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Extrusion processing: The effect on nutrients and based products

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Abstract

Primarily shaping process of the food products is known as extrusion. Mixture can be fed as a mash or subjected to further processing that usually involves heat or heat and pressure in combination to the ingredients that are grounded and mixed. The most common forms of this thermal processing in the food industry are steam flaking, extrusion/expansion, pelleting and roasting. It's been since long time, around 50 years that extrusion processing has been used in the preparation of human food. Extrusion is a highly flexible process for various raw materials. An extruder is considered as high temperature short time (HTST) bioreactor that transforms a variety of raw ingredients into modified intermediate and finished products. This review paper focuses on the change in nutritional composition due to extrusion and formulation of products which can be made using this process.

Keywords: Extrusion; bioreactor; steam flaking; pelleting

Introduction

The extrusion process is an effective continuous process in which few unit operations like mixing, shearing, heating, pumping, forming, and sizing combines uniquely to form the products. Food extruders can be classified on parameters, thermally as forming or cooking, and geometrically as single or twin screws. Variety of raw food materials like maize, starch, wheat, rice and soy is transformed into products such as snack foods, pasta, processed meats, fillings and pet by a single screw extruder. Extrusion cooking technology, a high temperature short time (HTST) process, is progressively used in the food industries for the development of new high dietary fiber cereal based snacks, breakfast cereals, baby foods and modified starch from cereals (Pawar *et al*, 2014; Navale *et al*, 2015) [29, 23]. As it is a HTST process, it inactivates enzymes and it reduces microbial contamination, the low water activity (0.1-0.4) of both hot and cold extruded foods is the principle strategy for preservation of the products (Bordoloi & Ganguly, 2014) [7]. Extrusion cooking is becoming well known in comparison to other regular processing methods due to its automated control, versatility, adaptability, energy efficiency, low cost, high capacity, continuous operation, high productivity. Moreover, it also enables design and development of new food products. That product also has high product quality and unique product characteristics. Its quality of energy saving and no effluent generation makes it even more demanding (Faraj *et al.*, 2004) [13].

Effects of extrusion on nutrients

Dietary fiber

Dietary fiber has ten or more monomeric units, is defined as “edible carbohydrate polymers” that are not hydrolyzed in the small intestine of humans by the endogenous enzymes (Codex Alimentarius, 2009b) [12]. During extrusion, dietary fiber is significantly modified leading to the changes in its total dietary fiber content and solubility. The morphological characteristics (i.e. size, shape, aspect ratio) of fiber are also changed during extrusion. (Redgwell *et al*, 2011) [32] When observed under light microscopy, the particle size of citrus fiber was reduced through extrusion. Due to increasing insoluble dietary fiber, the decrease in sectional expansion often leads to an increase in longitudinal expansion (Stojecska *et al*, 2008; Robin *et al*, 2011) [38, 33]. The bulk density of extruded products was also increased when adding insoluble fiber (Brennan *et al*, 2008) [8]. Dietary fiber has beneficial effects on improving the immune system, cardiovascular health, diabetes. It is also helpful in weight management (Anderson *et al*, 2009) [4].

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Protein

The shear forces during extrusion process play an important role in changing the nutritional value of proteinaceous materials. The change in the screw-speed during extrusion leads to the variation in shear forces. Researchers found behavior of molecular aggregation and chemical cross-linking of soybean protein at both low and high moisture content during extrusion. The results showed that, hydrophobic interactions, hydrogen bonds, disulfide bonds, and their interactions collectively hold the structure of protein extrudate regardless of the location and moisture level in the extruder and the contribution of non covalent bonds during process also exceeds covalent bonds to bring about the change (Chen *et al.*, 2011) [10].

Carbohydrate

The modification during extrusion process includes few transformations such as loss of starch crystalline structure, destruction of granular structure, rupture of glycosidic bonds, and new molecular interactions. (Gonzalez *et al.*, 2002) [16]. During extrusion process, starch undergoes various structural changes including gelatinization, melting, and fragmentation and the extent of the transformation depends upon moisture content, pressure, temperature, and shearing force. Granular starch generally result in a low expansion ratio at low temperature and high moisture shows and may remain almost unchanged.

