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Review Article

Definition of Extrusion Cooking Technology, the Food Industry in Focus: A Review

Oluchukwu Nwadi and Thomas Okonkwo

Department of Food Science and Technology, University of Nigeria, Nsukka, Enugu State, Nigeria

ABSTRACT

The aim of this paper was to review the different definitions of extrusion cooking of food available in literature. Extrusion cooking of food entails different unit operations in a single process whereby different food ingredients are uniformly mixed and forcefully passed through a die. It has been used in producing various shapes and sizes of food products. Extrusion technology is mostly applied in the manufacture of snacks, breakfast cereals and ready-to-eat food products and the more modern 3D breakfast cereals and snacks. Extrusion cooking involves a high temperature short time process and is very useful in producing low-fat snacks. Extrusion cooking of food entails different unit operations in a single process. An extruder has five major components, pre-conditioner, barrel, screw, die (usually with cutter) and the feeding system. It originated in the metallurgical industry. Food extruder may be classified thermally, geometrically or conveying mechanism based on applications, design and configurations. Extruders have the same operating principles, basically, a screw extruder is made up of a rotating screw in a fixed barrel and a die at the exit. Different types of extruders have advantages and limitations. Different researchers have used a variety of raw material for extrusion cooking ranging from flours of cassava, maize, wheat, corn, millet and soybean. Pasta and breakfast cereals are the commonest extruded cereal-based food products.

Key words: Cereals, extruder, high temperature, mixing, shear, short-time, snacks

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Corresponding Author: Oluchukwu Nwadi, University of Nigeria, Nsukka, Enugu State, Nigeria Tel.: +2348064189927

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INTRODUCTION

The five major components of an extruder include: Pre-conditioner, barrel, screw, die (usually with cutter) and the feeding system [1]. The very important operating parameters of an extruder include barrel temperature and pressure, die aperture diameter and rate of the shear. The rate of the shear is determined by barrel internal design, length:diameter ratio of the barrel, screw speed and screw geometry. There are different types of extruders, however classification of extruders can be based on number of screws, shear, heat generation and direction of rotation. Factors to consider when selecting an extruder for extrusion process include nature of ingredients, type of product, bulk density required in the product, the sensory properties of the product, feed rate. Feed rate is determined by some factors such as element and speed of the screw, moisture content, feeding element type. Also, feed rate determines some factors such as residence time, temperature of dough, pressure of the barrel, torque requirement[1]. High pressure and temperature are a requirement to produce expanded snack foods. These high pressure and temperature results in high shear in the extruders, usually characterized by shallow flights and screw speed which is high. The die design and swelling of the melt at the exit of the die determines the final shape of the extruded product. Different authors have concluded that extrusion cooking solubilizes fibre, increases protein and starch digestibility, inactivates antinutrients, toxins and harmful enzymes such as peroxidases. Hence the need to review these definitions.

Extrusion technology

Definition: The extruder originated in the metallurgical industry in 1797. It was in mid-1800 that extrusion was applied to food (casings were being stuffed with chopped meat). A single-screw extruder was first used in the pasta industry in 1930[2].

From the definitions given by different authors (Table 1), it may be summarized that extrusion cooking of food entails different unit operations in a single process whereby different food ingredients are uniformly mixed and forcefully passed through a die. It has been used in producing various shapes and sizes of food products. Extrusion technology is mostly applied in the manufacture of snacks, breakfast cereals and ready-to-eat food products and the more modern 3D breakfast cereals and snacks. Extrusion cooking involves a high temperature short time process and is very useful in producing low-fat snacks. Extrusion cooking solubilizes fibre, increases protein and starch digestibility, inactivates antinutrients, toxins and harmful enzymes such as peroxidases[3]. During extrusion cooking, the structure and texture after processing of the food products (extrudates) are changed.

