

Review Article

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Development and Quality Evaluation of Milk-based Snack “Milk Crisp”

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ABSTRACT

Milk is one of the most nutritious foods. It is rich in high quality protein providing all ten essential amino acids. Milk is not only a food, but also an essential ingredient of life itself by its very indispensable nature. It is highly nutritious commodity. It supplies body building proteins; bone forming minerals and health-giving vitamins and furnishes the energy giving lactose and milk fat. Since we are lacking in cold chain facilities, therefore there is imperative need to develop shelf stable milk products. The snacks available in the market are mainly prepared from starch rich foods and cereal grains especially potato and corn and they have low nutrient density and high calorie and/or fat content. The present study was undertaken to develop a good quality and highly acceptable shelf stable ready to-cook milk-based snack, which can be stored for longer period under ambient temperature. In preliminary trials, a wide variety of starchy flours, alone or in various combinations and different levels of skim milk coagulum were tried for preparing milk-based snacks to reach most acceptable combination. Based on the results of preliminary trials, formulation containing 55% of skim milk coagulum along with different combinations of flours was selected as control for further studies. Incorporation levels of two different extenders were separately optimized. The treatments containing optimum level of extenders and control (without extender) were evaluated for different physico-chemical characteristics along with yield, expansion percentage and percentage oil uptake etc. All sensory parameters were recorded between good to very good. Aerobically packaged milk-based snacks stored at $30 \pm 2^\circ\text{C}$ showed no marked changes in sensory, physico-chemical and microbiological qualities during storage up to 60 days. TBARS and pH values increased however, percentage oil uptake and expansion percentage were reduced during storage period. Thus, it can be concluded that technology developed for making shelf stable ready to-cook milk-based snack using skim milk coagulum can provide a nutritious, palatable product to the consumers and ensure effective utilization of skim milk.

Keywords

Sensory evaluation,
Milk crisp, Ready-
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Introduction

A snack should be balanced nutritionally, should provide quick energy, easy to eat and

of great taste. One requirement transcends all others and is that, a snack should be perceived as healthy (Pikuda and Ilelaboye, 2009). Snack foods being convenient food items are

most suitable for working women, school age children and highly mobile population (Lusas and Rhee, 1987). Snacks have become one of the major groups of the functional food products in diet (Roberts, 2002); it can serve the purpose of healthy food, entertaining and tasty food and ethnic cuisines of consumers (Anon, 1998).

These foods which are usually ready to eat are prepared by extrusion cooking, puffing, popping, flaking, frying, toasting etc. Snack food products include extruded snacks, puffed cereals, popcorns, rice flakes, potato chips, French fries and Indian home-made products like papads, kurdai, chakali etc. which may be consumed after frying or roasting (Nath *et al.*, 2007). Extruded snacks have the ability to satisfy short term hunger and are available in different forms and shapes such as chips, pretzels, crackers, nuts, fruit rolls, cookies, granola bars etc. (Harper, 1981). Good snacks should be convenient to consume, inexpensive, nutritious and have long shelf life (Roberts, 2002). According to Reid (1998) these foods have become an integral part of the eating habits of majority of world's population and they are prepared from natural ingredients or components to yield products with specified functional properties.

Snack Foods

The snack food industry has been around for centuries. The phenomenal growth of snack food industry world-over during the past two decades has brought about a perceptible change in the consumption pattern of food items by consumer as well as profitability of snack food industry (Jones *et al.*, 1981). Popcorn has been around since approximately 3000 B.C. Even the pretzel was created in southern France around 610AD. In the late 1890s, potato chips were developed and became a popular American snack. It started as a small business venture to get chips to

locals and caught on and spanned the globe. Thousands of types of chips, fruit snacks, cookies, and anything our hearts desire are available (McCarthy, 2001). Now the industry seeks healthier foods for snacking. People want low sodium, low oil and low calorie. Companies are baking chips to produce lower oil chips. Tortilla-chip sales boomed in the '90s and enjoyed double-digit growth even as other categories plateaued. Naturally, families with children and teenagers are the largest consumers (Mintel International Group, 2006). Snacks have become one of the major groups of the functional food products (Roberts, 2002).

Indian snack food market has reached a value of Rs 1530 crores. It is one of the largest snack markets in the world. Potato chips are by far the largest product category within snacks, with 85% of the total market share. Snack nuts and savory snacks also add to the market. There is a demand for Indian snack food (Ready-to-eat) in overseas markets. The Exports market is estimated at US\$ 33.4 Million and is growing at around 20% annually (Diamond and Oppenheim, 2004). A number of global trends and lifestyle factors are currently driving the snack food industry. Some of these factors are working women, changing and extended working hours, increasing number of single person households, different eating times and food choices by individual family members, kids' buying power, consumer's need for indulgence, and increasing perception of food as a reward (Promar International, 1997; Euromonitor, 2002).

Snack foods are cereal or grain-based products which are generally low in protein and often, high in fat content and normally considered as a low value product. Today's, consumers more and more believe that foods contribute directly to their health (Mollet and Rowland, 2002; Young, 2000). Today foods

are not intended to only satisfy hunger and to provide necessary nutrients for humans but also to prevent nutrition-related diseases and improve physical and mental well-being of the consumers (Menrad, 2003; Roberfroid, 2000). A lot of works have been done to improve the nutritive values of the snack products by incorporation of protein sources derived from plant or animal (Bhattacharya *et al.*, 1990; Park *et al.*, 1993a; Senthil *et al.*, 2002; Rhee *et al.*, 2004; Anton *et al.*, 2009).

