Fishery Technology 59 (2022) : 225 - 237

Effect of Extrusion Processing Parameters on Physical and Nutritional Properties of Fish Based Snack- A Review

Cibia George[1]* and C. N. Ravishankar[2]
[1] *Department of Food Science and Technology, KUFOS & Department of Food Technology, MES Mampad College, Malappuram*
[2] *ICAR-Central Institute of Fisheries Education, Mumbai*

Abstract

Extrusion Technology is one of the extremely versatile applications in food manufacturing industries, which yields a wide range of products of variable texture, size, taste, shape, nutritional status and flavor. The technology offers novel food products with high nutritional value, improved digestibility, long shelf life and wide acceptance among consumers with minimum undesirable effects like browning, production of off-flavors and inactivation of vitamins and essential amino acids. Starch from staple crops like rice, wheat, maize, potato and cassava are the raw materials for extruded products that get gelatinized during extrusion so that digestibility and food value is enhanced, the texture gets improved and expansion is maximized to get better products. Furthermore, nutritional deficiency of extruded products can be compensated by fortification with protein. Plant proteins from seeds of kidney bean, soybean etc. are mixed with cereal flour to enhance the nutritional profile of the snacks. Similarly, fish proteins containing amino acids of high biological value often find high application in these extruded products. This review highlights the major ingredients used for production of extruded products and their properties. It also emphasizes the changes in physical and chemical properties of fish-based snacks during extrusion process. The influence of extrusion on product characteristics and nutritional status too was investigated.

Keywords: Extrusion, nutritional changes, fish protein

Received 25 August 2022; Revised 13 October 2022; Accepted 24 October 2022

**Email: cibiageorge@gmail.com*

Introduction

Extrusion is an energy efficient, versatile processing method adopted by food industries employing high temperature and short-time (HTST) cooking to develop novel value-added products (Ackar et al., 2018; Gulati, 2016; Gu et al., 2019; Gu et al., 2020; Singh et al., 2016; Singkhornart et al., 2013; Stojceska et al., 2008a). During the process, starch-rich dough enriched with protein is extruded into various shapes (Chiruvella et al., 1996), resulting in a wide range of foods such as snacks, ready-to-eat cereals, pasta, textured vegetable protein, confectioneries and breakfast cereals (Singkhornart et al., 2013; Aluwi et al., 2016). High-temperature High-pressure extrusion is a method that can give gluten-free food an acceptable expanded crispy texture (Huber, 2000). Due to their high carbohydrate content, extruded snacks could be classified as energy food (Carvalho et al., 2012). Furthermore, to increase the calorific value, snacks are seasoned with oil or fat and salt (Capriles et al., 2009). The physical and chemical properties of the extrudates (Expansion ratio, density, water absorption and solubility) are influenced by the raw material, particle size of the flour, screw speed of the extruder, temperature of die and feed moisture.

Lipid components of feed play the role of lubricants and plasticizers by minimizing friction during the process and influencing stickiness, texture and other properties (Fasina et al., 2006; Ilo et al., 2000; Ilo et al., 2008; Steel et al., 2012). Extruded food products are commonly prepared with the help of twin screw extruders. Twin screw extruder has a higher production rate and better adaptability for handling various ingredients with a higher range of moisture content. It also has higher efficiency in mixing, self-wiping, fastness and uniform heat transfer to the ingredients as compared to single screw extruders (Ainsworth, 2011; Berk, 2009;

Gu 2017). Extrusion cooking parameters are classified as input (processes) dependent (system) and output (product) dependent system. Raw material quality, barrel temperature, feed rate, dimensions of die, screw speed and configuration are independent or input parameters. Back pressure, motor torque and specific mechanical energy are dependent characteristics. The quality of the product is determined by the starch content of the cereal and the sources of protein used (Gu, 2017).

Factors influencing extrusion

1. Specific Mechanical Energy

The amount of specific mechanical energy (SME) required to extrude the materials has an impact on the degree of starch breakdown, which depends on the flow rate, screw speed and torque (Fang et al., 2014; Filli et al., 2012; Godavarti & Karwe, 1997; Kowalski et al., 2015). When SME is high, higher degree of starch gelatinization takes place and SME decreases with higher temperature (Jafari et al., 2017). Increased SME was desired for expanded products (Meng et al., 2010; Hussain et al., 2017), which was in accordance with previous researchers (Baik, 2004; Masli et al., 2018b; Pardhi et al; 2019), who reported that with the increase in screw speed SME increases (Chevanan et al., 2010; Masli et al., 2018a; Mazlan et al., 2019). SME is related to the viscosity of the molten material that has a direct impact on resistance to work performed by screws on the feed material. Previous studies carried out suggest that high molecular weight linear polysaccharides such as amylose and fibers increased melt viscosity (Chaudhary et al., 2008; Zhu et al., 2010), which in turn is affected by the type of polymer used and its interactions with insoluble and soluble phenolic compounds found in plants such as Sorghum (Masli et al., 2018a).

In previous studies, it has been reported that an inverse relationship exists between particle size and SME values for barley (Al-Rabadiet al., 2011), corn (Carvalho et al., 2010) and Sorghum (Al-Rabadi et al., 2011). Contrastingly, lower SME values were found to be related with coarse fractions as shown in red genotypes and varieties of buck wheat (Vargas-Solórzano et al., 2014). Lowering of SME with rise in extrusion temperature was reported for rice flour amaranth product (Ilo et al., 1999) and chia-corn meal puffs. SME has been reported to be dropped with barrel temperature as the melt's lower viscosity reduced friction (Singh et al., 1998).

2. Feed moisture

Moisture is an important factor that affects expansion ratio, which is a desirable attribute during extrusion. On increasing moisture content from16 to 22%, the shear strength and expansion ratio reduced (Hagenimana et al., 2006). Significant decrease in expansion ratio for extrudates under high moisture condition has been well studied by Ye et al. (2018) and Kaisangsri et al. (2019).

3. Temperature

The effect of extrusion temperature on shrimp corn snack was studied. It was found that maximum expansion resulted at moderate temperature of 130ºC and low feed moisture of 17g/100g (Topuz et al., 2017).

Ingredients

Carbohydrate sources

1. Corn / Maize

Corn (*Zea mays*) is one of the principal grains used for cereal-based foods with its flour widely used in the manufacture of expanded snacks by extrusion cooking. Apart from attractive yellow colour, it has great expansion characteristics. Corn is the most suitable cereal for the production of extruded snacks due to its good expansion and texture properties (Estrada-Girón et al., 2015; Meng et al., 2010; Pérez-Navarrete et al., 2006). Expanded snacks from corn and bean flour with high anti-oxidant property (Felix-Medina, 2020), corn-based cheese flavoured snack with improved nutritive value etc. are examples for the acceptability. Corn has been shown to reduce the risk of chronic diseases such as type 2 diabetes, cardio vascular disease and obesity (Albertson et al; 2013).