Lipids

The changes in physicochemical properties of lipids are complex and vary with the hydrophilic–lipophilic balance of lipids, amount, type and the materials being extruded. These are due to lipid binding to starch. High temperature decreases the factors favoring free fatty acid development and oxidation of fatty acids because of the reduction in lipase and lipoxigenase activity. The extrusion-cooked foods are also affected by the rate of the lipid oxidation.

Minerals and vitamins

Studies show the effect of extrusion processing conditions on the stability of vitamins. Extrusion cooking have significant effect on the stability of vitamins in extruded snack food for example higher barrel temperatures and low feed moistures can lead to loss of ascorbic acid. They observed that extrudates obtained from short barrel (90 mm) extruders had a higher retention rate of B vitamin group (44–62%) compared to 20% for long barrel extruders (Athar *et al.*, 2006) [6]. The stability of vitamins during extrusion of Acha (*Digitaria exilis*)/soy bean blend showed 6% decrease in Riboflavin (B2), a 86.36% decrease in pyridoxine (B6), and no significant change in ascorbic acid content (Anuonye *et al.*, 2010) [5]. The stability of fat soluble vitamins such as vitamin A and E are also impacted by the high temperature, short-time extrusion cooking (Tiwari and Cummins, 2009) [40].

Food Products

Chakli

A deep fried snack makes the major share of the market among the convenience foods. These are manufactured by organized sector on the large scale as well as at small scale in cottage industries. For better preservation of fresh foods, the origin of most of these products lies into our traditional practices. Naturally fried foods became a choice due to their shelf stability (Kumari and Prakash, 2009) [21]. Lately,

incredible need is felt to restore our conventional food sector mainly to give force and value addition for sustainable development of it's largely cottage, tiny and rural sector (Kamat, 2008) [19]. In India, a number of mouth watering snack foods items can be prepared from a different raw materials like *urad* (black gram) dhal, *moong* (green gram) dhal, *besan* (Bengal gram flour), *maida* (refined wheat flour), alone or when combined with other cereals, legumes and spices. Their manufacturing processes may include cleaning, pre-treatment, soaking, roasting, frying etc. (Ravi *et al.*, 2011) [31]. Snacks contribute an important part of many consumers in daily nutrient and calorie intake (Chakraborty *et al.*, 2011) [9]. Individuals nowadays are more interested in consuming snack foods because of the quick and light meal that can be consumed anytime and anywhere compared to the main meal. Furthermore, due to very hectic lifestyle also many people love to consume snack foods to prevent them from hunger. Traditional foods play an important role in local identity of the region, consumer behavior, the transfer of cultural heritage from one generation to another for future generations, and the interaction of this heritage with the rest of the world. In number of nations, the advancement and assurance of traditional food is directed through quality, agricultural and special policies. 'Murukku' is one of Indian traditional savory snack that are protected by registering them in accordance with relevant laws (Albayrak *et al.*, 2010) [3]. India is a country that has a great heritage of traditional foods, where the peoples employ to the foods in diverse aspects like edible purpose, economic input and many other activities. Chakli is one of the traditional foods of West Bengal; the state of India has different ethnic communities with distinct identity, culture and food habit. The preparation of ethnic foods not only exhibit the creativity and treasure of food heritage of localized people but also their incremental learning to sustain the life and ecosystem as a whole (Singh *et al.*, 2007) [37].

Procedure for the preparation of chakli

1. Take rice and the roasted flour of urad dal and mix well.
2. Add all spices i.e. chilli powder, turmeric powder salt, sesame to the flour.
3. Add water and prepare the dough
4. Then put cylindrical balls of this dough into extrusion machine and form the chakli.