The amount of derivable protein from all the snacks analyzed has been found to be 3.49-18.883 g/100 g, which is lower than the (ADR) Average Daily Requirement (52.5 g) for adult (WHO, 1985), hence consumption of any of snacks alone will be grossly inadequate to meet the significant role of protein in human diet in controlling growth and cell differentiation. These products not only have low nutrient density and high calories and/or fat contents (Park *et al.*, 1993) but also lack in some essential amino acids such as threonine, tryptophan and lysine. The snacks available in the market are mainly prepared from cereal grains which are sometimes supplemented with vegetable proteins (Falcone and Phillips, 1988; Batistuti *et al.*, 1991; Laarhoven and Staal, 1991). The demands for snacks like fast food are continuously increasing due to its nutritional value, reduced fat content and calorie products image (Shaw, 1990). This image can be further enhanced by incorporation of milk solids. Milk based snacks, therefore, can prove to be a valuable snack food item as a source of essential amino acids and other nutrients.

Use of starchy flours/starch in snack products

The increasing demand for better quality and healthy milk products has stimulated the use of new non-milk components. Cereal grains are the commonest raw materials employed in

the manufacture of extruded products (Ding *et al.*, 2006; Hagenimana *et al.*, 2006). Starch is a polysaccharide component of most of the grains and tubers. It binds large quantity of water and under goes gelatinization on heating Starch content has shown to affect various properties of snacks e.g. wheat has a higher protein and lower starch content compared to rice and corn, therefore extruded wheat products are harder and less expanded (Camire, 1998; Guy, 2001; Riaz, 2006). Being multifunctional food ingredients starches have many functional applications, including adhesion, binding, emulsion stabilization, gelling, moisture retention (Pietrasik, 1999). Starch provides most of the texture and structure of expanded products made from cereals and tubers (Bhattacharya and Hanna, 1987). Types of starch vary in the size, shape, and gelatinization properties of granules (Pomeranz, 1991; Hosney, 1994). These differences and the ratio of amylose to amylopectin influence extrudate quality (Harper, 1981). Case (1992) reported that an increase in degree of gelatinization of wheat and corn starch during extrusion caused increased expansion and decreased bulk density.

Rice flour is more valuable than wheat flour or soy in terms of certain amino-acids such as phenylalanine, leucine and isoleucine (Traitilevich, 1984). Rice is relatively free from toxic substances and PER ratio (ratio of weight gain to protein consumed on a 10% protein diet) of rice (2.18) is almost equivalent to that of beef (2.30) (Hansen *et al.*, 1981). Studies have also been carried out on the extrusion properties of corn, soy, wheat and rice in the production of snack foods (Aguilera, 1976).

One of the popular snack foods in several Asian countries such as Thailand, Japan, Vietnam, Malaysia, and Indonesia is rice crackers, made from glutinous or sweet rice.

Glutinous rice (*Oryza sativa*) contains high amount of amylopectin in the starch. Therefore, the important characteristic of this rice is stickiness (Noomhorm *et al.*, 1997). Glutinous rice is usually used to produce fried, baked or popped snacks because of its sticky nature. Due to lack of amylose in the starch, it can expand readily to produce a porous texture of finished product. The glutinous rice crackers are prepared by washing and soaking milled rice in cold water for 16–18 h. After that the milled rice is drained and crushed by rollers into fine powder, and then steamed for 12–13 min. The resulting dough is kneaded and cooled at 2–4°C, and left for hardening for 2–3 days. The hard cake is cut and dried before adding various flavors to produce multiple products. The dried cake is fried to obtain crispy, crunchy texture of rice crackers.

Ragu *et al.*, (2005) prepared a high protein nutritional baked snack food comprising wheat flour, roasted peanut paste, sesame seeds, soybean flour and a well-balanced mixture of vitamins and minerals.

Davidson *et al.*, (1984) analyzed that at high temperature, starch granules undergo gelatinization and melting causes an increase in dough viscosity. Mechanical degradation of starch, which enhanced the susceptibility to amylase hydrolysis, was also reported. Heat and shear induced denaturation of proteins, which unravel and are subjected to cross-linking reactions. The result is the formation of a new molecular aggregate structure.

Chemical changes may also be derived from the hydrolysis of starch and sucrose increasing the reducing sugar content was observed by Noguchi *et al.*, (1982). Hadiman *et al.*, (1993) and Srilakshmi *et al.*, (2006) analyzed that the wide variation in the total yield, number of raw and fried Nere happala (traditional product) among the cereals and

millets may be attributed to the variation in the chemical composition. Being multifunctional food ingredient, starches have many functional applications including adhesion, binding, emulsion stabilization, gelling, moisture retention (Pietrasik, 1999). Cereal grains are the commonest raw materials employed in the manufacture of extruded products (Hagenimana *et al.*, 2006).

Research results indicate that pressure-induced gelatinization of starch is different from heat-induced gelatinization (Stolt *et al.*, 1999). During gelatinization of starch using heat, many changes take place simultaneously or successively, including granule-swelling, loss of birefringence, increase of viscosity and fragmentation of the granule (Stolt *et al.*, 2001). However, pressurization swells starch granules, allowing them to keep their granule-like and gelatinized structures without retrogradation.

Source of proteins

The nutritional key role of grain legumes is unquestionable, due to the massive presence of macro and micronutrients. Among these nutrients, proteins play a relevant role in consideration of their amino acid composition which can easily be balanced in the diet. Grain legumes are important sources of food proteins. In many regions of the world, legume seeds are the unique protein supply in the diet. Very often they represent a necessary supplement to other protein sources (Duranti and Gius, 1997). Therefore, the dietary importance of legume seeds is expected to grow in the years for the proteins (and other nutrients) demand of the increasing world population and the need of reducing the risks related to consumption of animal food sources, especially in the developed countries (Duranti and Scarafoni, 1999). Recently, it is being acknowledged that food proteins are not only a source of constructive and energetic

compounds as the amino acids, but also, they may play a bio-active role by themselves and/or can be the precursors of biologically active peptides with various physiological functions. From this point of view, the best-known examples are casein-derived peptides which have been proved to possess immuno-modulating, anti hypertensive, anti-thrombotic and opioid activities (Kostyra, 1996). Mikota *et al.*, (2003) extruded milk-based snack food products which have a high content of total milk solids (greater than or equal to 40% by wt).