2. Sorghum

Sorghum, the third major cereal crop in India can tolerate drought with minimum nutrient requirement. It also has high yield and hence low cost of production (Adebowale et. al., 2020). Consumption of Sorghum is advantageous as it reduces the risk of obesity and diabetes. It doesn't cause auto immune disorders, making it suitable for celiac disease patients. Recently, Sorghum has been emerged to be a commodity of diverse utility, with incorporation in value added food products, either as a whole or as ingredient (Rao et al., 2010;

Charyulu et al., 2013). These products include cookies, cakes, pasta and snack foods (Taylor et al., 2006). However, a major limitation of sorghum is the low solubility of its proteins and deficiency of essential amino acids like lysine (Chamla, 1984).

Protein solubility and functionality of Sorghum was found to be improved in ready-to-eat snack products developed by HTST extrusion cooking (Devi et al., 2013). Nutritious milk protein fortified sorghum-based snack was developed by Patel et al. (2016). Development of nutritious snack food from sorghum-soya composite were discussed by Anton et al. (2009); Vargas-Solorzano et al. (2014) with improved ammino acid profile and high protein efficiency ratio.With high gelatinization temperature, sorghum starch (SS) is in high demand as amedicinal or food component globally (Mukisa et. al., 2012; Sorour et al., 2019). Sorghum starch-based products like cakes, noodles etc. require a longer cooking time and hence higher thermal energy (Beta & Corke, 2001).

3. Barley

Incorporation of barley with beneficial dietary fibre like beta glucan has been incorporated into extruded products by Koa et al. (2017). Barley flour-based carrot pomace extruded snack with enhanced level of soluble dietary fibre was developed by Shirazi et al. (2020).

Protein sources for Enrichment

Extruded products are carbohydrate rich and are deficient in nutrients, which can be compensated by incorporation of protein. This improves nutritional status and the fortification enhances taste of the products with better consumer acceptance. Incorporation of low amount of soy protein increased the amino acid balance of the extrudates, whereas high percentage was not found to improve physical properties such as expansion (Kuna et al., 2013). Other proteins such as whey protein or legume protein have the potential to improve the nutritional and functional values of Sorghum-based products.

Fish proteins

Fish protein has substantially improved the nutritional quality and proved to be an optimal health food that is affordable to common population. Fish-based extruded products have more scope as fish meat and is a rich source of nutrients at low cost. Production of ready-to-eat extruded products such as snacks may be an alternative (Maluf et al., 2010) to improve human health by increasing consumption of fish products. Salt water fishes are good source of omega-3-fatty acids (Godoy et al., 2010; Lima et al., 2012). Though fresh water fish contain lesser amount of omega-3 fatty acids than marine fish, Tilapia is in high demand for human consumption. Justen et al. (2017) reported that the Tilapia meat contained plenty of various minerals and 23 fatty acids including the very important n-3 polyunsaturated fatty acid (PUFA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). As compared to proteins of plant origin, proteins from fish have high biological value, as amino acids such as cysteine and methionine are well balanced (Neves et al., 2004). Thus, fish supplemented snacks with good quality protein is important nutritionally (Justen et al., 2011). Incorporation of fish protein during extrusion cooking would help to rectify the nutritional deficiency. It would also provide a wide range of food products that is based on low-value or underutilized fish.The perishability problems associated with fish meat, especially that of low value fishes can be solved by their incorporation in extrusion products. This would also enable development of shelf-stable products at ambient temperature.

However, it was reported that incorporation of minced fish meat in carbohydrate-based snack foods may inhibit starch gelatinization, thereby reducing product expansion (Dehghan-Shoaret al., 2010). The addition of Tilapia, salmon, tuna and sardine was found to be effective in enhancing the nutritional value of extruded corn snacks. Salmon and tilapia meat-based snacks showed better sensory acceptance as compared to sardine and tuna snacks. However, protein enrichment by incorporation of protein-rich blanched dried fish powder was found to reduce expansion and increase hardness. But, the acceptability of the products declined as the concentration of fish meat content increased (Wianecki, 2007; Ganesan, 2017). On addition of fish mince at 10% level to corn starch, the physical parameters like expansion, color and shearing force were better for the extruded product developed using single screw extruder. Studies have also shown that fish-based extruded products have enhanced level of n-3 fatty acids (Goes et al., 2015), improved sensory properties (Jeyakumari et al., 2016), increased water absorption capacity and protein content (Parvathy et al., 2017), increased level of crude protein and minerals (Jesten et al., 2017) and enhanced dietary fibre level (Joshy et al., 2020).

Ready to eat high protein snack using corn flour and rice flour added with fish powder was developed by Deepika et al. (2021). The product had increased protein content and enhanced flavour due to incorporation of fish flour and shrimp head exudate. Extrusion of maize grits with fish flesh / fish protein can be utilised to provide fortified protein snacks for consumers and can thus enhance consumption of fish (Shaviklo et al., 2011a). The developed corn-based snack fortified with different levels of fish protein powder had better acceptability in terms of odour, texture and flavour.

Milk proteins

Milk proteins are known for their good digestibility (Hambraeus, 1992), therapeutic and nutritional value (Zimecki & Kruzel, 2007) and protein efficiency ratio (Walzem et al., 2002). These facts are taken into account while formulating a snack food with incorporated milk protein. It was also attempted to incorporate whey protein in extruded puffed products with adverse effect on textural properties of expanded products (Martinez-Serena & Villota, 1992; Onwulata et al., 1998; Onwulata & Konstance, 2006; Brncic et al., 2008). Matthey & Hanna (1997) reported that addition of more than 10% whey protein concentrate enhanced the colour parameter but decreased the expansion index. Zhang et al. (2019) reported that super critical fluid extrusion is advantageous for whey protein-based extruded snacks in minimizing browning due to protein carbohydrate interaction under standard conditions of high shear pressure and temperature. Milk based extruded snacks using concentrated Greek acid whey as a substitute for water was found to significantly improve the functional, sensory and nutritional properties of the product (Yoon & Rizvi, 2020).

Extrudate quality parameters

1. Bulk density

Bulk density is an important parameter in extrusion process. It is proven that with increase in moisture content, bulk density increases and resulted in extrudates denser than those produced with low water content (Koksel, 2004; Pardhi et al., 2019; Patil et al., 1990; Singh et al., 2019; Altaf et al., 2020). During extrusion, the elasticity of the dough may be reduced due to plasticization of the melt. With increased feed moisture content, SME reduced and led to less gelatinization, decreased expansion and increased density of extrudates (Ding et al., 2006; Singh et al., 2019). At high screw speed and temperature, with decreased residence time, complete gelatinization and lower bulk density was reported by previous researchers (Pardhi et al., 2019; Hussain et al., 2017). In a high shear environment, structural breakdown of proteins and starch also results in product with low density (Chinnaswamy & Hanna, 1988; Chavez et al., 2000; Ding et al., 2006; Lin et al., 2003; Wani & Kumar, 2016).

2. Expansion ratio

Expansion is an important characteristic that describes the textural property and sensory acceptability (Asare et al., 2012; Seth & Rajamanickam, 2012). Linko & Linko (1981) reported that with increase in the amount of starch, the rate of expansion of extruded product increased but with the incorporation of protein in the feed material, expansion volume decreased. Starch gets transformed into a viscoelastic material by gelatinization and melting under high temperature and pressure (Lai & Kokini, 1991; Ye et al., 2018). As the expanded starchy melt exit through the die, moisture evaporates leading to enlarged cell structure (Aluwi et al., 2016; Kowalski et al., 2015; Gu et al., 2017). The presence of fiber and fat caused a reduction in expansion as demonstrated by Pandiselvam et al. (2019). On increasing the amount of coconut milk residue in rice corn extrudates, Guy (1985) reported that increased proportion of fiber in the formulations with increased level of Sorghum flour presumably caused reduction in the expansion ratio.