Types of extrusion technology: Navale *et al.*[1] reported that different types of extruders differing in configurations and performances are in existence and are classified based on certain factors (applications, design, configurations). Muthukumarappan and Swamy[3] made an attempt to classify extruders (Fig. 1). Food extruders are classified thermally as forming (cold) or cooking (hot) and geometrically as single or

Table 1: Definition of extrusion

Definition	References
Food extrusion involves the process of forcing food materials to flow under a variety of operations, including kneading, melting and/or shear, through an orifice (die) which is specifically designed to shape and/or expand the material. Food extruders may be designed to perform several unit operations concurrently, including mixing or homogenization, shearing, starch gelatinization, protein denaturation, texturization, enzyme inactivation, thermal cooking, pasteurization, dehydration, shaping and size reduction	Offiah *et al.*[4]
Extrusion cooking is a process that combines the unit operations of mixing, cooking, shaping and forming to produce foods such as breakfast cereals, snack foods, soya meat analogues and confectionery. It is a high-temperature short-time process that inactivates microorganisms and enzymes and reduces the water activity of products but largely retains their nutritional value and improves organoleptic properties, especially texture	Fellows[5]
The extrusion process is an efficient continuous process, which uniquely combines several unit operations, viz: mixing, shearing, heating, pumping, forming and sizing	Tiwari and Jha[6]
Extrusion cooking technology, a high temperature short time (HTST) processing being used increasingly in the food industries for the development of new products such as cereal based snacks, including dietary fiber, baby foods, breakfast cereals and modified starch from cereals. As it is a HTST process, which reduces microbial contamination and inactivates enzymes, the main method of preservation of both hot and cold extruded foods is by the low water activity of product (0.1-0.4)	Navale *et al.*[1]
The extrusion process is defined as a high temperature short time treatment where feed material is exposed to friction and shearing forces	Bdour *et al.*[7]