By using a twin-screw extruder, Onwulata *et al.*, (2001) successfully incorporated whey protein into snack products to increase the protein content (up to 20%) and extend the nutritive value. Despite the increased use of extrusion processing on whey proteins to create and improve the desired functional properties of whey protein dispersions as structuring agents in dairy protein-based foods, it is still difficult to predict any structures, texture, or functionality resulting from a extrusion process was described by Purwanti *et al.*, (2010). Caseins are the most important class of milk proteins and are widely used as food ingredients mainly due to their water binding, emulsifying, foaming, gel forming and thickening capacities (Walstra, 1999). Caseins constitute extensive part of bovine milk and due to their nutritional acuteness and commercial significance; these are one of the food proteins the most extensively studied. Casein micelles are heterogeneous, both in composition and size, with a great poly dispersity, a loose packing and a higher porosity than many other protein assemblies (Liu and Guo, 2008).

Role of salts in dairy industry

The evolution of new food products that may add to attenuate issues related to public health in a positive way is a big challenge for the

dairy industry. Salt played a significant role throughout human olden times. History reveals that Egyptian called it 'natron' and the Latin term 'salarium' originates from salt and refers to the amount of salt that was given to the worker as his salary.

In the present circumstances, salt content in food is the core focus of consideration of the world food industry especially in the dairy one. Salt is one of the most commonly and extensively used additives in dairy industry for the reason of its low cost and varied properties. It brings out particular functions for example improves taste, texture, and enhances shelf life of dairy products (Albarracin *et al.*, 2011).

Moreover, its consumption is directly related to lifestyle, cultural, social, sensory, economical, psychological and technological factors (Purdy and Armstrong, 2007). Sodium Chloride (NaCl) is an alimentary salt widely used in dairy industry as it is a major determinant of water activity. In addition, it acts as preservative, contributes directly to the flavor as a consequence of its effect on different biochemical mechanisms and is a source of dietary sodium (Guinee, 2004).

During production (milk-based snack) process, salt is added at the end of process, after shaping and/or molding and pressing. Salting is carried out in the form of crystals and directly distributed over the surface of curd granules or milled curd chips prior to its molding and/or pressing, this method also called dry salting is applied to Cheddar and Stilton (Guinee and O' Kennedy, 2007).

Generally, salt is added to prevent the undesirable microbial growth by controlling the growth of lactic acid bacteria (McMahon, 2010) as well as provides an additional flavor (Rowney *et al.*, 2004) by improving cooking performance (Guo *et al.*, 1997) and

rheological properties (Guinee and O’Kennedy, 2007). In addition to these functions, concentration and distribution of salt influences enzymatic activities and biochemical changes such as glycolysis, proteolysis, lipolysis (Floury *et al.*, 2009; Guinee and O’Kennedy, 2007; Katsiari *et al.*, 2000) and para-casein hydration (Guinee, 2004) that take place during storage.

Use of hydrocolloids

Many food ingredients and additives can be used to improve fried food, but hydrocolloids are the principal category of functional agents that have been used for the past forty years. Hydrocolloids play two main roles in fried food development. One is to form a fine ‘invisible’ coating, practically on their own, when their main purpose is to avoid excessive oil absorption during the pre-frying and frying processes. In the other, when they are added to the batter among its other ingredients, they are used to avoid oil absorption too, but they also act as viscosity control agents, improve adhesion, pick-up control and freeze-thaw stability or help to retain the crispness of the battered/breaded fried foods. The wide spectrum of properties of the main dry ingredients basically wheat flour but other flours and starches too and their inherent variability are the main reason why batter viscosity needs to be controlled. Adding gum can reduce the variability of the batter’s viscosity.

The advantage of using gums rather than other hydrocolloids such as modified starches is their effectiveness at lower concentrations, thus avoiding dilution of the functional protein in the flour, which plays a critical role in the development of a characteristic gluten network. Hydrocolloids used generally in fried products are guar gum and CMC, HPMC, MC xanthan gum, gum acacia, gum tragacanth to reduce oil uptake.

Method of preparation/ Processing of Snack foods

Extrusion

Extrusion is an important food as well as feed processing technology. The term ‘extrusion has been derived from the verb – to extrude – which according to Webster means, ‘to shape by forcing through a specially designed opening after a previous heating of the material’ (Saurabh, 1996). Extrusion technology is an energy efficient, rapid, high temperature, short time and continuous system in which numerous ingredients and processing condition can be utilized (Harper, 1981).

It is reported that extruded products are highly impressive and nutritionally well accepted. Extrusion technology causes gelatinization of starch, protein denaturation, lipid modification, inactivation of enzyme and micro-organism and exerts antinutritional factors (Bhattacharya *et al.*, 1999). It is reported that extrusion cooking is a rapid and versatile system for the hygienic production of wide variety of snacks and pasta (Harper, 1981). This technology modifies starches (Mercier *et al.*, 1989) and helps in production of breakfast foods. By this technology, we can maximize expansion and crispiness of products and minimize heat damage of nutrients (Peri *et al.*, 1983). Extrusion cooking provides the conditions for gelatinizing starch, polymerizing proteins and cross-linking molecules to form expandable matrices as well as addition of proteins to starches increased sites for cross-linking and affected textural quality was showed by Rossi and Peri (1980).

Extrudate expansion and texture also depend on the interaction of shear, heat, and moisture in the extruder reported by Mercier, (1979) and Owusu-Ansah *et al.*, (1984). Holay and

Harpe (1982) investigated that the structure of the extrudate is formed in the extruder during mechanical shear. Moisture exerts a great influence on extrudate quality; by affecting cell structure, fragility of expanded products was described by Mercier, (1979) and Miller, (1985). Purwanti *et al.*, (2010) studied that the product characteristics of extrudates can vary considerably depending on the extrusion processing conditions such as barrel temperature, die geometry, extruder type, feed composition, feed moisture content, feed particle size, feed rate, screw configuration, and screw speed.