Jeyakumari et al. (2016) studied the effect of incorporation of shrimp powder and protein hydrolysate on the properties of rice/corn flour based extruded snack and found that with increase in the amount of shrimp protein hydrolysate, expansion ratio decreased. Increase in bulk density anddecrease in expansion with increase in bran was reported in extrusion - cooked cassavastarch (Hashimoto & Grossmann 2003) and incorn starch based extrudates incorporated with various types of fruit pomaces containing soluble and insoluble fibers (Wang et al., 2019).

3. Water Absorption Index (WAI) and Water Solubility Index (WSI)

Water Absorption Index (WAI) quantifies the water absorbed by starch, which varies depending on the moisture and temperature (Ding et al., 2005). It is used as an index of gelatinization (Sharma et al., 2016). An increase in water absorption index was reported with increase in feed moisture and extrusion temperature for extrudates made of corn starch (Gomez & Aguilera, 1983), noodles made of potato starch (Parvathy et al., 2017) and sorghum flour based extrudates (Jafari et al., 2017).

During optimization of physical property, by adding different levels of fish mince and wheat flour to ready to cook fish incorporated noodles, it was found that as percentage of fish mince increased, water absorption index decreased. Protein content of extrudates increases with the increase of legume proportion. WAI depends on the presence of hydrophilic groups in the protein sources and the gelation capacity of macromolecules (Gomez & Aguilera, 1983). The protein denaturation during extrusion causes the legume protein to lose their hydration capacity even though they have hydrophilic groups.

The WSI generally increases in the presence of damaged or dextrinized starch molecules (Sharma et al., 2014). WSI increases when the temperature in the extruder increases (Ding et al., 2005; Hagenimana et al., 2006). Similar results can also be found, when starch based extrudates are manufactured with twin or single screw extruders (Chauhan & Bains, 1988; Ding et al., 2006; Gujska & Khan,1990; Kadan et al., 2003). Water Absorption Index (WAI) and Water Solubility Index (WSI) are negatively correlated (Balasubramanian et al., 2012a; Balasubramanian et al., 2012b).

Changes during extrusion

Extrusion technology offers distinct advantages over other heat treatments as the material is subjected to extreme mechanical shear, structural disruption and mixing resulting in breakage of covalent bonds in biopolymers, alteration of functional characteristics and/or texturization of food ingredients (Asp & Bjorck, 1989; Carvalho & Mitchelle, 2000). During extrusion process, many changes occur viz. starch gelatinization, protein denaturation, lipid modification, enzyme inactivation, elimination of microbes, formation of amylase-lipid complex and degradation of pigments (Martínez et al., 2013; Wang et al., 2013). In a twin-screw extruder, starch and protein are subjected to heat and shear under hydration and the dough is converted into a melt, which in turn influence the product properties (Guy, 2001). The 'melt' of the dough showed two distinct stages with growth phase depending on viscosity of the melt and the bubble structure depending on its elastic property due to radial expansion. The growth and radial expansion of dough during extrusion influence the texture of the extrudate (Banerjee & Chakraborty, 1998; Rolf et al., 2000; Arhaliass et al., 2003). However, full expansion of starch is hindered by proteins and lipids (Moraru & Kokini, 2003; Allen et al., 2007; Day & Swanson, 2013; Offiah et al., 2019).

Change in Carbohydrates

The major carbohydrate source is starch that chemically consists of linear amylose and branched amylopectin, the ratio of which determines the product quality. When high energy input is supplied during processing, changes in intermolecular bonding impacts rheological property like viscosity (Wen et al., 1990; Brümmer et al., 2002). Gelatinization also facilitates enzymatic digestion and results in more viscous and smooth texture of the extrudate during processing (Alcázar-Alay & Meireles, 2015). Under limited water utilization during extrusion processing, a wide variety of starch molecules with varied levels of gelatinization process such as damaged, swelled gelatinized, un-gelatinized starch, un-swelled gelatinized, and completely disrupted starch granules are reported to be present (Riaz & Aldrich, 2007). Moreover, being the majoring redient, starch promote expansion of extrusion products (Malik et al., 2016).

Another component is dietary fiber (both soluble and insoluble), which has effect on expansion properties. Uniformly distributed insoluble dietary fiber results in expansion by strengthening the starch matrix (Masli et al., 2018a; Wang et al., 2019). There are reports of lesser rate of expansion at higher level of fiber (Devi et al., 2012). Insoluble dietary fiber is found to hinder starch gelatinization by competing with starch for water (Yanniotis et al., 2007; Robin et al., 2012; Masli et al., 2018a) whereas addition of soluble dietary fibers may not change expansion or increase slightly (Brennan et al., 2008; Robin et al., 2012; Wang et al., 2019). Another change is amylose-lipid complex formation where in, due to lubricating effect beyond a critical limit, lipids coat the starch particles and reduce water absorption for gelatinization (Ilo et al., 2008).

Change in Proteins

Mechanical and chemical process of extrusion cooking leads to denaturation of protein structures and subsequent protein digestion enhancing the biological value (Patil, 2016). It has also been reported that protein reorganization takes place during extrusion leading to improved digestibility (Fang et al., 2019; Osen et al., 2015; Steel et al., 2012). Extrusion processing of chickpea and wheat blends has resulted in protein and starch digestibility with significant enhancement of antioxidant activity of the product (Yagci & Evci, 2015).

Change in Amino Acids

Carbohydrate based extruded snacks with poor biological value are fortified with protein containing lysine and other necessary amino acids to increase the nutritional value. Extruded products are found to contain reduced level of essential amino acids, as compared to the raw dough, prior to cooking. The reducing sugars produced during extrusion heating act on the free amine groups of lysine and other amino acids (Steel et al., 2012). A decrease in amino acid levels occurs during Maillard reaction. Moscicki et. al. (2013) observed that extrusion causes loss of glutelins, prolamins, albumins and globulins. Loss of amino acids could be due to variable factors such as low feed moisture, high process temperature, presence of other sugars etc. Singh et al. (2007) reported that in steam-based extrusion cooking,there was substantial reduction of Sulphur containing amino acids and lysine. Retention of lysine has been reported to be achieved by reducing die diameter, increasing screw speed and reduction in residence time.

Change in Vitamins

Extrusion cooking was found to affect the vitamin stability for which minimizing shear and temperature within the extruder has been found to be important. For example, beta-carotene loss during extrusion has been reported due to thermal degradation. Similarly, reduction of thiamine, riboflavin, ascorbic acid etc. are also reported during extrusion process (Guzman-Tello & Cheftel, 1990). Athar et al. (2006) reported that extrudates had higher retention rate of B vitamins in short barrel extruder (90cm) compared to long barrel extruders. It was also shown that extrusion cooking at high temperatures and for short periods of time affects the stability of fat-soluble vitamins including vitamin A and E. An increase in processing temperature has resulted in decreased ascorbic acid level in concentrated citrus juice as reported by Brennan et al. (2011). The enhanced extrusion temperature has caused significant loss of vitamin C and beta carotene in carrot pomace-based products.

