Exploring the extrusion cooking behavior of Maize-A Review

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Abstract

Maize has significant importance in the countries, where rapidly increasing population has already outstripped the available food supplies. Extrusion technology has been around for a long period of time in one form or another in many food industries. Extrusion cooking is a quite latest form of food processing. Extrusion is exploited for the manufacture of ready to-eat cereals, snacks, and food additives with diverse swelling properties. The majority of the research on the thermo mechanical behavior of these materials concerned the variation of starch. Extrusion cooking is progressively more being used for production of a wide range of snack foods and breakfast cereals. Extrusion is an ultimate technique for producing a variety of extruded products such as snacks and breakfast cereals. Extrusion processing conditions (moisture content, low residence time and low temperature) help advanced preservation of amino acids, high protein and starch digestibility, and reduce lipid oxidation, higher retention of vitamins and higher absorption of minerals. Extrusion processing parameter Screw speed, temperature, and moisture content has considerable effect on the physical properties of extrudates and sensory properties of maize extrudates. No matter what the future convey, it’s simple to see that, from simple corn puffed snacks and balls to complex filled products, extrusion give the snack-food producer a flexibility and variety of processing technologies.

Keywords: Extrusion, Maize, consumers, emerging technologies, food processing

Introduction

Maize (Zea mays L) or corn instigate in middle Mexico about 7000 years back, starting from teosinte (Zea mays parviglumis) that will be cultivated. Maize is the member of the subfamily Panicoideae in the family Gramineae. The maize utilized around the world differs, range from cooked immature grain to processed kernels. A number of million people, mostly in the developing countries, meet up their protein and calorie necessities from maize. The maize grain accounts for about 15 to 36% of the total daily calories in diets of people in about 25 developing countries where animal protein is scarce and expensive and consequently, unavailable to a vast sector of population (Prasanna et al., 2001). The major uses of corn are: as food and as raw material for industry.

The maize utilized around the world ranging from cooked unripe grain to processed maize products (Bressani, 1991). In its diverse development forms maize is a vital food for great numbers of people in the developing world, providing considerable amounts of energy and protein. Maize is used in a large range of products around the world such as tortillas, tortilla chips, corn snacks, and others. Tortillas are flat breads made from either corn or wheat (Tia, 2003). Maize is a main cereal grain which is cultivated worldwide and position second only to wheat in overall production area and stand second to rice in total production (Fuhrmeister et al., 2003). Maize is of great significance in the human food and animal feed in various parts of the world (Pereira et al., 2008). The maize grain, like other cereal grains, comprise pericarp (6%), endosperm (82%) and germ (12%) (Prasanna et al., 2001). The amount of protein of various maize cultivars is reported as 6–12% (Chanvrier et al., 2005). Protein quality of maize is similar to wheat or sorghum (Boyer and Hannah, 2001) Maize proteins, like other seed proteins, may be categorized with respect to solubility of protein as described by Osborne into the albumins, globulins, prolamins and glucelins (Taylor and Belton, 2002). The proteins of the grains are usually ranked based on their solubility in number of solvents. The albumins and globulins both build up about 19% of total protein in maize flour. But, the percentage of these proteins is greatly lesser in the endosperm, about 3.5% in maize grain (Yau et al., 1999).

The most important chemical constituent of the maize grain is starch that gives up to 72 to 73% of the kernel weight. The chemical properties of maize starch have been deeply investigated due to its extensive utilization in food. Most of 80% of the entire global production of starch come up to from maize (Boyer and Hannah, 2003). In maize with high amylose contents can range from 50 to 80%. A variety of types of modified starches produced from maize that comprises distinctive properties which dissimilar from native starch. The characteristics of these starches differ extensively, and may demonstrate valuable in some example for the production of gluten-free foods. Various types of corn posses’ various extent of horny and floury endosperm. The floury endosperm is softer and easier to break than the horny endosperm (Sandhu et al., 2007). Different types of maize can be differentiating on the base of endosperm and grain composition (Dhanasekharan et al., 2003).