Drying

Drying is an excellent way to preserve foods that can add variety to meals and provide delicious and nutritious snacks. One of the biggest advantages of dried foods is that they take much less storage space than canned or frozen foods, further they also do not require cold chain facilities. Food drying is achieved by means of different techniques (Bimbenet *et al.*, 2002) which combine heat or pressure sources to remove water from the interior of the product and mechanical energy to remove water from its surface (convection and drip etc.). Drying is a complex operation involving transient heat and mass transfer along with physical transformations such as shrinkage, puffing, crystallization or glass transition and chemical or biochemical reactions which cause changes in color, texture, odor etc. On the whole, it affects the final quality of the end product. So, the selection criteria for drying methods relies on the type of the product to be dried, desired final product quality, the product's susceptibility to heat and the operation cost (Cohen and Yang, 1995).

One of the primary objectives of food processing is the conversion of perishable foodstuffs into stabilized products. Drying is

one of the oldest methods of food preservation and is a very important aspect of food processing (Vadivambal and Jayas, 2007). It can be defined as a simultaneous heat and mass transfer operation in which water activity of material is lowered by removal of water to a certain level so that microbial spoilage is avoided. Drying techniques mostly rely on extending the keeping properties of the food products by reducing the water activity i.e. the ratio of the equilibrium vapour pressure of the product to the equilibrium vapour pressure of pure water at the same temperature (Scott, 1953, 1957).

Dried or desiccated or low moisture foods are those which generally do not contain more than 25% moisture and have a water activity between 0.00 and 0.60. These include the traditional dried foods. Another category of shelf stable food called the intermediate moisture foods are those that contain moisture between 15 and 50% and a water activity between 0.60 and 0.85 (Jay *et al.*, 2005).

Convective drying of food products is extensively employed as a preservation technique. Oven drying is the simplest way to dry food. It is also faster than sun drying or using a food dryer. Adesso *et al.*, (1995) investigated production of chip like starch-based snacks. The moisture content of the dough sheets was reduced by heating in air, preferably in a gas-fired oven, to obtain chip-like snacks, such as potato chips and corn chips having low oil content, a blistered appearance and a crisp texture.

Frying

Fried foods are very common and generally acceptable worldwide. Surface appearance and texture are the most significant factors for consumer acceptability. Most foods cook rapidly and develop golden colour, crisp texture and good flavour at the frying

temperatures between 160 and 90°C. The linkage between colour and consumer perceptions of quality is often psychological. Instrumental measurement of texture and colour can offer a quantified basis for manipulating processing variables for quality improvement. During the frying process, the physical, chemical and sensory characteristics of the food are modified (Moyano, Rioseco, and Gonzalez, 2002).

Pedreschi and Moyano (2005); Pedreschi *et al.*, (2005), and Warner and Gupta (2005) found that oil temperature and sample thickness are the process parameters that affect the colour parameters significantly during frying. Krokida *et al.*, (2001) detected that the colour change phenomenon gets more intense at higher temperatures and smaller sample thickness. Apart from cross-sectional thickness of a sample and frying oil temperature, concentration of hydrogenated oil affect colour changes during deep fat frying.

Another important quality attribute of fried products is crispness. The forming of crispy crust depends on both the product and on process conditions. Force-deformation studies have been performed by Fan, Singh and Pinthus, (1997). A fried product becomes tougher as frying time increases up to an optimum value after which the product becomes brittle. Mass transfer during frying consists of moisture loss and oil absorption. Moisture loss during frying generally decreases exponentially with frying time.

Cassava or tapioca (*Manihot esculenta* Crantz) starch is widely grown around the world. Initially; cassava was mainly processed to meal and flour. Cassava crackers are popular snack foods in Southeast Asian countries. In the manufacturing process starch is mixed with hot water and partially gelatinized to form dough, which is

subsequently shaped and steamed or boiled to complete gelatinization. The cooked dough is then sliced and dried to a half finish product with about 12% moisture content. The half finish product is dipped in hot oil whereby it expands to a porous, low density and crispy product. The frying process is an important process to provide a puffed product. If the starch is not fully puffed, poor expansion and texture of cracker will follow. There are many influence factors for the puff process, such as temperature, warm up time, oil type, oil bath turbulence by stirring, frying time and equipment use (Alvis *et al.*, 2009). Deep fat frying is one of the oldest and most common unit operations used in the preparation of food, and is especially suited to develop snacks with unique flavors and texture (Gazmuri and Bouchon, 2009). The frying process involves simultaneous heat and mass transfer, which cause significant structural changes to both the surface and the body of the product. For cereal based foods, an expansion in volume associated with the creation of a porous structure usually takes place (Bhat and Bhattacharya 2001). In addition, many complex physic-chemical change occur during frying including protein denature, starch gelatinization, water vaporization, and color development (Maneerote *et al.*, 2009). Thus frying process is a critical step for producing cassava crackers with desirable characteristics

Crispness is a unique characteristic and an important parameter to be controlled in deep-fat fried products (Pedreschi and Moyano, 2005; Thanatuksorn *et al.*, 2007). Many researchers agree that crispness results from structural properties of food (Barrett *et al.*, 1994; Barrett and Peleg, 1992; Bouvier *et al.*, 1997). Crispness is conceived as being related to the cellular structure of foods. In general crispness is characterised by brittle fracture at a low fracture force and distinguishable fracture events. Also the emission of sound is

an important aspect for the perception of crispness and crunchiness (Luyten *et al.*, 2004). Sound can be produced from food by application of force. When a force is applied to a crisp item, its structure is stressed until a critical point is reached: the action of external force causes the rupture of the brittle walls of the cellular structure which start to vibrate. The vibration is transmitted through the air as acoustic waves, which generates the sound. Sensory crispness is therefore the perception of deformation and time events but, almost and primarily, of their simultaneous acoustical effects (Piazza *et al.*, 2007).