Change in PUFA

Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), the polyunsaturated fatty acids (PUFA) of omega -3 family, are reported to have immense health benefits such as prevention of coronary artery disease, improvement of retina and brain development, decreased incidence of diseases such as breast cancer, multiple sclerosis, rheumatoid arthritis, psoriasis and inflammation (Özoðul & Özoðul,2007). Topuz et al. (2017) reported development of extruded shrimp-corn snack. It was observed that higher proportion ofomega-3 contentwas found at lower temperature (110ºc), moderate moisture (20g/100g) and low screwspeed (200rpm)whereas high temperature (150ºc), moderate moisture (20g/100g) and high screw speed (500rpm) resulted in low omega 3 content.

Change in colour and flavour

Change in colour during extrusion cooking indicate degradation of pigments and provide valuable information on the extent of browning as well as Maillard reaction. In addition to Maillard reactions, caramelization, dextrinization and pigment degradation also result in development of color in extruded products (Steel et al., 2012). Due to high temperature and shearing force, starch is subjected to dextrinization and break down into dextrin. This is due to amylopectin debranching, which result in colour change of extrudates from yellow to brown. During storage, extruded foods gradually fade color and it was reported that certain colors faded at high temperatures over extended periods (Kinnison, 1974). When foods are heated, colored compounds develop due to Maillard reaction but the colour remain uncharacterized (Ames, 1992). Netto et al. (2014) developed tilapia mince incorporated Snack and noticed that addition of fish mince at 20% and 30% level scored better for color during sensory evaluation. Justen et al. (2017) studied that fish flavoured with 5% lipid decreased brightness as snacks turned dark. With higher levels of fish flour incorporation, extrusion took longer (Badrie & Mellowes, 1991) and consequently darkening increased due to Maillard reactions. Joshy et al. (2020) studied the effect of addition of wheat and oats dietary fiber on colour parameters offish sausage and was found to increase with increasing levels of fish mince, whereas lightness increased with the addition of wheat fiber to the sausage. While developing corn-based tuna meat corn extrudates, a decrease in colour values (L^*,a^*,b^*) was reported due to Maillard reaction with the extrudates exhibiting color similar to corn starch (Fang et al., 2019). The most common method for the addition of color, flavor and additives is by enrobing or surface coating to extruded products where the enrober with horizontally mounted, axially rotating cylindrical drum is inclined slightly and the product tumbles down (Harper, 1981).

Conclusion

Extrusion technology is a popular technique utilized for developing ready to eat snack, which is being influenced by selection of raw materials and application of extrusion process variables like temperature, screw speed and moisture. This review emphasized on major physical characteristics of products like expansion ratio, bulk density, hardness, color, nutritional changes and functional properties that influence palatability and protein enhancement. Study also revealed the scope for utilizing minor cereals like sorghum and fish for novel products.The consumer acceptance data revealed that overall acceptability was improved with the addition of protein sources.

References

Aèkar, Đ., Jozinoviæ, A., Babiæ, J., Milièeviæ, B., Balentiæ, J.P. and Šubariæ, D. (2018) Resolving the problem of poor expansion in corn extrudates enriched with food industry by-products. Innov Food Sci Emerg Technol. 47: 517-524

Adebowale, O.J., Taylor, J.R. and de Kock, H.L. (2020) Stabilization of wholegrain sorghum flour and consequent potential improvement of food product sensory quality by microwave treatment of the kernels. LWT. 132: 109827

Adem, M., Sadik, J. A., Worku, A. and Neela, S. (2019) Optimization of lupine (Lupinusalbus L.) composition, feed moisture content and barrel temperatures for best quality maize based extruded snack food. Food Nutr Sci 50(5): 853-869

Ainsworth, P. (2011) Extrusion. Food processing handbook: 429-453

Albertson, A.M., Franko, D.L., Thompson, D.R., Tuttle, C. and Holschuh, N.M. (2013) Ready-to-eat cereal intake is associated with an improved nutrient intake profile among food insecure children in the United States. J Hunger Environ Nutr. 8(2): 200-220

Alcázar-Alay, S.C. and Meireles, M.A.A. (2015) Physicochemical properties, modifications and applications of starches from different botanical sources. Food Sci. Technol. 35: 215-236

Allen, K.E., Carpenter, C.E. and Walsh, M.K. (2007) Influence of protein level and starch type on an extrusion expanded whey product. Int. J. Food Sci. 42(8): 953-960

Al-Rabadi, G.J., Torley, P.J., Williams, B.A., Bryden, W.L. and Gidley, M.J. (2011) Particle size of milled barley and sorghum and physico-chemical properties of grain following extrusion. J. Food Eng. 103(4): 464-472

Altaf, U., Hussain, S.Z., Qadri, T., Ishrat, S.A. and Kanojia, V. (2020) Optimization of extrusion process for development of nutritious snacks using rice and chickpea flour. J Sci Ind Res. (JSIR), 79(05): 430-436

Aluwi, N.A., Gu, B.J., Dhumal, G.S., Medina Meza, I.G., Murphy, K.M. and Ganjyal, G.M. (2016) Impacts of scarification and degermination on the expansion characteristics of select quinoa varieties during extrusion processing. J. Food Sci. 81(12): E2939-E2949

Ames, J.M. (1992) The Maillard Reaction. Di dalam: Hudson, BJF (ed.). J. Food Biochem: 99-153

Anton, A.A., Fulcher, R.G. and Arntfield, S.D. (2009) Physical and nutritional impact of fortification of corn starch-based extruded snacks with common bean (Phaseolus vulgaris L.) flour: Effects of bean addition and extrusion cooking. Food chem. 113(4): 989-996

Arhaliass, A., Bouvier, J.M. and Legrand, J. (2003) Melt growth and shrinkage at the exit of the die in the extrusion-cooking process J.Food Eng. 60(2): 185-19

Asare, E.K., SEFA DEDEH, SAMUEL., Afoakwa, E.O., SAKYI DAWSON, ESTHER. and Budu, A.S. (2012) Extrusion cooking of rice groundnut cowpea mixtures–effects of extruder characteristics on nutritive value and physico functional properties of extrudates using response surface methodology. J. Food Process. Preserv., 36(5): 465-476

Asp, N.G. and Björck, I. (1989) Nutritional properties of extruded foods. Extrusion cooking: 399-434

Athar, N., Hardacre, A., Taylor, G., Clark, S., Harding, R. and McLaughlin, J. (2006) Vitamin retention in extruded food products, J Food Compost Anal. 19(4): 379-383

Badrie, N. and Mellowes, W.A. (1991) Effect of extrusion variables on cassava extrudates. J. Food Sci. 56: 1334–1337

Baik, B.K., Powers, J. and Nguyen, L.T. (2004) Extrusion of regular and waxy barley flours for production of expanded cereals. Cereal Chem. 81(1): 94-99

Balasubramanian, S., Borah, A., Singh, K.K. and Patil, R.T. (2012a) Effect of selected dehulled legume incorporation on functional and nutritional properties of protein enriched sorghum and wheat extrudates. J. Food Sci. Technol. 49(5): 572-579