Table 1: Continue

Definition	References
Extrusion process is a contemporary food processing technology to produce wide variety of foods and products that are microbial safe because it is a high temperature and shot time process and extrusion process is best suited for large scale production and leaves no effluents	Shankar *et al.*[8]
Food extrusion is a process where a food material or a mixture of ingredients (called feed) is forced to flow (under various conditions of mixing, heating and shear) through a die which is designed to form and/or puff-dry the extrudate. Extrusion cooking has become a common processing method in the cereal, snack and vegetable protein industries for converting starchy and proteinaceous raw materials into fabricated products	Rhee *et al.*[9]
Cooking-extrusion is a multi-step, multi-functional thermal/mechanical process used in a large number of food applications	Boukid *et al.*[10]
Extrusion cooking is a short time, high temperature and high shear process. Typically, dry granulated starchy food material are fed into the extruder barrel where they are forced by rotating spiral screws from a small orifice. As the product leaves the die, typically at about 120C residual water in the starchy melt expands into steam forming a low density, crisp foam	Smith and Hardacre[11]
Extrusion cooking is food processing technology that combines several unit operations including mixing, cooking, kneading, shearing, shaping and forming	Oliveira *et al.*[12]
Extrusion cooking is a hydrothermal treatment of high temperature and short duration, during which flours or starches are subjected to high temperatures and mechanical shearing at relatively low levels of moisture content	Ruiz-Ruiz *et al.*[13]
Extrusion cooking is such a common processing effort for converting starchy and proteinaceous material into fabricated products at high temperature short time duration to produce expanded snacks	Choudhury *et al.*[14]
Extrusion cooking is a high-temperature, short-time process in which moistened, expansive, starchy and/or proteinaceous food materials are plasticized and cooked in a tube by a combination of moisture, pressure, temperature and mechanical shear, resulting in molecular transformation and chemical reactions	Ogunmuyiwa *et al.*[15]
In the extrusion process, the raw material is made to flour and moistened, then subjected to high temperature treatment for short time cooking, wherein the desired level of temperature is achieved through shearing and friction forces created in the extruder	Arivalagan *et al.*[16]
Extrusion cooking is an industrial cooking process that combines high pressure, heat and mechanical force in a short period of time, causing physical and chemical changes	Chávez *et al.*[17]
Extrusion cooking is a high-temperature short-time (HTST) process, since cooking temperature can be as high as 180-190 °C during extrusion but retention time is usually only 20-40 s. Extrusion uses a combination of a few parameters: pressure, shear, moisture and heat	Sujka *et al.*[18]
Extrusion is a mechanical process exposing material to high temperature, shear and pressure over a short period of time	Obiang-Obounou and Ryu[19]
Extrusion cooking of snack foods is a high temperature and shear process that is characterised by forming a melt from the starchy ingredient, at high temperature (140-180 °C) and low moisture content (~12%). Processing is rapid with a typical mean residence time of 15-30 s	Dehghan-Shoar *et al.*[20]
Extrusion cooking, particularly in the snack food industry, is a complex process that differs from conventional processing by using high shear rates and high temperatures (4150 1C) for very short periods (seconds)	Athar *et al.*[21]
Extrusion is a continuous food processing technique classified as a high temperature short time operation in which raw food materials are thermo-mechanically cooked in a screw-barrel assembly by a combination of moisture, pressure and temperature in order to be mechanically sheared and shaped	Rodríguez-Miranda *et al.*[22]
Extrusion cooking is a high temperature short time (HTST) cooking technique which provides thermal and shear energy to a food material to induce desirable physical and chemical changes	Yu *et al.*[23]
Extrusion cooking technology is a high temperature, short time, versatile and modern food operation that converts agricultural commodities from usually granular or powdered form into fully cooked shelf stable product with enhanced textural and flavour attributes	Jiddere *et al.*[24]
Extrusion cooking technology is a high-temperature, short-time, versatile and modern food operation that converts agricultural commodities, usually in a granular or powdered form, into fully cooked, shelf-stable food products with enhanced textural attributes and flavor	Berrios *et al.*[25]
Extrusion transforms starch- and protein-based solid materials into a viscoelastic fluid under high pressure and temperature conditions. A drop of pres- sure at the die point vaporizes the water embedded in the fluid, leading to the formation of pores and an increase of sectional expansion. The content and type of fibre present in the flours may determine physical (sectional expansion, porosity, wall thickness etc.) and sensory (crispiness, crunchiness, hardness etc.) characteristics of extruded snacks	Diaz *et al.*[26]
Extrusion cooking is the technology having the possibility of changing the functional properties of food ingredients. During extrusion cooking, the raw materials undergo many chemical and structural transformations, such as starch gelatinization, protein denaturation, complex formation between amylose and lipids and degradation reactions of vitamins and pigments	Pardhi *et al.*[27]
Extrusion is a method of physical texturing of a raw material for the purpose of its refinement and for imparting to it the features of a semi-product or product. In the food industry that technology is used for the production of a broad array of products such as breakfast flakes, diet supplements, functional foods, pastries and confectionery, snacks and feeds from e.g. waste materials from the agricultural and food industry	Timonen-Soivio *et al.*[28]
Extrusion technology is increasingly used in the food industry for producing different types of food products such as breakfast cereals and ready-to-eat snacks. It is a high temperature, high pressure, short time and continuous processing technique that enable manufacturers to produce highly nutritious food products with incorporation of different types of ingredients, flours and starches	Radovanovic *et al.*[29]