Fig 1: Chakli made up of standard rice flour

Pasta

In several nations of Southern Europe, particularly in Italy, dried pasta is one the basic food for the population. The concept of pasta for Italian consumers originates from their traditional habits. They are strictly dependent on the usage of durum wheat (*Triticum durum*) as crude material (Noni and

Pagani, 2010) [25]. Pasta mixture is a stable product is produced mainly by mixing durum semolina and water. Although these days other grains are also used to partially replace durum semolina (Chillo *et al*, 2008) [11]. Also, for special nutrition because of its gluten free characteristics or low glycemic index, pseudo grains have been used to prepare pasta (Alamprese *et al*, 2007) [2]. However, some people with a specific genetic nature suffer from celiac disease caused by the presence of gluten which is usually affecting the intestines and cause digestive malfunction. In this diet intake of storage proteins found in wheat, rye, barley, and oats are excluded (Yalcin and Basman, 2008; Schoenlechner *et al*, 2010; Juszczak *et al*, 2012) [44, 36, 18]. People who are suffering with celiac disease or other forms of allergies or wheat intolerance, millets are the appropriate choices as they are gluten free (Saravana and Soam, 2010) [35]. This information can be useful in assessing that new gluten reduced or gluten-free products like pasta are also become essential in the market. The quality characteristics of pasta can be determined by its functional properties including firmness, gruel loss and overall acceptability. High quality pasta has a good cooking resistance and firmness, does not release an excessive amount of organic matter into the cooking water and does not show stickiness. Moreover, low breakage susceptibility to dry conditions are also related with quality of pasta. There are previous studies that have been carried out to develop functional pasta such as cereal bran enriched pasta (Kaur *et al*, 2012) [20], fresh rice pasta (Fernandes *et al*, 2013) [14].

Noodles

It is believed that noodles are originated from China as early as 5000 BC (Fu, 2008) [15]. The world’s first instant was invented by Momofuku Ando, “Chicken Ramen TM,” noodle product manufactured by Nissin Foods, Japan, in 1958. This was a revolutionary accomplishment in culinary culture. Another achievement was the introduction of cup noodles by Nissin in 1971. Instant noodles are partially cooked by steaming and further cooked and dehydrated by a deep frying process. They are usually made from wheat flour either hard or soft (*Triticum aestivum*), starch, water, salt or kansui (an alkaline salt mixture of sodium carbonate, potassium carbonate, and sodium phosphate), and other ingredients can also be added basically for improvement in the texture and flavor of noodles. Pasta and noodles, both are wheat-based products, but they differ depending on the country of origin, raw materials, formula ingredients, manufacturing procedure as well as their consumption patterns. In comparison with other bakery products, noodle manufacturing involves lower water retention because of the process like sheeting and cutting of dough, which allows lower water addition. Noodles have become popular worldwide because of the properties like taste, nutrition, convenience, safety, longer shelf life, and reasonable price. Instant noodles are also used as space and emergency food. Noodle industry supplies 95.4 billion servings annually to consumers throughout the world, and the demands are on the rise. More than 80 countries consume instant noodles in more than 80 countries and have become internationally recognized food (Gulia *et al*, 2014) [14].