Balasubramanian, S., Singh, K.K., Patil, R.T. and Onkar, K.K. (2012b) Quality evaluation of millet-soy blended extrudates formulated through linear programming. J. Food Sci. 49(4): 450-458

Banerjee, S. and Chakraborty, P. (1998) Physico- chemical properties of extruded aquatic feed. Indian J. Fish, 45: 107-111

Berk, Z. (2009) Extrusion. In Food Process Engineering and Technology, Chapter 15: 333–350. Academic Press, San Diego

Beta, T. and Corke, H. (2001) Noodle quality as related to sorghum starch properties. Cereal Chem. 78(4): 417-420

Brennan, C., Brennan, M., Derbyshire, E. and Tiwari, B.K. (2011) Effects of extrusion on the polyphenols, vitamins and antioxidant activity of foods. Trends Food Sci. Technol. 22(10): 570-575

Brennan, M.A., Monro, J.A. and Brennan, C.S. (2008) Effect of inclusion of soluble and insoluble fibres into extruded breakfast cereal products made with reverse screw configuration. Int. J. Food Sci. 43(12): 2278-2288

Brnèiæ, M., Karloviæ, S., Bosiljkov, T., Tripalo, B., Jezek, D., Cugelj, I. and Obradoviæ, V. (2008). Enrichment of extruded snack products with whey protein. Mljekarstvo: èasopis za unaprjeðenjeproizvodnjeiprerademlijeka. 58(3): 275-295

Brümmer, T., Meuser, F., van Lengerich, B. and Niemann, C. (2002) Expansion and functional properties of corn starch extrudates related to their molecular degradation, product temperature and water content. Starke. 54(1): 9-15

Capriles, V.D., Soares, R.A., Pinto e Silva, M.E. and Arêas, J.A. (2009) Effect of fructans based fat replacer on chemical composition, starch digestibility and sensory acceptability of corn snacks. Int. J. Food Sci. 44(10): 1895-1901

Carvalho, A.V., Bassinello, P.Z., Mattietto, R.D.A., Carvalho, R.N., Rios, A.D.O. and Seccadio, L.L. (2012) Processamento e caracterização de snack extrudado a partir de farinhas de quirera de arroz e de bandinha de feijão. Braz. J. Food Technol. Campinas, SP. vol. 15, n. 1(jan./mar. 2012): p. 72-83

Carvalho, C.W. and Mitchell, J.R. (2000) Effect of sugar on the extrusion of maize grits and wheat flour. J. Food Eng. 35(6): 569-576

Carvalho, C.W., Takeiti, C.Y., Onwulata, C. I. and Pordesimo, L. O. (2010) Relative effect of particle size on the physical properties of corn meal extrudates: Effect of particle size on the extrusion of corn meal.J. Food Eng. 98(1): 103-109

Chamla, M.C and Lasztity, R. (1984) The Chemistry of cereal proteins. Bulletins and Memoirs of the Anthropological Society of Paris. 1 (4): 354-354. ABS

Charyulu, D.K., Bantilan, M.C.S. and Rajalaxmi, A. (2013) Development and diffusion of sorghum improved cultivars in India: impact on growth and variability in yield (No. 424-2016-27134)

Chaudhary, A.L., Miler, M., Torley, P.J., Sopade, P.A. and Halley, P.J. (2008) Amylose content and chemical modification effects on the extrusion of thermoplastic starch from maize. Carbohydr. Polym. 74(4): 907-913

Chauhan, G.S. and Bains, G.S. (1988) Effect of some extruder variables on physico-chemical properties of extruded rice—Legume blends. Food Chem. 27(3): 213-224

Chávez Jáuregui, R.N., Silva, M.E.M.P.andArìas, J.A.G. (2000) Extrusion cooking process for amaranth (Amaranthus caudatus L.). J. Food Sci. 65(6): 1009-1015

Chevanan, N., Rosentrater, K.A. and Muthukumarappan, K. (2010) Effects of processing conditions on single screw extrusion of feed ingredients containing DDGS. Food Bioproc Tech. 3(1): 111-120

Chinnaswamy, R., and Hanna, M.A. (1988) Optimum extrusion cooking conditions for maximum expansion of corn starch. J. Food Sci 53(3): 834-836

Chiruvella, R.V., Jaluria, Y. and Karwe, M.V. (1996) Numerical simulation of the extrusion process for food materials in a single-screw extruder. J. Food Eng. 30(3-4): 449-467

Day, L. and Swanson, B.G. (2013). Functionality of protein fortified extrudates. Compr. Rev. Food Sci. Food Saf. 12(5): 546-564

Deepika, B., Dhanapal, K., Madhavan, N., Madhavi, K., Kumar, G.P. and Manikandan, V. (2021) Development of an extruded snack product containing fish flour and shrimp head exudate by ingredient optimization and its quality analysis. Indian J Anim Res 60(2): 213-221

Dehghan-Shoar, Z., Hardacre, A.K. and Brennan, C.S. (2010) The physico-chemical characteristics of extruded snacks enriched with tomato lycopene. Food Chem. 123(4): 1117-1122

Devi, N.L., Shobha, S., Tang, X., Shaur, S.A., Dogan, H. and Alavi, S. (2013) Development of protein-rich sorghum-based expanded snacks using extrusion technology. Int. J. Food Prop. 16(2): 263-276

Ding, Q.B., Ainsworth, P., Plunkett, A., Tucker, G. and Marson, H. (2006) The effect of extrusion conditions on the functional and physical properties of wheat-based expanded snacks. J. Food Eng. 73(2): 142-148

Ding, Q.B., Ainsworth, P., Tucker, G.and Marson, H. (2005). The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. J. Food Eng., 66(3): 283-289

Estrada-Girón, Y., Martínez-Preciado, A.H., Michel, C.R. and Soltero, J.F.A. (2015) Characterization of extruded blends of corn and beans (Phaseolus vulgaris) cultivars: Peruano and black-querétaro under different extrusion conditions. Int. J. Food Prop. 18(12): 2638-2651

Fang, Y., Ji, J., Zhang, J., Liu, S., Liu, J. and Ding, Y. (2019). Effect of extrusion cooking on physicochemical properties of tuna meat-based extrudates. Food Sci. Technol. 39: 627-634

Fang, Y., Zhang, B. and Wei, Y. (2014) Effects of the specific mechanical energy on the physicochemical properties of texturized soy protein during high-moisture extrusion cooking., J.Food Eng. 121: 32-38

Fasina, O.O., Hallman, H., Craig-Schmidt, M. and Clements, C. (2006) Predicting temperature-dependence viscosity of vegetable oils from fatty acid composition. J.Am.OilChem.' Soc. 83(10): 899-903

Félix-Medina, J.V., Montes-Ávila, J., Reyes-Moreno, C., Perales-Sánchez, J.X.K., Gómez-Favela, M.A., Aguilar-Palazuelos, E. and Gutiérrez-Dorado, R. (2020) Second-generation snacks with high nutritional and antioxidant value produced by an optimized extrusion process from corn/common bean flours mixtures. LWT Food Sci. Technol. 124: 109172