Oil uptake is one of the most important parameters controlling the quality, crispness and color of fried rice crackers. Thus, frying is a critical step for producing rice crackers with desirable characteristics. Many complex physico-chemical changes occur during frying including starch gelatinization, protein denaturation, water evaporation, crust formation and the appearance of a golden color (Kochhar and Certz, 2004). Many factors have been reported as affecting oil uptake, including oil quality, frying temperature and duration, the product's shape, its moisture, solids, fat or protein contents and porosity, pre-frying treatments (drying, blanching) and coating, among others. It is generally agreed that the oil content in a product increases with frying time. Most of the food products have an optimum cooking time and temperature (Rossell, 2001). If the frying time exceeds the optimum time, the finished product will tend to have higher oil content (Esturk, Kayacier, and Singh, 2000; Kayacier and Singh, 1999), as the oil adhering to the surface of the product is drawn into its pore structure. In contrast, if the product is fried for insufficient time, it will not release the retained moisture and result in a soggy texture. It is clear that increasing frying temperature tends to decrease the oil uptake as the product spends less time in the fryer (Moyano and Predreschi,

2006; Predreschi and Moyano, 2005; Rossell, 2001). A study found that every 1°C increase in oil temperature was associated with 0.04 g/100 g decrease in oil content (Mackay, 2000). The optimum frying temperature is important to study to prevent a semi-raw and oily product at too low frying temperatures and a burnt product at too high frying temperatures (Rossell, 2001). Oil uptake in fried rice crackers could be described by condensation and capillary mechanisms discussed in literature (Mellema, 2003; Saguy and Dana, 2003). During the frying process, the moisture in rice crackers changed to vapor due to heat. The vapor evaporated from the rice crackers and created an over pressure inside the pores. As a result, the frying oil was not able to penetrate into the pores during frying. When the fried rice crackers were removed from the frying oil, the pore temperature inside rice crackers dropped and the vapor in the crust condensed. The over pressure turned into under pressure, while the oil adhered to the surface of the rice crackers. Therefore, the oil was driven into the pores (Mellema, 2003; Saguy and Dana, 2003). In another study, more than 80 g/100 g of the oil in potato chips was absorbed after the food was removed from the oil (Ufheil and Escher, 1996).

The rapid increase in volume of water during evaporation also causes expansion of fried food (Rossell, 2001). Due to high amount of amylopectin, the rice crackers could expand readily to produce a porous structure during frying. The addition of fish powder enhanced the protein content of rice starch. Protein reduced expansion of amylopectin, which resulted in decreased amount of pores in the fried rice crackers during frying (Yohii and Arisaka, 1994). The study reports less amount of oil penetration in the rice crackers with larger protein content. As the frying temperature increased, the oil uptake of fried rice crackers decreased. This result was in

agreement with several studies (Moyano and Predreschi, 2006; Pedreschi and Moyano, 2005; Rossell, 2001). However, there was no significant difference ($P < 0.05$) in oil uptake at frying temperatures of 220 and 240 °C. The results may be explained by the formation of a crust, which acts as a barrier to reduce the oil uptake. Besides, the crust formation might prevent the inside water from escaping to the outside and consequently preventing further oil uptake by rice crackers (Rossell, 2001).

Gamble *et al.*, (1987) and Kassama and Ngadi (2004) correlated fat absorption and moisture loss for a deep fat frying process and linear relationship was reported between oil uptake and moisture loss. They suggested that high frying temperatures cause formation of crust which facilitates oil absorption. Thus mass transfer process and development of texture characteristics during frying are related. The qualities of the frying oils and the fried food are intimately related was given by (Blumenthal, 1991). If foods are dried to too low a moisture content (less than about 2–3%) they may become susceptible to oxidation (Labuza, 1971).

Frying is basically a dehydration process and considered by many to be more an art than a science or technology (Grob, 1990). Deep-fat frying is a widely used food process, which consists basically of immersion of food pieces in hot vegetable oil. During deep fat frying several chemical and physical changes occur such as starch gelatinization, protein denaturation and crust formation. Deep fat frying is a process of simultaneous heat and mass transfer. Heat is transferred from the oil to the food, which results in evaporation of water from the food and absorption of oil by the food (Krokida *et al.*, 2000a, b). Deep fat frying generally involves three types of mass transfer such as (a) migration of water from the core of the food to surface, which is removed during frying; (b) absorption of

frying oil into the food and (c) leaching of liquefied food components from the food (Blumenthal, 1991). Fried products are judged by their functional properties. Crispness is typically a textural parameter for fried products which depends upon the ingredients, formulation (proper balance among ingredients), and processes (mixing and frying) (Chang *et al.*, 1993). It is still not clearly understood when and how the oil penetrates into the structure; however, numerous studies have shown that most of the oil is confined to the surface region of the fried product (Keller *et al.*, 1986; Lamberg *et al.*, 1990; Farkas *et al.*, 1992; Saguy *et al.*, 1997; Pedreschi *et al.*, 1999; Bouchon and Aguilera 2001) and there is evidence that it is mostly absorbed during the cooling period (Ufheil and Escher 1996; Moreira *et al.*, 1997; Aguilera and Bouchon *et al.*, 2000). Gamble *et al.*, (1987) concluded that most of the oil is pulled into the product when it is removed from the fryer because the condensation of steam produced a vacuum effect. They suggested that oil absorption depends on the amount of water removed and on the way this moisture is lost. Crust is formed during most of the deep fat frying processes that influences heat and mass transfer characteristics as well as oil uptake and physical properties of fried products (Keller *et al.*, 1986; Krokida *et al.*, 2000a, b). As the frying temperature increased, the oil uptake of fried rice crackers decreased Pedreschi, Aguilera, and Arbildua (1999). This result was in agreement with several studies (Moyano and Predreschi, 2006; Pedreschi and Moyano, 2005; Rossell, 2001).

