

## Role of Food Extrusion in Development of Healthy Food Products: A Review

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### Abstract

In food extrusion processes, healthy cooking of raw materials occur, as they are mixed and formed to produce essentially finished product in a single operation. The process mechanism of extrusion processing is to gelatinize the starch contents by rupturing the particles. As starch passes through the extruder, it is gelatinized and when it leaves the extruder it expands. This effect is caused by breaking down the granular structure and opening up the molecular chain. In extrusion, amylose and amylopectin molecules contribute to gel formation and viscosity to the cooked paste, respectively. This article reviews research work on extruded foods, scope and the potential value addition of cereals with legumes, dietary fibre (DF), antioxidants for extrusion processing and importance of nutritional quality of extrudates. The health promoting effect of fruits and their co-products in developing restructured products is also an addition to this review.

**Keywords:** Extruder; Fibre; Food - Interactions; Starch; Structure

### Introduction

Extrusion is a short time high temperature, thermal process (HTST) that combines a number of units operations i.e. mixing, cooking, kneading, shearing, puffing, shaping, and forming [1,2] of the food materials processed within a very short time periods (minutes), accompanied by many chemical changes such as protein denaturation and starch gelatinization [3] and can be used to create a wide variety of starchy foods like snack foods, ready to eat (RTE), cereals, and a large variety of other expanded products

[4-6]. Due to its product quality (unique texture and mouthfeel for its complex reactions [7], versatility, productivity, cost of production characteristics of extrusion process has gained attention in the food as well as in the feed industry [2,8].

Extrusion works by using either a single, or pair of screws to shear starch or protein based food material through a heated barrel and a small opening known as the die. Due to thermal and mechanical stresses generated by the screws rotating and the barrels

heated, and then formed and shaped by forcing it through a restriction, or die, Extrusion also known as thermomechanical process, in which heat transfer, mass transfer, pressure changes, and shear unit operations are combined to produce effects such as cooking, sterilization, drying, melting, cooling, texturizing, conveying, puffing, mixing, kneading, conching. [4,9-11].

Thermoplastic extrusion has been largely used to produce a large variety of products using starchy sources, particularly using maize, such breakfast cereals, infant foods, ready-to-eat snacks, gelatinized flours for instant creams and soups. The thermal energy generated by viscous dissipation during extrusion with combination of shearing effect cooks quickly the raw mixture so that the properties of the materials are modified by physicochemical changes of the biopolymers [12].

Currently, gluten free products becomes popular and increasing in demands among the consumers because hey belief that gluten free food products are nutritionally superior and healthier than the traditional gluten-containing foods [13,14]. But higher consumption of GF products results nutritional deficiencies (low protein and fibre and high calories), since they are elaborated with rice or corn flours or starches. This problem can be overcome by protein and/or fibre fortification of the rice-based food formulations with high nutritional flours [15-17].

Breakfast cereals are convenience foods but processing parameters may cause them to have high glycemic index (GI) that is undesirable. The high GI in RTE foods can be lowered by the addition of resistant starch (RS) and dietary fibre (DF). Consumers are conscious about what they eat and are by and large becoming aware of the benefits of RS, DF, antioxidants, vitamins and minerals. DF has functional properties, due to its beneficial effects such as increasing the volume of fecal content, decreasing the time of intestinal transit, cholesterol and glycemic levels, trapping substances that can be harmful for human beings (mutagenic and carcinogenic agents), and stimulating the proliferation of intestinal flora [18]. Extrusion technology is known to increase the level of dietary fibre in gluteneous and gluten-free ready-to-eat expanded snacks made from cereal and vegetable co-products [19-21]. Epidemiological studies have pointed out that consumption of fruit and vegetables impart health benefits, e.g. reduce risk of coronary heart disease and stroke, as well as certain type of cancer. Apart from dietary