Table 1: Continue

Definition	References
Extrusion cooking provides the conditions for gelatinizing starch, polymerizing proteins and crosslinking molecules to form expandable matrices. The addition of proteins to starches increases sites for cross-linking and affects textural quality	Kocherla *et al.*[30]
Extrusion is a process which combines several unit operations including mixing, cooking, kneading, shearing, shaping and forming. Usually the food is compressed and worked to form a semi-solid mass. This is then forced through a restricted opening (the die) at the discharge end of the screw. The main purpose of extrusion is to increase variety of foods in the diet by producing a range of products with different shapes, textures, colours and flavours from basic ingredients	Gbenyi *et al.*[31]
Extrusion is a processing method that combines the effects of mechanical shear and temperature to disrupt the cell wall structure. Study has shown that extrusion increases the content of soluble dietary fiber, probably due to disruption of covalent and noncovalent bonds, which would lead to smaller and more soluble molecular fragments. This also leads to increased production of short-chain fatty acids from the fecal microflora, which could have health benefits for humans. Furthermore, extrusion also reduces antinutritional factors and enhances the ability to lower cholesterol	Zhang *et al.*[32]
Extrusion cooking is a versatile, low-cost and efficient food processing technique. It cooks more rapidly than other techniques because it combines moisture, pressure, temperature and mechanical shear. Extrusion cooking induces numerous chemical and structural transformations in starchy and proteinaceous food materials; these transformations include starch gelatinisation, protein denaturation, complex formation between amylose and lipids and degradation of vitamins or pigments. In the case of starch gelatinisation, the high temperature, pressure and shear forces of extrusion cooking disrupt starch granules and create a dispersion. The higher the amylose content of the food material, the more energy is required to break the polymer bonds and gelatinise the starch molecules, leading to a rigid and stiff gel. The extrusion process fragments starch polymers, improving starch retrogradation, in which neighbouring starch molecules crystallise due to hydrogen bonding between their hydroxyl groups and amylose forms a double-helical crystalline structure	Kljak *et al.*[33]
Extrusion can be defined as the process of forcing a pumpable material through a restricted opening. It involves compressing and working a material to form a semisolid mass under a variety of controlled conditions and then forcing it, at a predetermined rate, to pass through a hole	Brennan[2]
Extrusion cooking offers an excellent alternative to traditional techniques for food processing; extruders can process a great variety of powder ingredients including whole grain flours and are very useful in producing low-fat products with high productivity and significant nutrient retention, reduce microbial contamination and inactivate some antinutritional factors (trypsin inhibitors, tannins and phytates)	Jacques-Fajardo *et al.*[34]
During extrusion cooking, starch or protein undergoes physicochemical changes (such as starch gelatinization, protein denaturation and hydrogen bond rupture) that result in new functional properties and substantial changes leading to greater or partial molecular disorganization	Hagenimana *et al.*[35]
Extrusion of food is universally explained as the process of forming and shaping a dough-like/semisolid food material by driving it through a die	Muthukumarappan and Swamy[3]
Extrusion cooking is a cost effective, high temperature short time process, used worldwide for production of snacks	Janve and Singhal[36]
Extrusion cooking is a continuous cooking, mixing and forming process which plays a key role in many food processing industries as a versatile, low cost and very efficient technology. During extrusion cooking, raw materials undergo many chemical and structural transformations	Ananthanarayan *et al.*[37]
Extrusion, classified as a high temperature/short time process, is an important food processing technique used worldwide for the production and modification or improvement of quality of various products	Lobato *et al.*[38]
Extrusion is a continuous cooking and shaping (forming) process designed to give unique physical and chemical functionality to food materials. It is a popular unit operation for producing a variety of food products from numerous ingredients requiring a wide range of processing conditions	Altan *et al.*[39]
Extrusion cooking is a process, which combines several unit operations and provides great opportunities in the creation of new food products	Nkama and Filli[40]
The process usually involves high temperature, high pressure and high shear rates, which induce chemical and physical changes to food materials	Luo and Koksel[41]
Extrusion cooking is a common physical method for dietary fiber modification, which is a short-time process of high temperature and pressure treatment along with mechanical shearing. Extrusion cooking employs high temperature, pressure and shear, which can destroy antinutrients in plant foods, including phytate and hence, may improve mineral bioaccessibility	Famuyide *et al.*[42]
Extrusion technology is applied to transform globular proteins from plant-based concentrates or isolates into more fibrous structures. This process aims to mimic the textural properties of products made with animal proteins. The low moisture extrusion process (10-35 % moisture) results in a textured dried protein with a not well-defined fiber structure, requiring hydration before consumption	Ariz-Hernandez *et al.*[43]
Extrusion cooking is a process that combines the moisture of the raw material with mechanical stress, temperature and pressure, generating important biochemical reactions, such as denaturation and aggregation of proteins, degradation and gelatinization of carbohydrates such as starch	Téllez-Morales *et al.*[44]
Extrusion-based cooking constitutes one of the most efficient and flexible food processing methods, being used to produce a wide variety of foodstuffs	Tica *et al.*[45]