Hard endosperm contains compact, polygonal starch granules, with abundant, directly associated protein
matrices. In soft endosperm, starch granules are larger and less aggregated. Good qualities of expanded products are achieved like snacks foods, and many breakfast cereals by the use of greater-shear force extruders. The physical properties of the corn extrudates are a sign of the efficiency of the extrusion cooking process and suitability of raw material constituent. However, food extrusion study was being performed more than 50 years; there are a number of deviations in the way of assessment of the characteristics as well as difference in sample size for determining them.

**Extrusion an emerging Technology for Maize processing**

Extrusion technology has been around for a long period of time in one form or another in many food industries. Extrusion cooking is a quite latest form of food processing. Forcing material in the course of a hole is the process of extrusion. During the 1930s heat was provided to the barrel include the screw; puffed corn curl snacks resulted product. The pressure produced as the ingredient moved beside the screw; this, collectively with the heating under pressure caused the corn to expand on exiting the dies. Since extrusion cooking processed more types of food, extruders became more particular for food use.

Extrusion cooking can formulate customary product to be more suitable in the swift changing society. Starch is generally the key food ingredient in extruded foods such as breakfast cereals, snacks and weaning foods. Humans do not readily digest native starch. Distinct several thermal processes, extrusion cooking gelatinizes starch fairly low (12-22%) moisture level. Increased temperature of barrel, shear force and pressure in extrusion raise the level of gelatinization of starch, but lipids, sucrose, dietary fiber and salts can impede gelatinization (Jin et al., 1994). While full gelatinization may not occur through extrusion, digestibility is frequently enhanced (Wang et al., 1993). Extrusion may progress protein digestibility by denaturing proteins, revealing enzyme-accessible sites. Enzymes and enzyme inhibitors mostly lose action due to denaturation (Della Valle et al., 1994).

There is a need to make use of locally-grown crops to produce of suitable local recipes in the under developed countries has been tense by international agencies as the most efficient channel for addressing depending world food harms (Iwe et al., 2001). Maize is the cereal of major importance in the developing world and has the maximum genetic production potential of all the cereal crops. Global grain production of maize is about 600 million tons a year (Pingali, 2001). In the year 2002, maize was the most important cereal crop with 29.7% of the world cereal production after rice and wheat (FAOSTAT, 2003). Maize processors have long described that flint type of maize cultivar show more expansion during extrusion cooking. It has also been found that endosperm protein composition is highly related with maize grain flintiness (Eyherabide et al., 1996).

More to the point being a key basis of food for human beings, maize also utilized as feed for livestock and as raw materials for industries for the manufacturing of many food and non-food products. Designing extruded snack foods today can be a difficult process to meet up varying consumer’s tastes and demands. The consumer’s requirement for “good for your health” and “distinctive flavor” extruded snacks leads to the indefinable exploration for something exceptional that also demand to a extensive range of peoples. Food extrusion is an energy-efficient process for the reason that a considerable quantity of mechanical energy from the drive motor and thermal energy system is degenerate as the extruder screw is in motion the gelatinous material within the barrel. Energy necessary to revolve the extruder screw can be expressed in terms of torque such that products involving greater demand of energy are more costly to process (Titus and Maduebibi, 2007).

Advantages of extrusion are adaptability, product shapes, high product quality, energy competence, production of new foods, and no effluent or waste material. Many ordinary snack foods are fried, making them high in fats while extruded snack foods are mostly not fried. Due to this an extruded snacks also well for health (Riaz, 2000). Extruded foods are composed mostly of cereals, starches. The most important role of these constituents is to provide structure, texture, mouth feel, bulk density and different properties desired for specific finished products.

**Consumer demand**

Consumer acceptance of extruded foods is largely due to the ease, value, eye-catching look and texture found to be exacting for these foods, particularly when it concern snack products (Anton et al 2008). While corn starch provides all the features for manufacture of greatly suitable extruded snack foods, its nutritional worth is far from pleasing the needs of health-conscious customers. Extrusions study continually focal point four different variables, while selection study performed to categorize important factors. These factors such as screw speed feed moisture contents and barrel temperature as principal factors which determine a secondary factors: specific mechanical energy (SME), product temperature (PT) and pressure (Meuser and Van Lengerich, 2003). These factors affect the viscosity of food in the extruder barrel, the residence time of the raw material in the extruder, and the shear force used for the food. Deviation caused by composition of feed material and preceding processing of the feed materials is vital base for experimental variation. Mostly in the snack food industry, extrusion was explained as a multifaceted technique which is different from straight processing technique with elevated shear rates and high temperatures (> 150°C) for
very short time (seconds). A large variety of mechanical and thermo-chemical reaction were concerned, with shear, maillard reactions, protein denaturation and hydrolysis. These processes end result in the physical, chemical and nutritional modification of food ingredient during extrusion (Jowitt, 2002).

