ingredients and the properties required in the product (e.g. its bulk density, texture, colour and other sensory properties) and the required production rate.

Dies have different shaped holes (e.g. round holes to produce rods, square holes for bars, or slots to produce sheets), or they may produce more complex shapes. The temperature and moisture content of the food and the extent of shearing in the barrel control the amount of expansion of the product and hence its texture. Some products require the dies to be heated to give the required degree of expansion, whereas others have cooled dies to reduce expansion. There are therefore a very large number of potential combinations of equipment design features and small-scale processors should seek advice from extruder manufacturers before purchasing a machine.

Ingredient mixture

Different mixtures of ingredients produce completely different products when the same operating conditions are used in the same extruder. This is because starch, proteins, moisture and other ingredients (e.g. oil or an emulsifier) have different effects on the structure and texture of the extruded food. For example, starch or proteins create a three-dimensional structure that contains the other ingredients. Starches from cereal or legume flours (e.g. maize, wheat, rice, barley, pea, bean), or from tuber flours (e.g. potato, cassava, tapioca) are used for extruded breakfast cereals, snackfoods, pasta and biscuits. Proteins from soybeans, sunflower seeds, rapeseed, or gluten from wheat, are used to make meat-like products such as texturised vegetable protein.

When making extruded snackfoods from cereal or potato starch, the process operates at high temperatures (130 - 180°C) to produce a 'fluid melt' that contains gelatinised starch and superheated water vapour. When this leaves the extruder it expands to form hard, porous, brittle snackfood products. Flavourings and/or colourings are sprayed onto the food after it is extruded. Snackfoods can also be made from extruded 'preforms' or 'half-products'. These are small, dense extruded pellets that are sold to other processors to make the final snackfood by frying or toasting the pellets. When half-products are heated, they soften and the residual moisture in the pellets turns to steam, which rapidly expands the pellets to produce the snackfood.

Extruded weaning foods are produced as flakes or pellets from a mixture of cereal and legume flours that have the correct protein and energy content for growing children. The extruded products may also be fortified with minerals and vitamins. In use, the products are ground to a powder and mixed with hot water to form a porridge that is fed to children. The high temperatures used in the extruder ensure that products are safe and have a shelf life in excess of 12 months when packed in moistureproof and airtight packaging. The process is used for both commercial weaning foods and foods used as emergency or supplementary foods by development agencies.

Extrusion cooking is also used to produce sugar confectionery products such as liquorice, toffee, fudge and boiled sweets from sugar, glucose and starch. Hard-boiled sweets are produced from sugar

and corn syrup with added colours, acids and flavours. They are extruded as a 'rope' and made into the required shapes using stamping or forming machines. Energy consumption using an extruder to produce confectionery is about half of that used in boiling pans.

Further information

- *Advances in Food Extrusion Technology*, Maskan, M. and Altan, A., 2011, Contemporary Food Engineering Series, CRC Press,
- *Extruders in Food Applications*, Riaz, M.N., 2000, CRC Press
- *Extrusion-cooking Techniques: applications, theory and sustainability*, Moscicki, L., 2011, John Wiley & Sons.
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- *The Complete Manual of Small-scale Food Processing*, Fellows, P.J., 2012. Practical Action Publishing, in preparation.

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