Increasing the solid content by pre-fry drying by employing hot air or infrared (Smith, 1951) as well as osmotic dehydration (Krokida *et al.*, 2000a) of potato slices was found to lower oil absorption on frying. Debnath and Bhat (2000) have shown that blending of chickpea flour with equal

proportion of gelatinized starch was very effective in reducing the oil content of the fried product. The pre-fry drying also has a significant effect on the deep fat frying. The increase in pre-fry drying time resulted in a decrease in moisture as well as oil transfer coefficients. A possible reason for the reduction in the oil content during frying due to pre-fry drying could be the compactness of the material matrix (reduced porosity) or increase in the solid content. The combination of convective air-drying and deep fat frying can result in a product with less fat uptake during frying with acceptable sensory attributes, which in turn result in a low-fat and economical product (Debnath *et al.*, 2003). Air or oil puffing ideally creates an aerated, porous, snack-like texture with the added benefits of dehydration. Blending the puffed products with different flavours and marketing them in moisture impermeable plastic film pouches provides enormous opportunities for increasing acceptance and usage of puffed products (Arya, 1992).

Physico-chemical and rheological characteristics of snack food products

In general the crispness of extruded products is directly correlated with acceptability of product and expansion is a major factor which contributes towards crispness (Peri *et al.*, 1983). For the texture of extruded products, shear force value appeared to be the most critical factor. Lower shear force value normally indicates lower bulk density and high expansion ratio (Park *et al.*, 1993b). The amount of moisture present in the mix directly affects the composition of product as well as expansion ratio, bulk density and shear force value (Conway, 1971; Park *et al.*, 1993b). Protein level in the snack products has an important effect on product characteristics.

Mukherjee (1997) obtained maximum volume expansion of 2.605 times while optimizing

ready-to-eat dehydrated puffed potato cubes with long shelf life by high temperature short time (HTST) whirling bed treatment at an air temperature of 210°C, retention time of 80seconds, initial moisture content of 40% and air velocity 3.76 m/s.

According to Nath *et al.*, (2007) observations for hardness for high temperature short time air puffed ready-to-eat (RTE) potato snacks were varied between 941.59 and 2932.31. Chandrasekhar (1989) reported decrease in hardness with increase in expansion ratio in case of rice puffing which was again observed to be a function of temperature, time, moisture content and air velocity. Fan *et al.*, (1999) reported that hardness decreased as moisture content and tempering time increased and increased as heating temperature and heating time increased during puffing of wheat cakes.

Prince *et al.*, (1994) reported that the hardness (highest peak of force–deformation curve) and crispness (steepness of force–deformation curve) of rice- soya crackers decreased as percentage of soya in the mix increased. These trends remained sharp up to 30% soya in the mix, and then slowed down.

Martinez-Serna *et al.*, (1990) and Onwulata *et al.*, (1998, 2001) investigated the effects of whey protein concentrate and isolate on the extrusion of corn and rice starch and reported a reduction in expansion at higher concentrations of protein. Breen *et al.*, (1977) reported that the bulk density was highest in the blends containing the lowest amount of starch.

Bulk density decreased gradually with increasing starch content and popped snack with low bulk density tended to expand well (Lee *et al.*, 2003). The kinetic coefficient for moisture transfer increased and for oil decreased as the temperature of frying was

increased. The pre-fry drying also has a significant effect on the deep fat frying. The increase in pre-fry drying time resulted in a decrease in moisture as well as oil transfer coefficients (Debnath *et al.*, 2003). Expansion is an important physical attribute for the extruded snacks that greatly affects consumer acceptability. Expansion of products ranged between 186% and 360% (Dehghan-Shoar *et al.*, 2010). Suknark *et al.*, (1998) observed that extrudates prepared from peanut flour and starches having low moisture content gave low shear strength as lower levels of moisture content provided lower product density, higher expansion and thinner cell walls which reduced the force necessary for shearing the extrudate.

Sensory characteristics of snack food products

Several researchers agreed that crispness resulted from the structural properties of a food (Bouvier *et al.*, 1997; Mohamed *et al.*, 1982; Stanley and Tung, 1976). According to Heidenreich *et al.*, (2004) crispness is perceived through a combination of tactile, kinesthetic, visual and auditory sensations and represents the key texture attributes of dry snack products. When force is applied to brittle snacks, rupture of the cellular structure occurs, generating a typical sound that contributes to the crispness sensation (Vickers and Bourne, 1976). Thus, quality evaluation of extruded snack foods seems to have correlation with sensory, instrumental and microstructure characteristics.

Various researchers have examined the mechanical property of crispness in snacks. Bourne *et al.*, (1966) studied crispness of potato chips at different moisture content by using the punch test, and observed a decreasing initial slope from the force–deformation curve as the water content increased. Bruns and Bourne (1975) used

instruments to examine crispness and reported that the initial slope of the force–deformation curve was a good indicator of crispness. But the mechanical analysis of potato chips did not produce any useful quantitative information.

According to Mittal and Usborne (1986), fat-protein ratio was negatively correlated with acceptable colour, brittleness, gumminess, chewiness, elasticity, hardness and shear force but positively correlated with texture, flavour and overall acceptability of snack foods. In such a food where expansion is desired and puffed products are expected, texture is the major importance, with crispness being one of the most important attributes (Pamies *et al.*, 2000). According to Heidenreich *et al.*, (2004), crispness is perceived through a combination of tactile, kinesthetic, visual and auditory sensations and represents the key texture attributes of dry snack products.

Crispy and crunchy textures are a desirable quality and contribute to our enjoyment of foods (Vickers, 1983). In brief, crispy and crunchy are words that are used to describe products that break rather than deform and the way in which they fracture under the application of a force (Fillion and Kilcast, 2002). From the sensory results, Primo-Martín *et al.*, (2010) found that panelists perceive a higher sound intensity from crispier foods. The mechanics and sound it is likely that other stimuli may be important for the sensation of “crisp” and “crunch” (Luyten *et al.*, 2004). An important reason for it is that there is no single receptor for texture, but that always several senses are involved (Szczeniak, 2002).

Storage characteristics of snacks

Snack foods are shelf stable foods and not generally affected by the storage factors but crispness is a critical factor which is affected

during storage under moist conditions (McKee *et al.*, 1995). Cereal based snack are indefinitely shelf stable (De-Freites and Molins, 1988). However, incorporation of dairy ingredients alters its microbiological and stability characteristics (Draughon, 1980; Harrison *et al.*, 1983). Application of extrusion technology helps in nutrient retention and inactivation of both contamination and disease producing microorganism (Harper, 1981).