fibre, these health benefits are mainly attributed to organic micro-nutrients such as carotenoids, polyphenols, tocopherols, vitamin C and others. Fibre containing foods give good hope for the promotion of health since hemicellulose and pectin share a remarkable ability to bind heavy metal compounds. Also to a smaller extent binding ability has been shown by cellulose and lignin. Agricultural and industrial food residues are attractive source of antioxidants. According to Elleuch, *et al.* [22] most of the by-products generated from residue/waste left behind in fruit processing industries can effectively be used in designing healthy foods for providing DF (non-digestible) and bioactive compounds (flavonoids). Thus incorporation of these fruit pomace rich in DF and bioactive compounds from industrial residues with traditional rice type (choukua rice) to form extruded breakfast cereal will help in providing a convenience food that has health promoting properties. Extrusion cooking is used extensively in the manufacture of ready-to-eat snacks/ Breakfast cereals and has dramatically transformed the cereal industry, the key being quality-extruded products offered to consumers at competitive prices [23]. This review comprehensively covers macromolecular degradation and characteristic changes of the extrudates. It also focuses on the development of healthy snacks as well as importance of ingredients in extruded products.

#### Extrusion cooked ready to eat (RTE) products

RTE products are increasingly popular due to their convenience of preparation, consumption such as appearance and texture [24]. RTE products (cooked during manufacturing) are manufactured from whole grain sources and predominantly flaked from steamed grains e.g. corn flacks. If the cereal is cooked with excess of water and only moderate heat as in boiling, the starch gelatinizes and becomes susceptible to starch-dissolving enzymes of the digestive system. If cooked with a minimum quantity of water, or without water, but at high temperature, as in toasting and extrusion cooking, non-enzymatic browning reaction between protein and reducing carbohydrate may occur, and there may be some dextrinization of starch.

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from cereal and vegetable co-products [19,20] Extrusion cooking of cereals improves the digestibility of starch due to partial gelatinization and fragmentation of starch, which is attributed to the mechanical shearing effect [25]. Earlier studies have reported that the application of extrusion process in the manufacture of RTEBC's enhances the protein digestibility [26-28]. Similarly Chen, *et al.* [29] reported an increase in protein solubility and potential degradation of soybean protein which might be due to shear on protein structure and conformation. Extrusion not only alters the digestibility of protein and starch but also having significant effect on the bioavailability of nutrients compared to conventional cooking processes [30-32]. Gujral, *et al.* [33] has observed increase in total phenolic and antioxidant activity of extrudate snacks made from pregerminated brown rice as compared to the native one.

#### Scope for extruded RTEBC's having functional properties

Breakfast cereals are convenience foods but processing parameters may cause them to have high glycemic index (GI) that is undesirable. The high GI in RTE foods can be lowered by the addition of resistant starch (RS) and dietary fibre (DF). Consumers are conscious about what they eat and are by and large becoming aware of the benefits of RS, DF, antioxidants, vitamins and minerals. Synthetic additives are more and more rejected and foods fortified with natural sources are gaining much popularity. Brennan, *et al.* [24] stated the applicability of extrusion cooking technology for incorporating bioactive compounds and development of nutritious and healthy RTE snacks.

#### Legumes as protein source

Legumes are a prime source of plant proteins, calories and other nutrients. Legumes are not only a source of energy but also polyphenols like flavonol glycosides, catechins, anthocyanidins, isoflavones and phenolic acid. However due to presence of high antinutritional factors and low protein and starch digestibility, their health benefit appears to be limited. Extrusion cooking of legumes increases the digestibility of legume protein even though there is loss of essential amino acids due to cross-linking which occur on heating. Beans containing lectins, trypsin and alpha amylase inhibitors are inactivated that enhances starch and protein digestibility of extrusion cooked legumes. Lysine reduction is higher at high extrusion temperature but it is less than that occurring in baking process. The reduction of antinutritional factors on extrusion cooking of legumes occurs at a lower cost than other heating