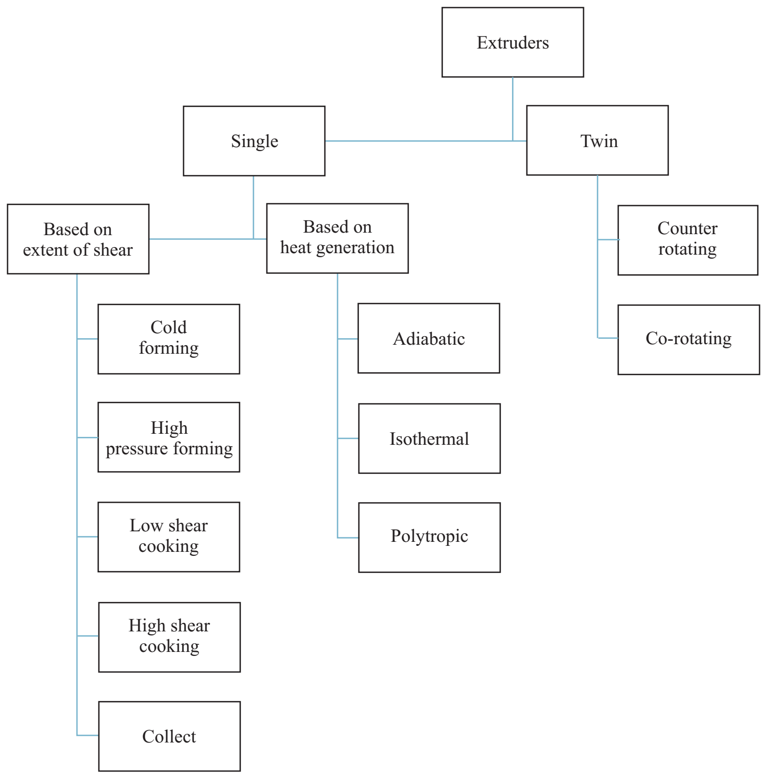

Fig. 1: Classification of extruders based on number of screws, shear, heat generation and direction of rotation
Source: Muthukumarappan and Swamy[3]

Table 2: Advantages and limitations of different types of extruders

Type of extruder	Advantages	Limitations
Single-screw	Lower capital, operating and maintenance costs (capital cost about half of a twin-screw machine). Wet single-screw extruders have higher capacity, higher capital costs but lower operating costs than dry extruders	Does not self-clean. There may be problems emptying the extruder barrel if it is allowed to cool and the product solidifies
	Less skill required to operate and maintain	Not able to process materials that contain >12-17% fat or >30% moisture due to product slippage in the barrel
	Less complicated assembly of screw configurations	More limited ingredient particle size range (very fine powders and coarse ingredients are not suitable)
	Wet single-screw extruders have greater processing control that produce superior-shaped products compared to dry extruders	Dry extruders require higher motor power and undergo greater wear than other types of extruder. The high exit pressures make it difficult to shape products <2 mm or process highly viscous materials
Twin-screw	Can produce intricate shapes and small sizes (<1.0 mm)	More complex than single-screw extruders
	Greater flexibility and control than single-screw extruders	More expensive (twice the price of single-screw machines) and have higher maintenance costs
	Can handle very viscous, oily (18-27% fat), wet (up to 65% water) or sticky materials (up to 40% sugar compared to 10% in single-screw machines)	
	Self-wiping screws are easier to clean without dismantling, giving more rapid product changeover. Can handle very fine ingredients or coarse ingredients directly without pretreatments	

Source: Fellows[5]

twin screws[6]. Extruders may also be classified based on conveying mechanism: Piston, roller or screw[4]. Irrespective of extruder design or type, extruders have the same operating principles, basically, a screw extruder is made up of a rotating screw in a fixed barrel and a die at the exit[4]. The two types of extruders have advantages and limitations (Table 2).