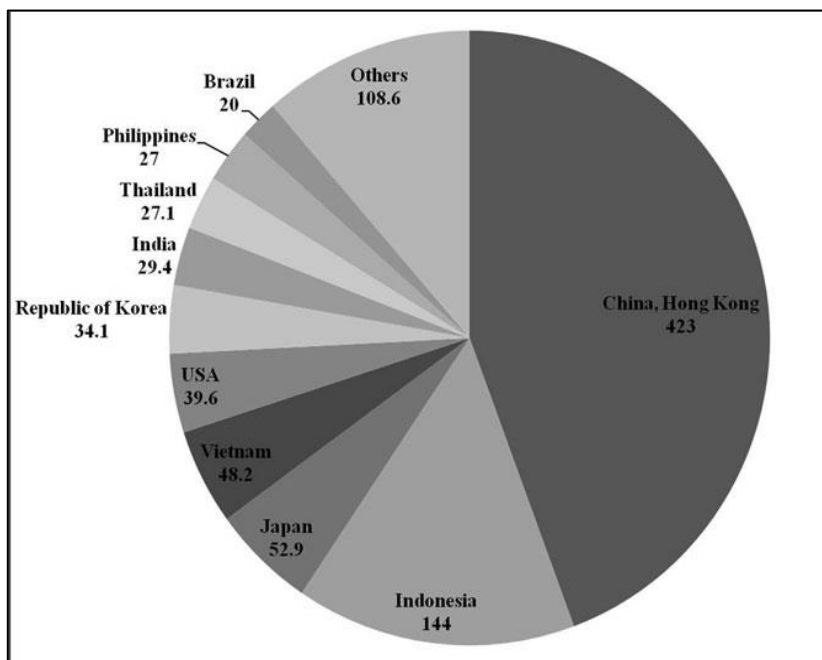


Fig 2: Instant noodles consumption in different countries [data figures represents 100 million packets; plotted using data from WINA (2011)].

Figure No. 2 revealed that instant noodles are a fast-growing sector of the noodle industry as widely consumed throughout the world. Global consumption of the noodles is on the 2nd position after consumption of bread. Noodles are made from unleavened dough which is stretched, extruded, or rolled flat and cut into one of a variety of shapes is a staple food in many cultures (Okoye *et al*, 2008) [26]. According to (Lee *et al*, 2008) [22] noodles came to China in 5000 BC, and then spread to other Asian countries such as Japan, Thailand, Korea and

Malaysia. With the compound annual growth rate (CAGR) reaching 4% Worldwide and now, it has become one of the fastest growing sectors in the world. According to the world instant noodle association, China ranks first in the consumption of noodles followed by Indonesia, Japan and Vietnam. To boost various nutrients like fiber, protein etc, wheat flour noodles can be supplemented with a range of materials (Ross, 2013) [34]. Recently, the demands for high fiber food have

increased so food manufacturers have been trying to meet demands of consumer by developing products in which high-fiber ingredients. Increase water holding capacity, oil holding capacity, emulsification and/or gel formation are few functional properties that increase by increasing dietary fiber in food substances it has been added. Traditionally, consumers have chosen foods such as whole grains, fruits and vegetables as sources of dietary fiber. Flour of hard wheat (*Triticum aestivum* L.) is used as primary ingredient to make instant noodles. This flour is low in fiber and protein contents

as well as poor in essential amino acid, lysine. Other flours can also be used to make noodles like rice, buckwheat, and starches derived from potato, sweet potato, and pulses (Tan *et al*, 2009) [39]. Most of the essential nutrients are lack in traditional noodles such as dietary fiber, vitamins and minerals, which are lost during wheat flour refinement. Thus, noodle products which represent a major end-use of wheat, are suitable for enhancing health after incorporating sources of fiber and essential nutrients (Neha and Ramesh, 2014) [24].