systems such as baking, autoclaving, etc. due to a more efficient use of energy and better process control [34]. Chakraborty and Banerjee [35] optimized the extrusion process for development of protein rich extrudates from rice-green gram blend. Cereals blended with legumes produce expanded snack foods and instant flour, which could serve as high energy density gruel [36,37]. Balasubramanian, *et al.* [37] has reported better rheological and nutritional properties for selected dehulled legumes-blended rice extrudates. Jisha, *et al.* [38] also reported high digestibility and very low fat content for extrudates made of cassava flour blended with legume and cereal flour. It has been reported that germination of legumes can increase protein content and dietary fibre, reduce tannin and phytic acid content and increase mineral bioavailability. Germinated legume is also reported to have higher vitamin concentration and bioavailability of trace elements and minerals [39]. There is scope for developing germinated legumes and cereal based extruded snacks with increased nutritional benefits.

#### Fruit co-products as dietary fibre

Fibre containing foods give good hope for the promotion of health since hemicellulose and pectin share a remarkable ability to bind heavy metal compounds. DF has functional properties, due to its beneficial effects such as increasing the volume of fecal content, decreasing the time of intestinal transit, reducing cholesterol and glycemic levels, trapping substances that can be harmful for human beings (mutagenic and carcinogenic agents), and stimulating the proliferation of intestinal flora.

Agricultural and industrial food residues are attractive source of antioxidants. Many fruit and vegetable residues like grape skin, apple pomace, orange peel are rich in dietary fibre which are increasingly being considered to prevent and treat many diseases such as intestinal problems, cancer and diet related health problems [40]. Utilization of fruit by-product as a source of dietary fibre is increasingly being promoted [21]. The fibre rich by-products can fortify foods, increase their dietary fibre content and result in healthy products serving as non-caloric bulking agents, enhance water and oil retention, and improve emulsion and oxidative stability [41,42]. A diet rich in dietary fibre and RS was reported to significantly increase the weight of the pancreas, liver and intestine, and the length of the intestine in rats [43]. However, the effectiveness of dietary fibres in controlling hyperglycemia is generally affected

by their composition, source, and preparation. With the growing awareness of the beneficial effects of healthy diet on the quality of life as well as on cost-effectiveness of health care, the food industry is facing the challenge of developing new products with special health enhancing characteristics. Recycling of the byproducts has been supported by the fact that polyphenols have been located specifically in the peels [44], and that processing conditions are known to influence the phenolic content [45,46]. The recovery of the antioxidant compounds from by-products would help in the maintenance of the environmental equilibrium [47]. Incorporation of food products will facilitate by-product utilization to enhance dietary fiber content. Foods containing fiber can prevent constipation and provide other health benefits as well, such as helping to maintain a healthy weight and lowering your risk of diabetes and heart disease. Biscuits developed by incorporating fibre from various have shown highly acceptable physicochemical and organoleptic properties [48,49]. Vitali, et al. [50] reported improved nutritional and functional properties and antioxidant activity for biscuit made of whole grain blended with certain legumes and apple pomace. Borah, et al. (2016) [21] had developed nutritious extruded breakfast cereal by blending seeded banana and carambola pomace. Altan, et al. [41,42] had also briefly described the prospect of healthy product development by incorporating tomato and grape pomace into barley flour. Reactive oxygen species in the form of superoxide anions, hydrogen peroxide anion, hydrogen peroxide and hydroxyl radicals are the natural by-products of body metabolisms. These are the results of oxidative damage to the cells which are responsible for chronic diseases like cancers and cardiovascular diseases. In this regard consumption of plants rich in antioxidants and phyto-nutrients notably flavonols and polyphenols is suggested to minimize the damage by oxidative changes. Further minimizing the oxidative damage may well be one of the most important approaches to the primary prevention of ageing associated with health ailments.

### Conclusion and Feature Prospective

The primary motivation is to minimize environmental impact of these by-products and to utilize valuable constituents that remain. Healthier snack products could be produced from cereals by the incorporation of naturally derived phytochemical ingredients. One viable method for utilization of fruit and vegetable byprod-

ucts along with legumes into useful products is extrusion processing due to its versatility, high productivity, relative low cost, energy efficiency and lack of effluents.

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