Low moisture extrusion is frequently used to make breakfast cereals and snack foods. Many variable process parameters affect the extrudates of both twin screw and single screw extruders. Variables which can be modified by using a single screw extruder and controlling the parameters like speed of screw, feeding rate, moisture contents and temperature of extrusion (Nelson, 2003) Both the expansion and structure of food ingredients depend on starch gelatinization that was affected by extrusion processing conditions (i.e., moisture content, screw speed, temperature) and composition of raw material (Chinnaswamy and Hanna, 1991). Different high-temperature-short-time extrusion techniques had been used to get the optimum expansion of raw material like starches and cereals. But, all cereals and starches do not expand equally, due to the variability in raw material quality and composition and extrusion process variations (Rangan, 1993).

Maize Extrusion

The maize grain is changed into vital foods and industrial products by dry milling and wet milling process. The dry milling produce grits, meal and flours as major products. The wet milling process produces starch and other vital resulting products. Maize by means of less test weight frequently has an inferior percentage of hard endosperm; therefore it give a lower yield of principal, large grits when milled. Robutti et al., (2002) studied that the maize endosperm hardness related to the maize grain chemical composition. Hardness of endosperm cause compacted, polygonal starch granules, with rich protein material. In softness of endosperm cause the starch granules to be larger and show less aggregation. Maize grits were the core raw material for the manufacturing of expanded corn snacks. Grits from harder maize are preferred to use by Processors, because of the improved texture of the product obtained as compared to softer maize grits (Robutti et al., 2002). Maize grain contain different ratio of hard and soft endosperm. Cultivars of maize with almost all hard endosperm are called “flint” maize, and those with soft endosperm are called “Dent” maize. “Dent” maize cultivars differ in ratio of hard and soft endosperm. The percentage of hard-to-soft endosperm can also differ due to genotype difference, or environment (Pomeranz et al., 1984), Sandhu et al., (2007) reported that yellow corn consist on a horny endosperm, and extra carotenoids contents (74–86%), that impart yellow color in corn, while the floury endosperm (9–23%). Hardness and breakage propensity are allied properties which affect the use of corn, changes solubility of protein. Grits from harder maize and extrudates from harder Quality characteristics of maize cultivars which may help breeders to develop cultivars best adapted to diversified extrusion conditions. Extrusion cooking changes protein hydrophobicity and level of aggregation, conversely variation between the maize cultivars. The maize kernel hardness is an important economic trait. Enough hardness is essential to keep kernel integrity all through mechanical harvesting, while being handled during marketing and in storage (Anderson et al, 1991).

Maize cultivars that have large proportion of hard endosperm are best suited for dry milling process as they give better production of excellent flaking grits.