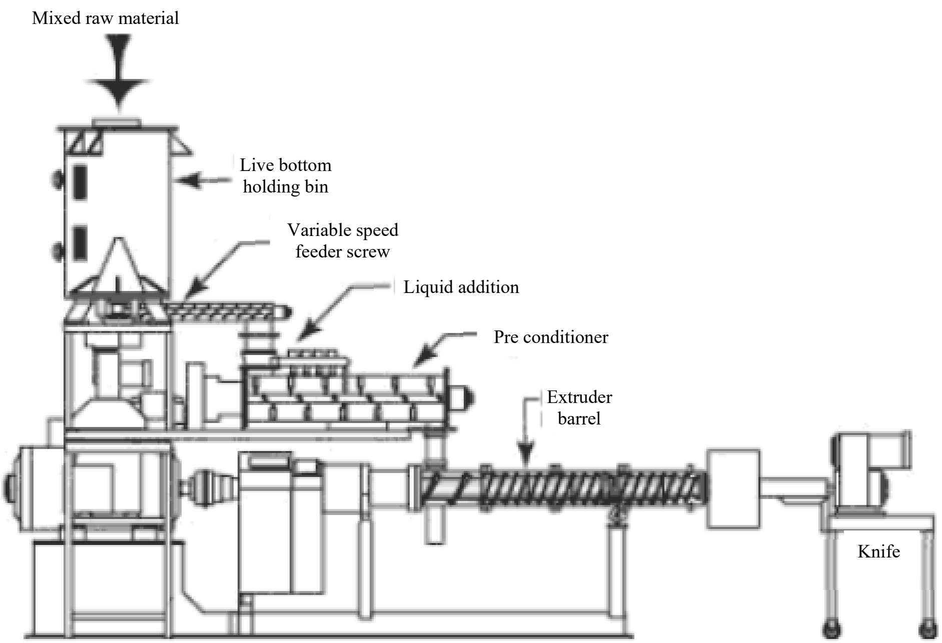

Fig. 2: Layout of a typical snack food line for direct expanded products
Source: Tiwari and Jha[6]

Extrusion equipment: The five major components of an extruder include: pre-conditioner, barrel, screw, die (usually with cutter) and the feeding system[1]. The very important operating parameters of an extruder include barrel temperature and pressure, die aperture diameter and rate of the shear (Fig. 2). The rate of the shear is determined by barrel internal design, length:diameter ratio of the barrel, screw speed and screw geometry. Factors to consider when selecting an extruder for extrusion process include nature of ingredients, type of product, bulk density required in the product, the sensory properties of the product, feed rate[5]. Feed rate is determined by some factors such as element and speed of the screw, moisture content, feeding element type. Also, feed rate determines some factors such as residence time, temperature of dough, pressure of the barrel, torque requirement[1].

High pressure and temperature are a requirement to produce expanded snack foods. These high pressure and temperature results in high shear in the extruders, usually characterized by shallow flights and screw speed which is high[5]. The die design and swelling of the melt at the exit of the die determines the final shape of the extruded product[46].