Filli, K.B., Nkama, I., Jideani, V.A. and Ibok, I.U. (2012) System parameters and product properties responses during extrusion of fura from millet-soybean mixtures. Niger. Food J. 30(1): 82-100

Ganesan, P., Rathnakumar, K., Nicy, B.A. and Vijayarahavan, V. (2017)Improvement of nutritional value of extruded snack product by incorporation of blanched dried fish powder from sardine and Lizard fish and selection by organoleptic evaluation. J. Entomol. Zool. Stud. 5(6): 2552-2554

Godavarti, S. and Karwe, M.V. (1997) Determination of specific mechanical energy distribution on a twin-screw extruder. J. Agric. Eng. Res. 67(4): 277-287

Godoy, L.C.D., Franco, M.L.R.D.S., Franco, N.D.P., Silva, A.F.D., Assis, M.F.D., Souza, N.E.D. and Visentainer, J.V. (2010) Análise sensorial de caldos e canjaselaborados com farinha de carcaças de peixedefumadas: aplicaçãona merenda escolar. Food Sci. Technol. 30: 86-89

Goes, E.S.D.R., SOUZA, M.L.R.D., Campelo, D.A.V., Yoshida, G.M., Xavier, T.O., MOURA, L.B.D. and Monteiro, A.R.G. (2015) Extruded snacks with the addition of different fish meals. Food Sci. Technol. 35: 683-689

Gomez, M.H. and Aguilera, J.M. (1983) Changes in the starch fraction during extrusion cooking of corn. J. Food Sci. 48(2): 378-381

Gu, B.J., Kowalski, R.J. and Ganjyal, G.M. (2017) Food extrusion processing: An overview

Gu, B.J., Wolcott, M.P. and Ganjyal, G.M. (2020) Optimized screw profile design proved to inhibit re-agglomeration that occurs during extrusion of fine-milled forest residuals for producing fermentable sugars. Ind Crops Prod. 154: 112730

GUJSKA, E. and Khan, K. (1990) Effect of temperature on properties of extrudates from high starch fractions of navy, pinto and garbanzo beans. J. Food Sci. 55(2): 466-469

Gulati, P., Weier, S.A., Santra, D., Subbiah, J. and Rose, D.J. (2016) Effects of feed moisture and extruder screw speed and temperature on physical characteristics and antioxidant activity of extruded proso millet (Panicum miliaceum) flour. Int. J. Food Sci. 51(1): 114-122

Guy, R. (2001)Extrusion Technology; Technologies and Applications: 75-89

Guy, R.C.E. (1985) Extrusion revolution. Food manufacture: 60, 26

Guzman-Tello, R. andCheftel, J.C. (1990) Colour loss during extrusion cooking of beta carotene-wheat flour mixes as an indicator of the intensity of thermal and oxidative processing, Int. J. Food Sci. 25: 420–434

Hagenimana, A., Ding, X. and Fang, T. (2006) Evaluation of rice flour modified by extrusion cooking. Cereal Chem., 43(1): 38-46

Hambraeus, L. (1992) Nutritional aspects of milk proteins. Fox, PF, Ed. Advanced dairy chemistry-1: Proteins

Harper, J.M. (1981) Extrusion of Foods.vol. 2 CRC Press. Boca Raton, FL

Hashimoto, J.M. and Grossmann, M.V.E. (2003) Effects of extrusion conditions on quality of cassava bran/ cassava starch extrudates. Int. J. Food Sci. 38(5): 511-517

Huber, G.R. (2000) Twin-screw extruders. Extruders in food applications: 81-114

Hussain, S.Z., Afshana, B. and Amin, T. (2017) Utilization of broken rice and walnut kernels for development of nutritious snacks using extrusion technology. Pharma Innov J.6(10): 91-101

Ilo, S., Liu, Y. and Berghofer, E. (1999) Extrusion cooking of rice flour and amaranth blends. LWT. 32(2): 79-88

Ilo, S., Schoenlechner, R. and Berghofe, E. (2000) Role of lipids in the extrusion cooking processes. GrasasAceites 51(1-2): 97-110

Jafari, M., Koocheki, A. and Milani, E. (2017) Effect of extrusion cooking on chemical structure, morphology, crystallinity and thermal properties of sorghum flour extrudates. Cereal Chem., 75: 324-331

Jeyakumari, A., Rahul Das, M.S., Bindu, J., Joshy, C.G. and Zynudheen, A.A. (2016) Optimisation and comparative study on the addition of shrimp protein hydrolysate and shrimp powder on physicochemical properties of extruded snack. Int. J. Food Sci. 51(7): 1578-1585

Joshy, C.G., Aswathy, K.S., Zynudheen, A.A., Greeshma, S.S., Ninan, G. and Ravishankar, C.N. (2020) Development of dietary fibre incorporated tuna sausage employing response surface methodology and quality evaluation during chilled storage using multivariate control charts. Indian J. Fish. 67(3): 89-98, 2020

Justen, A.P., Franco, M.L.R.S., Monteiro, A.R.G., Mikcha, J.M.G., Gasparino, E. and Delbem, A. B. (2011) Inclusión de harina de pescadoen snacks INFOPESCA Int. 47(3): 35-38

Justen, A.P., Souza, M.L.R.D., Monteiro, A.R., Mikcha, J.M., Gasparino, E., Delbem, Á.B. and Del Vesco, A.P. (2017) Preparation of extruded snacks with flavored flour obtained from the carcasses of Nile tilapia: physicochemical, sensory, and microbiological analysis., J. Aquat. Food Prod. Technol. 26(3): 258-266

Kadan, R.S., Bryant, R.J. and Pepperman, A.B. (2003) Functional properties of extruded rice flours. J. Food Sci. 68(5): 1669-1672

Kaisangsri, N., Kowalski, R.J., Kerdchoechuen, O., Laohakunjit, N. and Ganjyal, G.M. (2019) Cellulose fiber enhances the physical characteristics of extruded biodegradable cassava starch foams. Ind Crops Prod. 142: 111810

Kayacier, A., Yüksel, F. and Karaman, S. (2014) Simplex lattice mixture design approach on physicochemical and sensory properties of wheat chips enriched with different legume flours: An optimization study based on sensory properties. LWT— Food Sci. Technol.58(2): 639-648

Kinnison, J.W. (1974) Color additives—current status. J. Cereal Sci.