Grain hardness is a vital grain quality feature which had a great role in the processing of maize grains and in the final-use quality of maize grain based products like snack foods (Bettge and Morris, 2000). Under the processing circumstances of their study, maize grits of harder texture show more expansion, use a lesser amount of energy during extrusion, and cook more quickly than the maize grits of softer texture. The variation in product quality characteristics is related to conflicting protein contents and textures of endosperm of maize cultivars (Robutti et al., 2002). Sandhu et al., (2007) studied that the protein was the major factor in grain hardness as it comprises a matrix contiguous and embedding of the granules of starch. Hardness of grains reason of the deposition of prolamins and antifungal proteins in larger quantity than softer maize grains. Sandhu et al., (2007) found that the area of hard endosperm in the corn grain have a larger alpha and gamma zein protein. Pratt et al., (1995) reported that the hardness of endosperm in maize and sorghum are strongly associated mutually with protein composition and protein content. The most rich endosperm proteins of maize and sorghum are the prolamins that are further divided into subclasses based on solubility, structure, and amino acid order. Pratt et al., (1995) studied the interaction among the prolamin subclasses and hardness of grain and also described that the vitreous endosperm of maize grains is greater in total protein and total prolamin, whereas the floury endosperm is more affluent in γ-prolamins in contrast to vitreous endosperm. Two maize-grits samples were obtained from a yellow dent and a white flint type of maize at different temperatures, 150 and 180°C and at different moisture content. These grits samples were extruded using a Brabender 10 DN extruder. The end result of extruded product showed that more expansion and higher cooking degrees for white flint maize samples. Flint type of maize had the harder texture as compared to dent type of maize. The grits from flint type of maize, shows better expansion values with higher level of extrusion cooking and minimized the mechanical resistance, that result in improved product texture, hence sustaining the first choice of the snack industry for flinty maize grits. It was valuable to note that the diversity in texture hardness of two maize grits shown under study were generally...
moisture levels a considerable structural breakdown of the starch granules occur indicative of a significant alteration in the molecular structure of the starch (Lin et al., 2000). Speed of screw had no considerable influence on the bulk density, specific length, and expanded ratio of product. Increased product temperature was due to decrease in moisture content of raw material and by increasing screw speed that was greatly associated with quality of an expanded product. By an elevated screw speed and a high product temperature, specific corn allied flavors were developed. Extrusion processing conditions and ingredient characteristics affect the extrudates physical and chemical properties. These influences were significantly studied (Singh et al., 2007). Studied effects comprises that the extrusion cause the destruction of anti nutritional components of food, gelatinization of starch, increased soluble dietary fibers and decrease the lipid oxidation. On the other hand, maillard reactions during extrusion, among protein and sugars lessen the nutritional significance of the protein. High moisture content, small residence time and low temperature enhance the nutritional value, while increase extrusion temperatures (200°C) low moisture contents (<15%) and variable composition of raw material can damage nutritional value.

Moisture content in the range (21-23%) and adding of soybean flour (0-40%) proved important influence on the texture of the extrudates. Addition of soybean flour in the range from 0 to 40% improved the expansion ratio, reduces the hardness and changes the specific volume and chew ability of the extrudates. Higher the moisture content from 21 to 23%, result in decreased specific volume, and increased the hardness of the extrudates (Siquan et al., 2005). Plahar et al., (2003) make a standardized extrusion cooking process for manufacture of a good protein contents weaning food found on peanuts, maize and soybeans. Consequences described that bulk density and hardness improved at the same time as expansion reduce with raise in feed moisture level. At a set series of moisture level, bulk density of extruded food product and firmness reduce whereas expansion improved by means of escalating extrusion temperature. For most excellent product quality extrusion processing conditions established were mix together formulation of 75 % maize, 10 % peanut and 15 % soybean: mesh size of 300-400 μ, speed of screw 500 r. p. m., feed rate of 4.6 kg/min, moisture level of 16–18 % and extrusion cooking temperature of 100°C-105°C.

Diverse extrusion processing conditions such as screw speed, moisture contents, and temperature alter the physical properties of extrudates like expansion ratio, bulk density and level of betaglucan. Reducing sugars like glucose and lactose take part in Maillard reactions. The shear forces in extrusion can also produce reducing sugars from complex carbohydrates as well as from sucrose and other sugars (Noguchi and Cheftel, 2002). Whereas sucrose contents loss may affect color of
the product and flavor, there is an opportunity to decrease the amount of indigestible oligosaccharides that result in flatulence. Sucrose, raffinose and stachyose reduce extensively in extruded product. (Borejszo and khan, 1992). Corn soy snacks have inferior degree of both stachyose and raffinose compared to unextruded soy grits and flour, but value were not accurate for the 50-60% corn present. Starch and stachyose were lesser in quantity in extruded peas compared to raw peas (Alonso et al., 2000), but an enhance in total free sugars did not fully account for these sufferers. Addition of sucrose in different concentration levels 0 and 12.5% by weight to corn grits prior to extrusion largely affect the textural properties of corn extrudates. The effects of sucrose on texture of the end products were:

1. The internal structure and cell size of extrudates reduced by adding sucrose.
2. The crispness of products estimated by puncturing increased with the sucrose content until an optimum whatever the flour.
3. The addition of sucrose in corn reduced overall product expansion
4. Increasing the amount of sucrose in the mix induced greater molecular degradation of corn starch (Mezreb et al., 2006).