Change in Physico-chemical characteristics

pH of snack dips decreased during storage at 24-25°C (De-Freitas and Molins, 1988). The potato snack packed in LDPE bags (100 and 500 gauge) and in friction top tins stored at room temperature (13-38°C) were monitored for their moisture content and peroxide value (Kalra *et al.*, 1987). The author observed following finding- the moisture content of potato snacks changed from 4 to 5.8% in 100 gauge LDPE bags, to 5.1% in 150 gauge LDPE bags and to 4.7% in friction top tins during six months of storage at room temperature and then peroxide value (PV) of the products increased from 0.05 to 7.98 meq O₂/kg of the products. These authors also reported that the moisture contents of potato snacks prepared from cold stored admixed with maize starch changed from 4.2 to 4.7% in 100-gauge LDPE and friction top tins during the similar period of storage and PV of this products changed from nil to 2.2 meq O₂/kg of the products. The authors found increases in moisture contents from 0.9 TO 2.8% during 40 days of storage in LDPE (150 gauge) + polypropylene pouches (120 gauge) at 30-35°C and PV of the products changed from 0 to 1.07 meq O₂/kg under same packaging and storage conditions.

The onset of Maillard reactions spoils the appearance as well as the flavour of milk powder. Traditionally, the degree of Maillard

reaction is measured as the content of hydroxymethyl furfural (HMF), but in this study the browning of milk powder was followed directly by tristimulus calorimetry on the powder surface and on reconstituted milk. The milk powder turned yellower during storage, as shown for measurements of the Hunter b-value. Only a small increase in Hunter b-value with storage temperature was found for milk powders stored at the lower water activities, whereas the colour change was more profound for milk powder stored at high a, which turned more yellow at higher temperatures. The direct tristimulus calorimetric measurement provides results in agreement with the results reported by Lea and Hannan (1949) who found the rate of reaction of non-enzymatic browning in milk powder to increase with increasing a, up to 0.60.7. Not surprisingly, the non-enzymic browning, as measured directly from powder colour, was favoured by the high storage temperature, in accordance with the results of Ipsen and Hansen (1988) who found a significant increase in HMF content only at storage temperatures higher than 30°C and also with the results of Kieseker and Clarke (1984), who found changes in HMF content to be more pronounced for high-heat powders stored at 40°C. Water activity is the amount of water available for deteriorative processes in a food product and is defined as the ratio of vapor pressure of the product (p) to the vapor pressure of water (p^o) at the same temperature.

$$a_w = p/p^o$$

When solutes like sugar or salt are added to the water, the water activity reduces due to water molecule and salt/sugar interactions which lead to a reduction in available water (Henning, 2004). Low moisture content is only an indication of food stability and not a guarantee. The availability of moisture for microbial growth has more impact on product

safety than water content. Water activity is considered as a limiting factor of microbial growth as it determines the osmotic stress (Franks, 1991). Each microorganism has a critical a_w below which growth cannot occur. The minimum available water necessary for bacterial growth varies with the type of organism.

There are only limited details about the relation between water content and water activity (Serra *et al.*, 2005). Reducing the water activity and pH may retard or impede microbial growth. Controlling water activity helps to maintain proper structure, texture, stability, density and high values of water activity tend to increase non-enzymatic and enzymatic reactions, lipid oxidation, vitamins degradation and protein denaturation (Maltini *et al.*, 2003).

Microorganisms are significantly affected by pH of growth medium because of the absence of a mechanism for adjusting their internal pH. Not only the rate of growth of microorganism is affected by pH but the rate of survival during processing also get affected. Growth of most bacteria is favoured by neutral pH although some, such as those that form acid are favoured by moderate acidity. Lower pH values decrease the enzymatic reactions taking place in a food product (Granda, 2005). Higher acidity, salt content, cooking, frying and low moisture reduces the microbial load of the product.

Lipid hydroperoxides are primary lipid oxidation products and have, together with the free radicals which precede them, practically no impact on the sensory properties. In contrast, the secondary lipid oxidation products, such as the aldehydes, formed by cleavage of the lipid hydroperoxides, have a profound impact on both sensory and functional properties.

The measurement of thiobarbituric acid reactive substances (TBARS), once thought to be specific for the secondary lipid oxidation product malondialdehyde, is the most commonly used method for evaluating the oxidative status of foods and biological systems (Slater, 1984). Traditionally, the absorbance at 532nm of the pink pigment formed in the reaction is measured, even though only a slight amount of this pigment is formed in milk products due to their low content of polyunsaturated lipids. This led Patton and Kurtz (1955) and Jennings *et al.*, (1955) to propose measurement of the more intensively absorbing yellow pigment at 450 nm for dairy products. Since TBARS is a measure of the formation of secondary oxidation products, e.g. carbonyls, being responsible for the sensory impact of lipid oxidation (Hall and Andersson, 1985), this method has been found to correlate well with sensory quality (Stapelfeldt *et al.*, 1992). Secondary lipid oxidation products were accordingly evaluated by the TBARS method both as the pink (TBA532) and yellow (TBA450) reaction products. The absorbance of the yellow product was approximately 10 times higher than that of the pink, and as these analyses gave rise to similar qualitative conclusions, TBA450 was consequently preferred. According to Stapelfeldt *et al.*, (1997) in accordance with storage temperature effects on formation of free radical precursors, TBARS increased steadily during storage of milk powders at 45°C while TBARS only increased slightly at 25°C. These results are in accordance with the findings of Tuohy *et al.*, (1981) and of Ipsen and Hansen (1988), of whom the latter found the TBA value to increase with storage temperature and to be doubled after 70 weeks of storage at 30°C compared to 20°C irrespective of heat treatment.