Koa, S.S., Jin, X., Zhang, J. and Sopade, P.A. (2017). Extrusion of a model sorghum-barley blend: Starch digestibility and associated properties. J. Cereal Sci. 75: 314-323

Köksel, H., Ryu, G.H., Basman, A., Demiralp, H. and Ng, P.K. (2004). Effects of extrusion variables on the properties of waxy hulless barley extrudates. Food/ Nahrung, 48(1): 19-24

Kowalski, R.J., Morris, C.F. and Ganjyal, G.M. (2015) Waxy soft white wheat: extrusion characteristics and thermal and rheological properties. Cereal Chem. 92(2): 145-153

Kuna, A., Devi, N.L. and Kalpana, K. (2013) Utilization of fish powder in ready-to-eat extruded snacks. Fishery Technol. 50(3)

Lai, L.S. and Kokini, J.L. (1991) Physicochemical changes and rheological properties of starch during extrusion (a review). Biotechnol. Prog 7(3): 251-266

Lima, M.D.M., Mujica, P.I.C. and Lima, A.M. (2012) Caracterizaçãoquímica e avaliação do rendimentoemfilés de caranha (Piaractusmesopotamicus). Braz. J. Food Technol. 15: 41-46

Lin, Y.H., Yeh, C.S. and Lu, S. (2003) Extrusion Processing of Rice Based Breakfast Cereals Enhanced with Tocopherol from a Chinese Medical Plant. Cereal Chem. 80(4): 491-494

Linko, P. and Linko, Y.Y. (1981) Bioconversion processes. Cereals: a renewable resource: theory and practice: 339-494

Shirazi, L.S., Koocheki, A., Milani, E. and Mohebbi, M. (2020) Production of high fiber ready-to-eat expanded snack from barley flour and carrot pomace using extrusion cooking technology. J. Food Sci. Technol. 57(6): 2169-2181

Malik, H., Nayik, G.A. and Dar, B.N. (2016) Optimization of process for development of nutritionally enriched multigrain bread. Int. J. Food Process. Technol. 7(01): 1

Maluf, M.L.F., Weirich, C.E., Dallagnol, J.M., Simões, M.R., Feiden, A. and Boscolo, W.R. (2010). Elaboração de massa fresca de macarrãoenriquecida com pescadodefumado. Rev Inst Adolfo Lutz (Impresso). 69(1): 84-90

Martínez, M., Oliete, B. and Gómez, M. (2013) Effect of the addition of extruded wheat flours on dough rheology and bread quality.J. Cereal Sci. 57(3): 424-429

Martinez-Serna, M.D. and Villota, R. (1992) Reactivity, functionality, and extrusion performance of native and chemically modified whey proteins. Food extrusion science and technology: 387-414

Masli, M.D.P., Gu, B.J., Rasco, B.A. and Ganjyal, G.M. (2018a) Fiber rich food processing byproducts enhance the expansion of cornstarchextrudates. J. Food Sci. 83(10): 2500-2510

Masli, M.D.P., Rasco, B.A. and Ganjyal, G.M. (2018b) Composition and physicochemical characterization of fiber rich food processing byproducts. J. Food Sci. 83(4): 956-965.

Matthey, F.P. and Hanna, M.A. (1997) Physical and functional properties of twin-screw extruded whey protein concentrate–corn starch blends. LWT- Food Sci. Technol. 30(4): 359-366

Meng, X., Threinen, D., Hansen, M. and Driedger, D. (2010) Effects of extrusion conditions on system parameters and physical properties of a chickpea flour-based snack. Int. Food Res. J. 43(2): 650-658

Mohamad Mazlan, M., Talib, R.A., Mail, N.F., Taip, F.S., Chin, N.L., Sulaiman, R. and Mohd Nor, M. Z. (2019) Effects of extrusion variables on corn-mango peel extrudates properties, torque and moisture loss.Int. J. Food Prop. 22(1): 54-70

Moraru, C.I. and Kokini, J.L. (2003) Nucleation and expansion during extrusion and microwave heating of cereal foods. Compr. Rev. Food Sci. Food Saf. 2(4): 147-165

Moœcicki, L. and van Zuilichem, D.J. (2011) Extrusion-cooking and related technique. Extrusion-cooking techniques, Theory Appl. Categories: 1-24

Mukisa, I.M., Muyanja, C.M., Byaruhanga, Y.B., Schüller, R.B., Langsrud, T. and Narvhus, J.A. (2012) Gamma irradiation of sorghum flour: Effects on microbial inactivation, amylase activity, fermentability, viscosity and starch granule structure. Radiat. Phys. Chem. 81(3): 345-351

Netto, J.D.P.C., Oliveira Filho, P.R.C.D., Lapa-Guimarães, J. and Viegas, E.M.M. (2014) Physicochemical and sensory characteristics of snack made with minced Nile tilapia. Food Sci. Technol. 34(3): 591-596

Neves, R.A.M., De Mira, N.V.M. and Marquez, U.M. (2004) Caracterização de hidrolisadosenzimáticos de pescado. Food Sci. Technol. 24(1): 101-108

Offiah, V., Kontogiorgos, V. and Falade, K.O. (2019) Extrusion processing of raw food materials and by-products: A review. Crit. Rev. Food Sci. Nutr. 59(18): 2979-2998

Onwulata, C.I. and Konstance, R.P. (2006) Extruded corn meal and whey protein concentrate: Effect of particle size. J. Food Process. Preserv. 30(4): 475-487

Onwulata, C.I., Konstance, R.P., Smith, P.W. and Holsinger, V.H. (1998) Physical properties of extruded products as affected by cheese whey J. Food Sci. 63(5): 814-818

Osen, R., Toelstede, S., Eisner, P. and Schweiggert Weisz, U. (2015) Effect of high moisture extrusion cooking on protein–protein interactions of pea (Pisum sativum L.) protein isolates. Int. J. Food Sci. 50(6): 1390-1396

Özogul, Y. and Özogul, F. (2007) Fatty acid profiles of commercially important fish species from the Mediterranean, Aegean and Black Seas. Food Chem. 100(4): 1634-1638

Pandiselvam, R., Manikantan, M.R., Sunoj, S., Sreejith, S. and Beegum, S. (2019)Modeling of coconut milk residue incorporated rice corn extrudates properties using multiple linear regression and artificial neural network. J. Food Process Eng. 42(2): e12981

Pardhi, S.D., Singh, B., Nayik, G.A. and Dar, B.N. (2019) Evaluation of functional properties of extruded snacks developed from brown rice grits by using response surface methodology. J. Saudi Soc. Agric. Sci. 18(1): 7-16

Parvathy, U., Bindu, J. and Joshy, C.G. (2017) Development and optimization of fish fortified instant noodles using response surface methodology. Int. J. Food Sci. 52(3): 608-616

Patil, H., Tiwari, R.V. and Repka, M.A. (2016) Hot-melt extrusion: from theory to application in pharmaceutical formulation. AAPS PharmSciTech17(1): 20-42

Patil, R.T., Singh, D.S. and Tribelhorn, R.E. (1990) Effect of processing conditions on extrusion cooking of soy-rice blend with a dry extrusion cooker. J. Food Sci. Technol. 27(6): 376-378

Pérez-Navarrete, C., Cruz-Estrada, R.H., Chel-Guerrero, L. and Betancur-Ancona, D. (2006) Caracterizaciónfísica de extrudidospreparados con mezclas de harinas de maíz QPM (Zea mays L.) y fríjol lima (Phaseolus lunatus L.). Rev. Mex. Ing. Quim. 5(2): 145-155

Rao, P.P., Basavaraj, G., Ahmed, W. and Bhagavatula, S. (2010) An analysis of availability and utilization of sorghum grain in India. SAT e Journal, 8

Riaz, M.N. and Aldrich, G. (2007). Extruders and expanders in pet food, aquatic and livestock feeds. Agrimedia

Robin, F., Schuchmann, H.P. and Palzer, S. (2012) Dietary fiber in extruded cereals: Limitations and opportunities. Trends Food Sci. Technol. 28(1): 23-32

Rolfe, L. A., Huff, H. E. and Hsieh, F. (2000) The effect of processing conditions on the quality of extruded catfish feed. Trans ASABE43(6), 1737-1743