Food extrusion has advantages such as versatility, high productivity, flexible, multifunctional, low cost, product shapes, high product quality, high nutritional value, energy efficiency, production of new foods, shelf stability and no effluents or waste (Zasyptkin et al., 1998). Cooking of ingredients during extrusion leads towards gelatinization of starch, denaturation of protein, inactivation of raw food enzymes, destruction of naturally occurring toxic substances and diminishing of microbial counts in the final product elevated barrel temperature, small moisture and high shear increased the Maillard reactions. Browning can take place yet when reducing sugars are excluded from recipe for the reason that new reducing sugars may be produced from breakdown of sucrose, starch and other polysaccharides. (Bates et al., 1994). Lysine can be conserved, yet, if extruder processing conditions and recipe are cautiously balanced. Corn-soy blends extruded for reconstitutions as porridge lysine preservation (Konstance et al., 1998).

Extrusion cooking also develops the nutritional value of foods by demolish various natural contaminant and anti nutrients. A problem present as to whether it is necessary to eliminate these compounds. Enzymes inhibitors, and other compounds like, saponins and other compounds may possibly mess up growth in children, but these similar compounds may propose protection against chronic diseases in adults.alergens and mycotoxins are extremely challenging to thermal processing, but extrusion with chemical treatment via reactive extrusion may successfully lower these compounds to secure levels. Microwave cooking in contrast with other processes their effect on anti nutritional factors like phytic acid, tannins, trypsin inhibitors was studied (Habiba, 2002). Extrusion Cooking decreased phytic acid and tannin contents. Regular cooking, that receive much time, was most valuable in reduction of phytic acid contents upto (47.9%), whereas microwaving heating provide the maximum reduction (25.7%) in pea tannins. It has been demonstrated that various anti-nutritional factors can be destroyed during extrusion. Nawab (2006) studies that the extrusion cooking of maize for the manufacture of a variety of conversational products cause in the reduction of phytic acid contents. Fresh mature maize grains have a smaller amount of phytic acid. The reduction of phytic acid contents differs from 18.1 to 46 percent for fresh maize and from 11 to 52% for dry maize correspondingly for the duration of extrusion cooking. Abd El-Hady and Habiba (2003) proposed that extrusion process has been an effective solution to improve the digestibility and remove the anti-nutrients at the same time. Mukhopadhyay et al (2007) optimized the values of the extrusion process variables like barrel temperature (82°C), extruder speed (90 rpm) and oilseed moisture content (41.22%) for linseed tannin detoxification founded to be 61.25%. Wu et al (2008) investigated the optimized results, including the temperature (146.0 °C), the feeding rate (60 kg/h) and the screw speed (152.5 rpm) for the removal of HCN (84.38%) in flaxseed. Killeit (1994) study that vitamin preservation in extruded foods. Further study on the bioavailability of added and endogenous vitamins is required, principally in light of strengthening programs for folate and new vitamins Lasekan et al., (1996) investigated the effect of extrusion process on the nutritional worth, storage stability and sensory characteristics of an native maize-based snack food. Product was evaluated for existing lysine loss, protein dispersibility index, variation in total carbonyls (lipid oxidation) and sensory characteristics during storage (at 25, 30 and 40 °C). Extruded product suffered little loss (10%) in available lysine but had an significant decline in protein dispersibility. In addition, high storage temperature (40 °C) extensively decreases the sensory acceptance of the maize-based puffed snacks.. Concern of abridged vitamin levels exclusive of impediment some producer to use vitamins before extrusion. Current study has focused on vitamin stability during extrusion (Marchetti et al., 1999). Vitamins like D and K are quite stable during extrusion processing conditions, but are not used in several extruded human food products. Vitamin E and related tocopherol act as mutually vitamin and antioxidant during extrusion. Gamma and delta tocopherols lost upto (40%) while alpha and beta forms of tocopherols lost (23-28%) (Suknark et al., 2001). Tocopherol present in rice bran gets lower at higher extrusion temperature (Shin et al., 1997)