Fat oxidation is an important deterioration reaction causing flavour, colour, and textural

changes associated with rancidity (Pedrosa and Regenstein, 1988). A red pigment is formed as a result of condensation reaction of two molecules of acidified TBA with one molecule of malonaldehyde, a secondary product in the oxidation of polyunsaturated fatty acids. TBA measures deterioration in both extractable and non-extractable lipids (Kirk and Sawyer, 1991). The acceptability of a food product depends on the extent to which deterioration has occurred. Development of rancidity is associated with oxidative deterioration of lipids and is a major cause of food deterioration. This, in turn represents a major cause of loss of nutritional quality as well as cause of concern for food safety, as the oxidized fats in very high dosage have been shown to have toxic effects (Allen and Hamilton, 1983).

The acceptability of a food product depends on the extent to which deterioration has occurred. Development of rancidity is associated with oxidative deterioration of lipids and is a major cause of food deterioration. This in turn represents a major cause of loss of nutritional quality as well as cause of concern for food safety, as the oxidized fats in very high dosage have been shown to have toxic effects (Allen and Hamilton, 1983). Determination of thiobarbituric acid reacting substances (TBARS) number is a method for measuring oxidative deterioration of lipids in muscle foods. It measures the amount of malonaldehyde, a water-soluble secondary product obtained mainly from the oxidation of polyunsaturated fatty acids in food samples (Pearson *et al.*, 1983).

Labuza (1971) concluded that if foods are dried to too low a moisture content (less than about 2–3%) they may become susceptible to oxidation. For some systems it has been found that an optimal water activity exists, and lipid oxidation reactions proceeded faster below

and above this optimal water activity (Labuza, 1980).

Drying extends the shelf life of food by reducing the moisture content. Dried products usually have water activity below 0.7 (Lewicki, 2004). Kulkarni *et al.*, (1997) reported that traditional dried savoury products like black gram and green gram *war I* (dehydrated dried product) developed moulds at moisture levels between 22.6 and 36.6%.

Change in Sensory quality

Snack foods are considered as shelf stable foods and are not much affected by storage factors but crispiness is a critical factor which is affected during storage under moist conditions (McKee *et al.*, 1995). Stickiness of snack dips increased within 3 hrs during storage at 24-25°C (DeFreitas and Molines, 1988).

Change in microbiological quality

The study of microbiology and keeping quality of milk products is a very well-developed area. Sufficient work has been done on microbiology of processed milk products. However, little information is available on the microbial quality of milk-based snack. Park *et al.*, (1993b) reported very low count of aerobic bacteria, yeast and moulds, coliforms and *E. coli* in the extruded breakfast cereals and cereal based snack products stored up to 150 days at 37°C.

According to FAO (2010), the lowest water activity for normal bacteria, yeast, molds and salt tolerant bacteria is 0.91, 0.88, 0.80 and 0.77, respectively. It was reported that toxin production by *Staphylococcus aureus* is inhibited at water activity of 0.92 for anaerobic condition and less than 0.90 for aerobic condition.

Packaging, Storage and Shelf life of milk snack

Rahman *et al.*, (2008) reported that Papads were prepared from Mungbean, Grasspea (Khasari dal), Black gram (Mashkolai dal) incorporating soya flour show no remarkable changes in moisture content, texture and flavour were observed up to 5 months of storage in ambient condition (27 to 35°C) indicating that the products were shelf-stable up to 5 months. MAP is a well-established technique in which the gases surrounding a product are altered resulting in an atmospheric composition different from that of air (Tareq Al-Ati and Hotchkiss, 2002). The interaction between product, barrier material and environment determines the gas composition inside the package at the steady state (Rai and Paul, 2007). Oxygen, nitrogen and carbon dioxide are the most usual gases used in MAP (Gimenez *et al.*, 2002).

Nitrogen delays oxidative rancidity and inhibits the growth of aerobic microorganisms by displacing the oxygen in packs (Stammen *et al.*, 1990; Farber, 1991; Philips, 1996; Church, 1998). Since, carbon dioxide acts as an antimicrobial agent (Stammen *et al.*, 1990), it inhibits the growth of microorganisms during the logarithmic phase and extends the lag phase (Genigeorgis, 1985; Church, 1998; Philips, 1996). Nitrogen is an inert gas with a low solubility in both water and fat. Its use in MAP is mainly to displace oxygen and it indirectly influences the shelf-life of perishable foods by retarding the growth of aerobic spoilage organisms (Parry, 1993).

To extend the shelf life of product, packaging is an important tool. For this purpose vacuum packaging, aerobic packaging and modified atmosphere packaging can be utilized depending on the nature of product and their shelflife (Sahoo and Anjaneyulu, 1995).

Packaging can reduce the weight loss, cost of transportation and increase the shelf life of products. Snacks are mostly packaged in laminated pouches for convenience. From a food packaging perspective, the effect of oxygen pressure and humidity on the oxidative stability of snack and cereal products is of major concern and may be decisive of the choice of, packaging material, initial headspace gas composition, initial product water activity and gas and water vapour permeability of the packaging material (Robertson, 1993).

In conclusion a process was standardized for the manufacture of ready to cook milk-based snack using skim milk coagulum. To simulate the expansion ratio and sensory attribute of the conventional product, addition of bulking agents such as Gum *tragacanth*, ascorbic acid, table salt and 2:1 combination of sodium carbonate and sodium bicarbonate were also optimized. Skim milk coagulum was successfully replaced (5 to 10 %) with extender like black gram and green gram flours for the manufacture of extended milk crisp. The pH of prepared ready to cook milk-based snack was almost acidic (<pH 5.5), and it was found most suitable to reduce the maillard reaction. As the level of skim milk coagulum decreases in products their protein, fat, gross energy and moisture content reduces but yield, ash and carbohydrate content increases.

Moisture content of product directly related to its shear force value. Physio-chemical studies of green gram incorporated milk crisp samples revealed that its low moisture, protein and shear force value enhance expansion ratio and percentage oil uptake significantly. Improvement in the sensory attributes of milk crisp was noticed by addition of legume flours especially in case of green gram incorporation. Considering the significance of milk crisp as a dairy food, its

production with legume flours could be highly beneficial for consumers who require/desire such crispy snacks.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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