Extrusion technology and microstructure of extruded foods: The microstructure of food is affected by food processing. The food components such as proteins, vitamins and starch are usually involved in irreversible changes during processing. The proteins are denatured most times while the water soluble vitamins are lost. Extrusion cooking of food entails different unit operations in a single process whereby different food ingredients are uniformly mixed and forcefully passed through a die. It has been used in producing various shapes and sizes of food products. Extrusion technology is mostly applied in the manufacture of snacks, breakfast cereals and ready-to-eat food products and the more modern 3D breakfast cereals and snacks. Extrusion cooking involves a high temperature short time process and is very useful in producing low-fat snacks. Extrusion cooking solubilizes fibre, increases protein and starch digestibility, inactivates antinutrients, toxins and harmful enzymes such as peroxidases[3]. During extrusion cooking, the structure and texture after processing of the food products (extrudates) are changed but most researchers have not paid attention to these changes. Nuclear magnetic resonance and scanning electron microscope techniques can be used to investigate these microstructural changes. There are various classifications of extruders. An extruder basically has a single screw, however, depending on the desired extrudate, adjustments could be made in its design such as number of screws and their direction of rotation. Different extrudates usually have their various differences in texture and structure. Muthukumarappan and Swamy[3] reported that most researchers have not investigated into the microstructure of extrudates. It has been confirmed that there are numerous tiny air cells, extrudate brittleness is decreased while its crunchiness is improved upon and the cell walls are pervious and rough at high extrusion temperatures. Using Fourier Transform Infrared Spectroscopy (FTIR), it was shown that extrudates from pea protein isolate, extruded at a low moisture level, resulted in expansion of the protein network. This was assumed to be kept in steady state by increased aggregation of protein which might have been formed by some sheets and helical structures. The SDS-PAGE (sodium dodecyl sulfate polyacrylamide gel electrophoresis) suggested that the protein's vicilin and convicilin were not altered except for the legumin. It was concluded that extrusion cooking decreases the solubility of protein in water[47]. Analysis of corn meal extrudates showed different pore sizes for samples with similar expansion index. Magnetic resonance imaging and X-ray microtomography of the samples gave values which were not significantly different from each other. However, X-ray microtomography gave a superior spatial resolution[48]. The porosity of rice grits and rice grit extrudates were compared in a study using mercury intrusion porosimetry, water vapour desorption and nitrogen adsorption. It was reported that extrusion cooking results in a more porous end product. Compared with rice grits, the extrudates had a smaller radius[18]. Scanning probe acoustic microscopy was carried out on starch material extrudate and acoustic images were correlated with X-ray diffraction data. The result showed that the acoustic image contrast had a straight line relationship with the amylose component of the extrudate[49]. Zhang *et al.*[50] investigated the structure of cooked and extruded maize starch using NMR and reported that they were similar but differed in density.

The microstructure of foods changes on extrusion, depending on method of extrusion. Variation in the extrusion parameters can lead to extruded products with different and unique microstructure leading to differences in texture and, of course, varieties of products would result. A more detailed probe into the structure and texture of various food extrudates is now possible through modern techniques such as FTIR, NMR and microscopic techniques such as scanning electron microscope.

Extruded snacks: Direct expanded products are classified as second generation snack food because they are produced through extrusion cooking, in other words, it expands as soon as it leaves the die of the extruder. Only minor treatments (such as drying or frying basically to reduce the moisture content) may be required before consumption. Extrusion technology is mostly applied in production of pasta products, baby foods, texturized foods, breakfast cereals and snacks[51,52]. Extrusion has also been widely used in the production of functional foods[26,53]. Robin and Palzer[46] reported that pasta and breakfast cereals are the commonest extruded cereal-based food products. Extrusion cooking changes the properties of starch and proteins significantly. Robin and Palzer[46] reported that extrusion cooking promotes cereal flour properties as seen in cold extrusion which favours production of protein network around starch granules which are not cooked, an example is pasta. In hot extrusion, the high temperature and pressure cooks the starch resulting in a ready-to-eat food product as seen in breakfast cereals and extruded snacks. Extrusion cooking creates room for different ingredients to be combined into a single product. Chemical and structural changes take place during extrusion cooking[37]. Extrusion cooking is now being preferred to conventional cooking due to some textural properties such as high expansion ratio and more crunchiness[54]. Most extruded product contain cereal. Robin and Palzer[46] reported that different factors (application, geography, consumer habits) affect the type of grain used in extruded foods. Altan *et al.*[55] produced an expanded snack from barley grits and barley flour. Mäkilä *et al.*[54] produced antioxidant-rich extruded snack from blackcurrant juice press residues, cereals, starch from potato, sugar and salt.