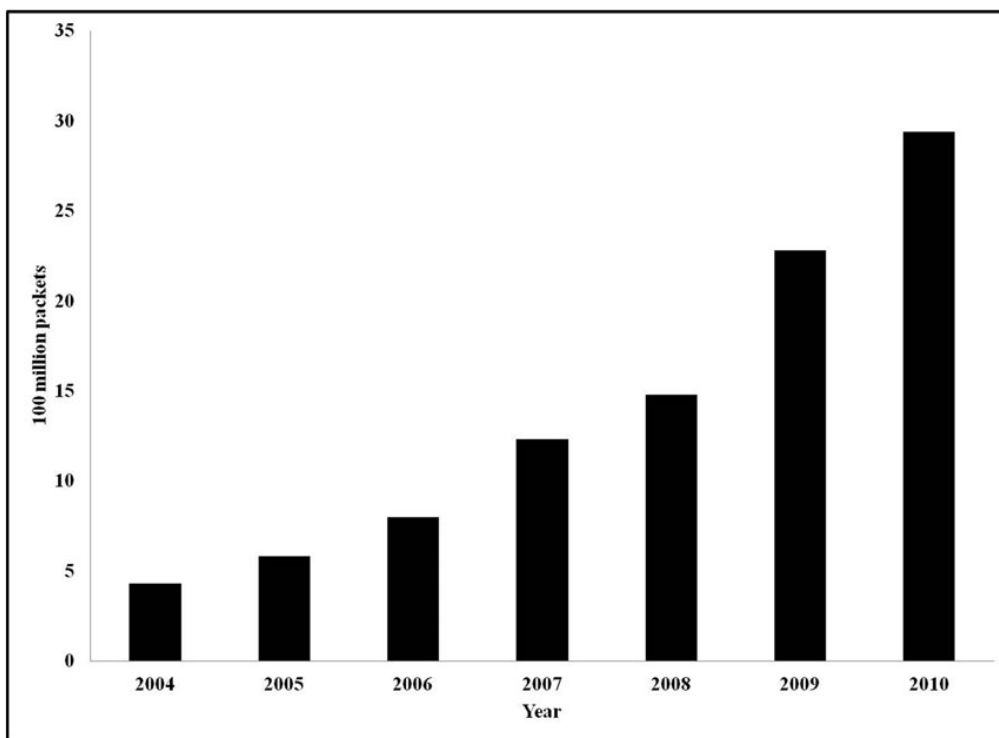











Fig 3 In India: Instant noodles consumed in recent years (WINA, 2011).

Table 1: Types of Pasta

Types of pasta	Description
	Angel hair: They are very fine and delicate strands which needs about 3-5 min for cooking. The available size are 1 lb.
	Penne: They are like small tubes that are typically 2 – 4" long, available in white colour. They are best made when tossed with sauce Available sizes are 12 oz. or 20 lb. Their cooking time is 10-12 minutes
	Macroni: Short, C-shaped tubes which are used in baked dishes, saads and soups. Cooking time is 6-8 min and available sizes are 1- 20 lb.

	<p>Shells: They are small shell shaped that are that has an open cavity which collects sauce. They are about 20 lb in size and and used majorly in baked dishes. It takes about 10-12 min to cook.</p>
	<p>Ziti: They are medium-width tubes that are at least 2" long. Cooking time is 10-12 min and are of size of 20 lb.</p>
	<p>Lasagna: Square or rectangle sheets of pasta that sometimes have fluted edges (<i>lasagne ricce</i>). The square of pasta is <i>lasagna</i> while the dish is lasagne</p>
	<p>Spaghetti: Thin round strands that are about 10" long, available in white or wheat. It takes about 9 – 11 minutes. Tossed with sauce and are 1 lb., 20 lb. in sizes.</p>
	<p>Rotini: Spiral-shaped to retain sauces and ingredients, available in white or tri-color. They take 10 – 12 minutes to cook. Tossing with sauce, pasta salad are recommended with it Ideal sauces and ingredients are Tomato, cream, vinaigrette, meat Available sizes are 12 oz., 1 lb., 20 lb.</p>
	<p>Fettuccine: Long, flat egg noodles that are about 1/4" wide. They take about 15 minutes to cook. Tossed with sauce, cream and cheese. Size is 1 lb.</p>

Procedure for making noodle

1. Raw materials are selected.
2. Mixing of the ingredient to form a dough and let dough rest for 40 min
3. Rolling out into the thin sheet and extrusion to form fine strands
4. Steaming and drying at 60°
5. The noodles are prepared and can be packed (Parakhe, 2016) ^[27].

Conclusion

Extrusion processing comes out to be an easier and efficient technique in formulation of the products like noodles, pasta and chakli. The consumption of extruded products is high in world and it is growing each day. It carries both tradition and suitable in today’s modern world as well.

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Conflict of interest

There is no conflict of interest between the authors.

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