Seth, D. and Rajamanickam, G. (2012) Development of extruded snacks using soy, sorghum, millet and rice blend–A response surface methodology approach. Int. J. Food Sci. 47(7): 1526-1531

Sharma, P. and Gujral, H.S. (2014) Cookie making behavior of wheat–barley flour blends and effects on antioxidant properties. LWT- Food Sci. Technol. 55(1): 301-307

Sharma, S.K., Bansal, S., Mangal, M., Dixit, A.K., Gupta, R.K. and Mangal, A.K. (2016)Utilization of food processing by-products as dietary, functional, and novel fiber: a review. Crit. Rev. Food Sci. Nutr. 56(10): 1647-1661

Shaviklo, G.R., Olafsdottir, A., Sveinsdottir, K., Thorkelsson, G., & Rafipour, F. (2011a) Quality characteristics and consumer acceptance of a high fish protein puffed corn-fish snack. J. Food Sci. Technol. 48(6): 668-676

Shaviklo, G.R., Thorkelsson, G., Rafipour, F. and Sigurgisladottir, S. (2011b) Quality and storage stability of extruded puffed corn fish snacks during 6 month storage at ambient temperature. J. Sci. Food Agric. 91(5): 886-893

Singh, N., Smith, A.C. and Frame, N.D. (1998) Effect of process variables and monoglycerides on extrusion of maize grits using two sizes of extruder. J. Food Eng. 35(1): 91-109

Singh, B., Sekhon, K.S. and Singh, N. (2007) Effects of moisture, temperature and level of pea grits on extrusion behaviour and product characteristics of rice. Food Chem. 100(1): 198-202

Singh, J.P., Kaur, A., Shevkani, K., Singh, N. and Singh, B. (2016) Physicochemical characterisation of corn extrudates prepared with varying levels of beetroot (Beta vulgaris) at different extrusion temperatures. Int. J. Food Sci. 51(4): 911-919

Singh, J.P., Kaur, A., Singh, B., Singh, N. and Singh, B. (2019) Physicochemical evaluation of corn extrudates containing varying buckwheat flour levels prepared at various extrusion temperatures.J. Food Sci. Technol. 56(4): 2205-2212

Singkhornart, S., Gu, B.J. and Ryu, G.H. (2013) Physicochemical properties of extruded germinated wheat and barley as modified by CO 2 injection and difference extrusion conditions. Int. J. Food Sci. 48(2): 290-299

Sorour, M.A., Mehanni, A.E., Taha, E.M. and Rashwan, A. K. (2019) Characteristics of isolated starch granules of two sorghum varieties. SVU- Int. J. Agric. Sci. 1(1): 56-69

Steel, C.J., Leoro, M.G.V., Schmiele, M., Ferreira, R.E. and Chang, Y.K. (2012) Thermoplastic extrusion in food processing. Thermoplastic elastomers, 265

Stojceska, V., Ainsworth, P., Plunkett, A., Ýbanoðlu, E. and Ýbanoðlu, Þ. (2008a) Cauliflower by-products as a new source of dietary fibre, antioxidants and proteins in cereal based ready-to-eat expanded snacks. J. Food Eng. 87(4): 554-563

Taylor, J.R., Schober, T.J. and Bean, S.R. (2006) Novel food and non-food use for sorghum and millets. J. Cereal Sci. 44(3): 252-271

Topuz, O.K., Gokoðlu, N., Jouppila, K. and Kirjoranta, S. (2017) Development of extruded shrimp-corn snack using response surface methodology. Turkish J. Fish.17(2): 333-343

Vargas-Solórzano, J. W., Carvalho, C. W. P., Takeiti, C. Y., Ascheri, J. L. R., & Queiroz, V. A. V. (2014) Physicochemical properties of expanded extrudates from colored sorghum genotypes. Int. Food Res. J. 55: 37-44

Walzem, R.L., Dillard, C.J. and German, J.B. (2002) Whey components: millennia of evolution create functionalities for mammalian nutrition: what we know and what we may be overlooking. Crit. Rev. Food Sci. Nutr.42(4): 353-375

Wang, S., Gu, B.J. and Ganjyal, G.M. (2019) Impacts of the inclusion of various fruit pomace types on the expansion of corn starch extrudates. Lwt. 110: 223-230

Wang, Y.Y., Norajit, K., Kim, M.H., Kim, Y.H. and Ryu, G.H. (2013) Influence of extrusion condition and hemp addition on wheat dough and bread properties. Food Sci. Biotechnol. 22(1): 89-97

Wani, S.A. and Kumar, P. (2016) Fenugreek enriched extruded product: optimization of ingredients using response surface methodology. Int. Food Res. J. 23(1): 18

Wen, L.F., Rodis, P. and Wasserman, B.P. (1990) Starch fragmentation and protein insolubilization during twin-screw extrusion of corn meal. Cereal Chem. (USA)

Wianecki, M. (2007) Evaluation of fish and squid meat applicability for snack food manufacture by indirect extrusion cooking. Acta Scientiarum Polonorum Technologia Alimentaria, 6(4): 29-44.

Yaðcý, S. and Evci, T. (2015) Effect of instant controlled pressure drop process on some physicochemical and nutritional properties of snacks produced from chickpea and wheat. Int. J. Food Sci. 50(8): 1901-1910

Yanniotis, S., Petraki, A.andSoumpasi, E. (2007) Effect of pectin and wheat fibers on quality attributes of extruded cornstarch. J. Food Eng. 80(2): 594-599

Ye, J., Hu, X., Luo, S., Liu, W., Chen, J., Zeng, Z., Liu, C. (2018) Properties of starch after extrusion: a review. Stark, 70(11-12): 1700110

Yoon, A. K., & Rizvi, S. S. (2020) Functional, textural, and sensory properties of milk protein concentrate-based supercritical fluid extrudates made with acid whey. Int. J. Food Prop. 23(1): 708-721

Zhang, Y., Zhang, Y., Li, B., Wang, X., Xu, F., Zhu, K. and Li, S. (2019) In vitro hydrolysis and estimated glycemic index of jackfruit seed starch prepared by improved extrusion cooking technology. Int. J. Biol. Macromol. 121: 1109-1117

Zhu, L.J., Shukri, R., de Mesa-Stonestreet, N.J., Alavi, S., Dogan, H. and Shi, Y.C. (2010) Mechanical and microstructural properties of soy protein–high amylose corn starch extrudates in relation to physiochemical changes of starch during extrusion. J. Food Eng. 100(2): 232-238.

Zimecki, M. and Kruzel, M.L. (2007) Milk-derived proteins and peptides of potential therapeutic and nutritive value. J Exp Ther Oncol. 6(2):89-106

Patel, J.R., Patel, A.A. and amp; Singh, A.K. (2016) Production of a protein-rich extruded snack base using tapioca starch, sorghum flour and casein. J. Food Sci. Technol., 53(1): 71-87

Maluf, M.L.F., Weirich, C.E., Dallagnol, J.M., Simões, M.R., Feiden, A., and amp; Boscolo, W.R. (2010) Elaboração de massa fresca de macarrãoenriquecida com pescadodefumado. revista.ial.sp.gov., 69(1): 84-90