The preservation vitamins of B Group throughout extrusion cooking were compared with the other cereal and under diversified extrusion conditions in a single screw extruder). By Using single screw extruders,
Lorenz and Jansen (2007) study that preservation of over 90% for thiamine, riboflavin, vitamin B₉, and folic acid in corn snack that are processed at higher temperature. The results prove that short barrel extruders employ for snack production preserve the B group vitamins between 44% and 62%. This is significantly higher than the 20% preservation for maize described formerly for long barrel extruders. Only the Thiamin was lost during extrusion cooking (Athar et al. 2006). Phytic acid contents were in the form of phosphorus in various cereals. It is an anti nutritional factor, because it makes unavailable other nutritionally important cations. Consequently, there are evident reasons for lowering the level of phytic acid in the snacks (Feil, 2001) Mineral and their bioavailability are usually maintained during extrusion cooking. While corn meal, that has small dietary fiber content, had no vary in total component, (Camire and Dougherty, 1998). Extrusion somewhat higher the iron accessibility in corn snacks (Hazzel and Jhonson, 1998). Snacks prepared from maize on a single screw extruder had adequate textural characteristics with additional calcium hydroxide levels of 0.02-0.078% (Zazueta-Morales et al, 2001). The equipment must be replaced and refurbished periodically due to this wear, as the metal accumulates in the extruded food. Extrusion cooking performance and product properties of flint type of maize and sweet corn grits was seriously effected by moisture contents temperature of extrusion and screw speed. Moisture contents demonstrate the most prominent effect on die pressure, expansion ratio and Water Solubility Index. Die pressure of the extruder was extensively greater for sweet corn than flint type of maize grits. The grits from both types vary greatly with respect to extrusion response and final product quality under same extrusion conditions. High screw speed and temperature produce extrudates with better expansion and less degree of bulk density (Gujral et al. 2001). Extruded product density and expansion ratio reliant on moisture content, screw speed and temperature. More distinctively, the obvious bulk density of extrudates had an increasing development with moisture content and residence time, whereas it reduces with temperature of product. Porosity and expansion ratio of extrudates reduced a lot with feed moisture level and residence time, (Thymi et al., 2004). Gujska and Khan (1991) study the effect of moisture in raw material on functional properties and trypsin inhibitor behavior of extruded bean high starch fractions. For all beans, water solubility index reduced with increasing moisture level. Color of extrudated product was also affected by moisture level of material. The extrusion cooking decreased trypsin inhibitions activity about 70%. The reduced level of this anti nutritional factor was accessed by moisture content of raw material and temperature during extrusion cooking.

Bhatnagar and Hanna (1994) performed extrusion of the normal corn starch having 25 % amylose with and exclusive of stearic acid and at different combination of barrel temperatures, screw speeds, and moisture levels. The existence and quantity of stearic-stearic acid complexing was measured using iodine binding capacity. Utmost complexing was reported at 110-140 °C barrel temperatures, 140 r. p. m. screw speed, and 19 % moisture. Physical properties (expansion ratio, bulk density) of extruded starches were also estimated. Gujska (1991) deliberate the mechanical properties of cereal extrudates which were professed by the absolute consumer as criteria of quality. They scrutinize one of the significant characteristics of extrudates, mechanical hardness, which is one of the foremost texture properties. Textural properties has a control on taste sensory evaluation, and thus on the suitability of the product. Characteristics which have enormous effect on acceptability are crispness, flexibility, hardness and softness. These characteristic are only just associated to, and affected by, the process variables. Factorial experimental design was applied to study the effect of temperature of expansion, screw speed, moisture content and feeding rate, and their relations, on the mechanical hardness of extrudates. Moisture content, screw speed and temperature are to initiate manipulate, while feed rate does not have considerable effect on extrudates hardness.

Conclusion

Despite the fact that extensive work been done in the area of extrusion in general, and extrusion expansion in particular, this complex field carry on to some degree to dexterous art rather than a apparent science. There are many areas that require further research regarding extrusion and nutrition. Very little has been published on the effects of extrusion on photochemical and other healthful food components. Prospect study may be focused on the association between compositional changes on product worth together with dietary and sensory characteristic. High moisture extrusion and utilize of with a reduction of reactive sugars may developed an innovative contour of research objectives.

References