Some researchers have produced extrudate with wheat as an ingredient. Some of them include: Peressini *et al.*[56] for example, produced extrudate rich in fibre from wheat flour, defatted soy flour, corn starch, rice flour, corn grits, inulin, sugar and salt. Chakraborty *et al.*[57] from some ingredients including wheat, coriander leaves, rice and corn flours. Stojceska *et al.*[58] from some ingredients including wheat flour and corn starch. Mezreb *et al.*[59] from wheat flour and yellow corn. Dehghan- Dehghan-Shoar *et al.*[20] from wheat semolina, rice flour, corn grits and tomato paste or skin powder. Oliveira *et al.*[12] and Oliveira *et al.*[60] from wheat flour and corn. Robin *et al.*[61] and Singkhornart *et al.*[62] from wheat flour. Jafari *et al.*[63] from wheat flour and sorghum. Pitts *et al.*[64] from some ingredients including wheat and corn flour. Starch and protein materials are mostly used in extrusion process, sugar-based materials may also be used (Table 3). Navale *et al.*[1] reported some raw materials used by different researchers for extrusion cooking (Table 4).

Table 3: Examples of extruded foods

Starch-based products	Protein-based products	Sugar-based products
Breadings	Caseinates	Chewing gum
Breads, including flatbreads, breadsticks,	Fish pastes	Chocolate, caramel crispbreads and croutons
Expanded Snack foods	Processed cheeses	Fruit gums
Pasta products	Sausages, frankfurters and hot dogs	Fudge
Pastry doughs	Semi moist and expanded pet foods, animal feeds, aquatic feeds	Hard boiled confectionery (e.g. toffees, caramels, peanut brittle
Pregelatinised and modified starches	Surimi	Liquorice
Ready-to-eat and puffed breakfast cereals	Texturised Vegetable Protein (TVP) or 'meat analogues'	Nougat
Weaning foods		Praline

Source: Fellows[5]

Table 4: Raw material used by different researchers for extrusion cooking

Sr. No.	Raw material
1	Cassava, maize and wheat flour
2	Wheat, mungbean and groundnut
3	Water yam starches
4	Rice-Sweet potato and rice-yam
5	Broken rice flour, pineapple waste pulp powder and red gram powder
6	African yam bean and cassava flour
7	Pearl millet
8	Tef, corn and soy protein isolated blends
9	Corn, millet and soybean
10	Carrot pomace, rice flour and pulse powder
11	Arrowroot starch
12	Barnyard millet and red gram
13	Defatted soy flour and rice
14	Corn grits
15	Lentil based snacks
16	Cassava starch
17	Rice and moong flour
18	Faba bean and rice
19	Soy and maize
20	Lentil starches
21	Defatted chick pea, corn and bovine lung flour
22	Full fat soy flour (FFSF) and cereal or pulse flour
23	Broken rice and corn grits
24	Mustered oil and rice grits
25	Faba beans
26	Yam flour
27	Potato and wheat flour
28	Rice flour and amaranth
29	Soy flour and maize
30	Garbanzo bean, lentil, whole peas and split peas
31	Soybean-sweet potato mixture
32	Rice and chick pea
33	By product from wheat mill with yellow corn, wheat starch and isolated soy protein
34	Wheat starch, whole wheat meal and oat flour
35	Maize grits
36	High moisture fish and soy protein
37	Wheat/ rice semolina and potato grits
38	Soyabean meal
39	Barley and rice flour, wheat flour
40	Soyabean and sorghum flour
41	Wheat flour, rosted Bengal gram, green gram, ground nut, jowar, skimmed milk powder and jaggery
42	Rice and soyabean residues
43	Maize
44	Full fat soy flour
45	Corn starch
46	Sorghum varieties

Source: Navale *et al.*[1]

Extruded snacks are expected to be crisp and crunchy. The ingredients and process determine the texture. The process variables referred to include temperature, pressure, feed rate among others[65].

CONCLUSION

Many definitions by different authors abound in literature, however, basically, during extrusion cooking, the structure and texture after processing of the food products (extrudates) are changed. The microstructure of foods changes on extrusion, depending on method of extrusion. Variation in the extrusion parameters can lead to extruded products with different and unique microstructure leading to differences in texture and, of course, varieties of food products would result. Extrusion improves acceptability and retains nutrients which makes extruded food products more beneficial to man when consumed.

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